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The Debate over the Hydrogen Bomb

A recently declassified report sheds light on the original U.S. decision to develop the "Super." The unanimous opposition of the Oppenheimer committee, overruled then, appears now to have been basically correct

10/29/75. Herb York glosses over the situation a lot. The advisory com wished to drop Oppenheimer from its membership so he was not reappointed, thus his clearance dropped. Gen Nichols (personal communication) says that they didn't want to hurt his feelings, so he was withheld that he wasn't wanted & so he fought the action as coming from the "AEC" & not that by Herbert F. York if he were to be cleared he would be restored to the Commission. This was impossible because once the clearance became in the open so he insisted the things that were overlooked now became cast to deny him a clearance. He had lied to the security people & [illegible] confused it etc. Together with it was a form of self punishment for some reason stafford warren

In 1948 Czechoslovak Communists carried out a coup in the shadow of the Red Army and replaced the government of that country with one subservient to Moscow. Also in 1948 the Russians unsuccessfully attempted to force the Western allies out of Berlin by blockading all land transport routes to the city. In early 1949 the Communist People's Liberation Army captured Peking and soon afterward established the People's Republic of China. Taken together, these and similar but less dramatic events were generally perceived in the West as resulting in the creation of a monolithic and aggressive alliance stretching the full length of the Eurasian continent, encompassing almost half of the world's people and threatening much of the rest. Then in the fall of 1949 the Russians exploded their first atomic bomb and ended the brief American nuclear monopoly.

At the end of World War II most atomic scientists in the U.S. had estimated that the U.S.S.R. would need four or five years to make a bomb based on the nuclear-fission principle; the time interval from the first American test to the first Russian one turned out to be four years and six weeks. Even so, nearly everyone, including most U.S. Government officials and most members of Congress, reacted to the event as if it were a great surprise. Many of them had either forgotten or had never known the experts' original estimates, and in any case the accomplishment simply did not fit the almost universal view of the U.S.S.R. as a technologically backward nation.

Besides being a great surprise the Russian test explosion was a singularly unpleasant one. The U.S. nuclear monopoly had been seen by many as compensating for the difference between the hordes of conscripts supposedly available to the Communist bloc and the smaller armies available to the Western countries. Coming as it did at a time when virtually all Americans saw the cold war as rapidly going from bad to worse, the Russian test was seen as a challenge that demanded a reply. The immediate challenge being nuclear, a particularly intensive search for an appropriate response was conducted by those responsible for U.S. nuclear policy.

Most of the proposed responses involved substantial but evolutionary changes in the current U.S. nuclear programs: expand the search for additional supplies of fissionable material, step up the production of atomic weapons, adapt such weapons to a broader range of delivery vehicles and end uses, and the like. One proposal was radically different. It called for the fastest possible development of the hydrogen bomb, which was widely referred to at the time as the superbomb (or simply the Super). This weapon, based on the entirely new and as yet untested principle of thermonuclear fusion, was estimated to have the potential of being 1,000 or more times as powerful as the fission bombs that had marked the end of World War II. Work on the theory of the superbomb had already been going on for seven years, but it had never had a very high priority, and so far it had yielded no practical result. A number of scientists and politicians endorsed the proposal, but for years Edward Teller had been its leading advocate. The superbomb proposal led to a brief, intense and highly secret debate.

The opponents of the proposal argued that neither the possession of the new bomb nor the initiation of its development was necessary for maintaining the national security of the U.S., and that under such circumstances it would be morally wrong to initiate the development of such an enormously powerful and destructive weapon. In essence they contended that the world ought to avoid the development and stockpiling of the superbomb if it was at all possible, and that a U.S. decision to forgo it was a necessary precondition for persuading others to do likewise. Furthermore, they concluded that the dynamism and relative status of U.S. nuclear technology were such that the U.S. could safely run the risk that the U.S.S.R. might not practice similar restraint and would instead initiate a secret program of its own.

The advocates of the superbomb maintained that the successful achievement of such a bomb by the Russians was only a matter of time, and so at best our forgoing it would amount to a deliberate decision to become a second-class power, and at worst it would be equivalent to surrender. They added that undertaking the development of the superbomb was morally no different from developing any other weapon.

The secret debate about what the American response ought to be took place within the Government itself. Many organizations were involved, including the National Security Council, the Department of Defense, the Department of State and the Congressional Joint Committee on Atomic Energy, but the initial focus of the debate lay within the Atomic Energy Commission.

The early official reaction of the AEC's Los Alamos Scientific Laboratory to the Russian test was a proposal to step up the pace of the nuclear-weapons program in all areas. Among other measures, Norris E. Bradbury, the director, recommended that the laboratory go on a six-day work week and that they expand the staff, particularly in theoretical physics.

This acceleration was to include not only programs for improving fission

weapons by conventional means bu ,o tests of the booster principle. (In this context "booster" refers to a synergistic process in which the explosion of a comparatively large mass of fissionable fuel, say plutonium or uranium 235, causes a comparatively small mass of thermonuclear fuel, say deuterium and tritium, to burn violently. The high-energy neutrons produced in the thermonuclear process then react back on the fission explosion, boosting, or accelerating, it to a higher efficiency than would otherwise be the case.) The booster concept had been known for several years, and even before the Russian test it had been agreed to include a full-scale experimental test of the process in a 1951 nuclear-test series. The AEC's Director of Military Application, General James McCormack, Jr., received these proposals from the Los Alamos laboratory and sought the advice of the AEC's scientific experts on them. Other AEC division heads were similarly studying proposals for expanding the relevant programs within their jurisdiction.

At the same time Teller, then at Los Alamos, Ernest O. Lawrence, Luis W. Alvarez and Wendell M. Latimer at the University of California at Berkeley, Robert LeBaron at the Department of Defense, Senator Brien McMahon, Chairman of the Joint Committee on Atomic Energy, his staff chief William L. Borden and Commissioner Lewis L. Strauss of the AEC had all come to focus on the superbomb as the main element of the answer to the Russian atomic bomb, and they initiated a concerted effort to bring the entire Government around to their point of view as quickly as possible.

As a result of all this concern and activity the AEC called for a special meeting of its General Advisory Committee to be held as soon as possible. This committee was one of the special mechanisms established by the Atomic Energy Act of 1946 for the purpose of managing the postwar development of nuclear energy in the U.S. Its function was to provide the AEC with scientific and technical advice concerning its programs. The members of the committee were all men who had been scientific or technological leaders in major wartime projects. J. Robert Oppenheimer, who was elected chairman of the committee,

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FIRST SUPERBOMB TEST in which a large thermonuclear, or fusion, explosion was successfully ignited by a comparatively small fission explosion took place at the Eniwetok Proving Ground in the Marshall Islands on November 1, 1952 (local time). The device, with the code name Mike, released an amount of energy equivalent to that released by the explosion of 10 megatons, or 10 million tons, of TNT. As had been predicted five years earlier by the scientist members of the General Advisory Committee of the Atomic Energy Commission, yield of first superbomb was approximately 1,000 times larger than the yield of the first atomic, or all-fission, bombs.

had been director of the Los Alamos laboratory during the period when the first atomic bomb had been designed and built there. The other members, all scientists, were Oliver E. Buckley, James B. Conant, Lee A. DuBridge, Enrico Fermi, I. I. Rabi, Hartley Rowe, Glenn T. Seaborg and Cyril S. Smith. Many of the members of this committee and later General Advisory committees also served on other high-level standing committees and some key *ad hoc* committees, and so a rather complex web of interlocking advisory-committee memberships developed. As a result several of these men, including Oppenheimer, had much more influence than the simple sum of their various committee memberships would indicate.

Oppenheimer was not only the formal leader of the General Advisory Committee but also, by virtue of his personality and background, its natural leader. His views were therefore of special importance in setting the tone and determining the content of the committee's reports in this matter, as in most other matters.

Throughout Oppenheimer's service on the committee he generally supported the various programs designed to produce and improve nuclear weapons. At the same time he was deeply troubled by what he had wrought at Los Alamos, and he found the notion of bombs of unlimited power particularly repugnant. Ever since the end of the war he had devoted much of his attention to promoting the international control of atomic energy with the ultimate objective of achieving nuclear disarmament. He and Rabi had in effect been the originators of the plan for nuclear-arms control that later became known as the Baruch Plan. Oppenheimer's inner feelings about nuclear weapons were clearly revealed in an often quoted remark: "In some sort of crude sense which no vulgarity, no humor, no overstatement can quite extinguish, the physicists have known sin, and this is a knowledge which they cannot lose."

The call for the special meeting, in addition to raising the question of a high-priority program to develop the Super, also asked the committee to consider priorities in the broadest sense, including "whether the Commission is now doing things we ought to do to serve the paramount objectives of the common defense and security." As for the Super, the Commission wanted to know "whether the nation would use such a weapon if it could be built and what its military worth would be in relation to fission weapons." The meeting of the Oppenheimer committee was held on October 29 and 30, 1949; all members were present except Seaborg, who was in Europe. The committee in the course of its deliberations heard from many outside experts in various relevant fields, including George F. Kennan, the noted student of Russian affairs, General Omar Bradley, Chairman of the Joint Chiefs of Staff, and the physicists H. A. Bethe and Robert Serber. Toward the end of the two-day meeting the advisers had a long session with the Atomic Energy commissioners and with their intelligence staff. The next day the committee prepared its report.

The General Advisory Committee report consisted of three separate sections that were unanimously agreed on and two addenda giving certain specific minority views. In 1974 the report was almost entirely declassified, with only a very few purely technical details remaining secret.

Part I of the report dealt with all pertinent questions other than those directly involving the Super. The advisory committee in effect reacted favorably to the proposals of the various AEC division directors with regard to the expansion of the facilities for separating uranium isotopes, for producing plutonium and for increasing the supplies of uranium ore. These proposals and the committee's endorsement of them were followed eventually by a substantial increase in the rate of production of fissionable materials.

In Part I the committee also recommended the acceleration of research and development work on fission bombs, particularly for tactical purposes. Under the heading "Tactical Delivery" the report stated: "The General Advisory Committee recommends to the Commission an intensification of efforts to make atomic weapons available for tactical purposes, and to give attention to the problem of integration of bomb and carrier design in this field."

This quoted paragraph deserves special emphasis, since it has often been suggested that Oppenheimer, Conant and some of the others opposed nuclear weapons in general. They did apparently find them all repugnant, and they did try hard to create an international control organization that would ultimately lead to their universal abolition. In the absence of any international arms-limitation agreements with reliable control mechanisms, however, they explicitly recognized the need to possess nuclear weapons, particularly for tactical and defensive purposes, and they regularly promoted programs designed to increase their variety, flexibility, efficiency and numbers. For the next few years, right up to the time Oppenheimer's security clearance was removed, he continued strongly to promote the idea of an expanded arsenal of tactical nuclear weapons. The only type of nuclear weapon the General Advisory Committee opposed—and it did so openly—was the Super.

Part I of the report further recommended that a project be initiated for the purpose of producing "freely absorbable neutrons" to be used for the production of uranium 233, tritium and other potentially useful nuclear materials. Perhaps most important of all in the present context, Part I also stated: "We strongly favor, subject to favorable outcome of the 1951 Eniwetok tests, the booster program." This short phrase makes it abundantly clear that the Oppenheimer committee favored conducting research fundamental to understanding the thermonuclear process, and that its grave reservations were specifically and solely focused on one particular application of the fusion process.

Part II discussed the Super. It outlined what was known about the hydrogen bomb, and it expanded on the unusual difficulties its development presented, but it concluded that the bomb could probably be built. In part it said: "It is notable that there appears to be no experimental approach short of actual test which will substantially add to our conviction that a given model will or will not work. Thus, we are faced with a development which cannot be carried to the point of conviction without the actual construction and demonstration of the essential elements of the weapon in question. A final point that needs to be stressed is that many tests may be required before a workable model has been evolved or before it has been established beyond reasonable doubt that no such model can be evolved. Although we are not able to give a specific probability rating for any given model, *we believe that an imaginative and concerted attack on the problem has a better than even chance of producing the weapon within five years.*"

That last sentence (the italics are added) deserves special emphasis. It has been suggested in the past that the General Advisory Committee in general and Oppenheimer in particular were deceptive in their analysis of the technological prospects of the Super; in other words, that they deliberately painted a falsely

gloomy picture of its possibilities in order to reinforce their basically ethical opposition to its development. Given the technological circumstances then prevailing, this statement of the program's prospects could hardly have been more positive.

The report then discussed what might be called the "strategic economics" of the Super as they were then conceived: "A second characteristic of the super bomb is that once the problem of initiation has been solved, there is no limit to the explosive power of the bomb itself except that imposed by requirements of delivery. [In addition there will be] very grave contamination problems which can easily be made more acute, and may possibly be rendered less acute, by surrounding the deuterium with uranium or other material.... It is clearly impossible with the vagueness of design and the uncertainty as to performance as we have them at present to give anything like a cost estimate of the super. If one uses the strict criteria of damage area per dollar, it appears uncertain to us whether the super will be cheaper or more expensive than the fission bombs."

In Part III the committee members got to what to them was the heart of the matter, the question of whether or not the Super should be developed: "Although the members of the Advisory Committee are not unanimous in their proposals as to what should be done with regard to the super bomb, there are certain elements of unanimity among us. We all hope that by one means or another the development of these weapons can be avoided. We are all reluctant to see the United States take the initiative in precipitating this development. We are all agreed that it would be wrong at the present moment to commit ourselves to an all-out effort toward its development.

"We are somewhat divided as to the nature of the commitment not to develop the weapon. The majority feel that this should be an unqualified commitment. Others feel that it should be made conditional on the response of the Soviet government to a proposal to renounce such development. The Committee recommends that enough be declassified about the super bomb so that a public statement of policy can be made at this time."

In the two addenda those members of the committee who were present (that is, all except Seaborg) explained their reasons for their proposed "commitment not to develop the weapon." The first addendum was written by Conant and signed by Rowe, Smith, DuBridge, Buckley and Oppenheimer. In part it said: "We base our recommendation on our belief that the extreme dangers to mankind inherent in the proposal wholly outweigh any military advantage that could come from this development. Let it be clearly realized that this is a super weapon; it is in a totally different category from an atomic bomb. The reason for developing such super bombs would be to have the capacity to devastate a vast area with a single bomb. Its use would involve a decision to slaughter a vast number of civilians. We are alarmed as to the possible global effects of the radioactivity generated by the explosion of a few super bombs of conceivable magnitude. If super bombs will work at all, there is no inherent limit in the destructive power that may be attained with them. Therefore, a super bomb might become a weapon of genocide.

"We believe a super bomb should never be produced. Mankind would be far better off not to have a demonstration of the feasibility of such a weapon until the present climate of world opinion changes.

"In determining not to proceed to develop the super bomb, we see a unique opportunity of providing by example some limitations on the totality of war and thus of limiting the fear and arousing the hopes of mankind."

Contrary to a frequently suggested notion, the members of the Oppenheimer committee were not at all unmindful of the possibility that the U.S.S.R. might develop the Super no matter what the U.S. did. Indeed, they regarded it as entirely possible and explained why it would not be crucial: "To the argument that the Russians may succeed in developing this weapon, we would reply that our undertaking it will not prove a deterrent to them. Should they use the weapon against us, reprisals by our large stock of atomic bombs would be comparably effective to the use of a 'Super.'"

The minority addendum, signed by Fermi and Rabi, expressed even stronger opposition to the Super but loosely coupled an American renunciation with a proposal for a worldwide pledge not to proceed: "It is clear that the use of such a weapon cannot be justified on any ethical ground which gives a human being a certain individuality and dignity even if he happens to be a resident of an enemy country.

"The fact that no limits exist to the destructiveness of this weapon makes its very existence and the knowledge of its construction a danger to humanity as a whole. It is necessarily an evil thing considered in any light.

"For these reasons we believe it important for the President of the United States to tell the American public, and the world, that we think it wrong on fundamental ethical principles to initiate a program of development of such a weapon. At the same time it would be appropriate to invite the nations of the world to join us in a solemn pledge not to proceed in the development of construction of weapons of this category."

As with the majority, Fermi and Rabi also explicitly took up the possibility that the Russians might proceed on their own, or even go back on a pledge not to: "If such a pledge were accepted even without control machinery, it appears highly probable that an advanced state of development leading to a test by another power could be detected by available physical means. Furthermore, we have in our possession, in our stockpile of atomic bombs, the means for adequate 'military' retaliation for the production or use of a 'Super.'"

On December 2 and 3, five weeks after the special meeting, the General Advisory Committee convened for one of its regularly scheduled meetings and carefully reviewed the question of the Super once again. According to Richard G. Hewlett, the AEC's official historian, Oppenheimer reported to the commissioners that no member wished to change the views expressed in the October 30 report.

For a time it appeared that the views of the Oppenheimer committee had a chance of being accepted. David E. Lilienthal, chairman of the AEC, was receptive to the committee's point of view. He similarly favored two parallel responses to the Russian test: (1) increasing the production of fission weapons and developing a greater variety of them, particularly for tactical situations, and (2) officially announcing our intention to refrain from proceeding with the Super while simultaneously reopening and intensifying the search for international control of all kinds of weapons of mass destruction. Lilienthal considered the complete reliance on weapons of mass destruction to be a fundamental weakness in U.S. policy, and he viewed a "crash" program on the hydrogen bomb as foreclosing what might be the last good opportunity to base U.S. foreign policy on "something better than a headlong rush into war with weapons of mass destruction." "We are," he said, "today relying on an asset that is readily depreciating for us, i.e., weapons of mass destruction. [A decision to go ahead with

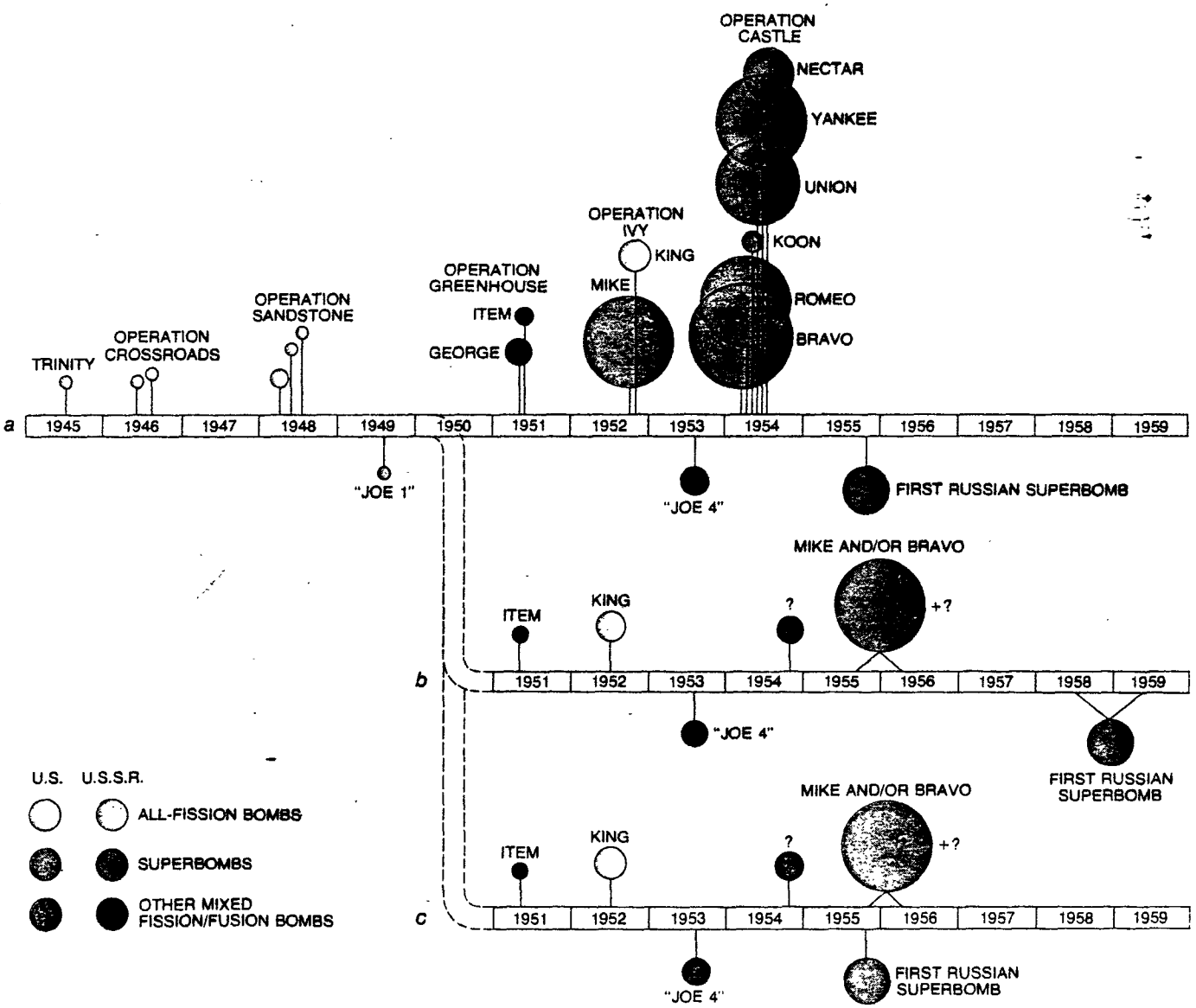
the Super] would tend to confuse ε unwittingly, hide that fact and make it more difficult to find some other course."

As we know now, the advice of the Oppenheimer committee was rejected. Early in 1950 President Truman, acting on the basis of his own political judgment and on the totality of the advice he had received on the matter, issued directives designed to set in motion a major U.S. program to develop the hydrogen bomb.

It is not possible here to give a full description of what happened next, but the following chronological outline of the Russian and American superbomb programs is designed to show how the "race" for the superbomb did in fact come out, and to facilitate making judgments about the General Advisory Committee's advice and about "what might have been."

First of all, it is now known that both countries initiated high-priority programs for the development of a hydrogen bomb at about the same time (late 1949—early 1950), and both had been seriously studying the subject for some years before that.

The first U.S. test series that included experiments designed to investigate thermonuclear explosions took place at Eniwetok in the spring of 1951. Known as Operation Greenhouse, the series included two thermonuclear experiments. One, with the code name Item, was a test of the booster principle. This experiment, it must be emphasized, was planned and programmed before the first Russian atomic-bomb test. The other (which actually took place first) was called George. It was a response to Joe 1, as the first Russian atomic-bomb test was called by the U.S. intelligence establishment. Reduced to its essentials, the purpose of the experiment was to show, as a minimum, that a thermonuclear reaction could under ideal conditions be made to proceed in an experimental device. This experiment came to play a key role in the Super program. As Teller later put it: "We needed a significant test. Without such a test no one of us could have had the confidence to proceed further along speculations, inventions and the difficult choice of the most promising possibility. This test was to play the role of a pilot plant in our development."



TWO HYPOTHETICAL OUTCOMES are postulated in an effort to evaluate how much risk would have been involved in a U.S. decision not to proceed with the superbomb. They are depicted in this historical chart as branches of the time line representing the actual world (*a*). The first branch is referred to by the author as the "most probable alternative world" (*b*), the second as the "worst plausible alternative world" (*c*). Both branches originate at January, 1950, the date President Truman announced his decision to go ahead with the superbomb. The circles denote nuclear-test explosions; the labels are U.S. code names. Area of each circle is proportional to the region that could be destroyed by that bomb. Bombs of "nominal" size (less than 50 kilotons) have been omitted after 1950.

The George shot served its purpose well. During the final stages of calculations concerned with the expected performance of this device, Teller and Stanislaw Ulam came up with the climactic idea that made it possible to achieve the goal of the superbomb program: they invented a configuration that would make it possible for a small fission explosion to ignite an arbitrarily large fusion explosion.

The first test of a device designed to ignite a large thermonuclear explosion by means of a comparatively small quantity of fissionable material took place at Eniwetok on November 1, 1952 (local time). The device, known as Mike, produced a tremendous explosion, equivalent in its energy release to 10 megatons (10 million tons) of TNT. As had been repeatedly predicted since the early 1940's, the yield was roughly 1,000 times larger than the yield of the first atomic bombs. For certain practical reasons relating to the pioneering nature of the test, this first version of the Teller-Ulam configuration had liquid deuterium as its thermonuclear fuel. (The last point needs special emphasis. The Teller-Ulam invention, contrary to folklore, was not the notion of substituting easy-to-handle lithium deuteride for the hard-to-handle liquid deuterium. That possibility had been recognized several years earlier.)

Also in November, 1952, the U.S. tested a very powerful fission bomb, with the code name King, that had an explosive yield of 500 kilotons, or half a megaton. Its purpose was to provide the U.S. with an extraordinarily powerful bomb by means of a straightforward extension of fission-weapons technology, in case such large bombs should become necessary for any strategic or political reason. Originally proposed by Bethe as a substitute for the Super program, it became instead a backup for it.

The first Russian explosion involving fusion reactions took place on August 12, 1953. Russian descriptions of this test and later ones confirm that it was not a superbomb. It was only some tens of times as big as the standard atomic bombs of the day, about the same size as but probably smaller than King, the largest U.S. fission bomb. It evidently involved one of several possible straightforward configurations for igniting a fairly small amount of thermonuclear material with a comparatively large amount of fissionable material. It was the first device anywhere to use lithium deuteride as a fuel, and presumably it could have been readily converted into a practical weapon if there had been any point in doing so. It seems to have been a development step the U.S. bypassed in its successful search for a configuration that would make it possible to produce an arbitrarily large explosion with a relatively small quantity of fissionable material.

In the spring of 1954 the U.S. successfully exploded six more variants of the superbomb in Operation Castle. Their yields varied widely. The first and most famous of these tests, with the code name Bravo, was exploded on March 1, 1954, at Bikini. Its design, which was initiated before the Mike explosion, also incorporated the Teller-Ulam configuration, but it had the more practical lithium deuteride as its thermonuclear fuel. Bravo's yield was 15 megatons, even more than Mike's, and it was readily adaptable to delivery by aircraft.

On November 23, 1955, the U.S.S.R. exploded a bomb that had a yield of a few megatons. According to a statement made by Secretary Khrushchev, this device involved an "important new achievement" that made it possible by "using a relatively small quantity of fissionable material... to produce an explosion of several megatons." Khrushchev's remark is generally taken as confirmation that the test was the first one in which the Russians incorporated the Teller-Ulam configuration or something like it. It also used lithium deuteride as a fuel and was therefore a true superbomb, comparable to the U.S. Bravo device exploded 20 months earlier, except for its yield, which was still probably only about a fifth the yield of Bravo.

With this chronology in mind, what can one say about what might have happened if the U.S. had followed the advice of Oppenheimer and the rest of the General Advisory Committee, backed by Lilienthal and the majority of the AEC commissioners, and had not initiated a program for the specific purpose of developing the Super in the spring of 1950?

At best the invention of very large, comparatively inexpensive bombs of the Super type would have been forestalled or substantially delayed. Very probably the work on the booster principle, which presumably would still have gone forward, would have led eventually to the ideas underlying the design of very big bombs, but those ideas might well have been delayed until both President Eisenhower and Secretary Khrushchev were in power. Those two leaders were both more seriously interested in arms-limitation agreements than their predecessors had been, and it is at least possible that they might have been able to deal successfully with the superbomb. To be sure, such a favorable result was not very probable (certainly it had much less than an even chance of coming about), but its achievement would have been so beneficial to mankind that at least some small risk was clearly worth running.

To evaluate just how much risk would have been involved let us next examine three other outcomes, which I have labeled the "actual world," the "most probable alternative world" and the "worst plausible alternative world" [*see illustration on opposite page*].

In both of the hypothetical alternative worlds I assume that the U.S. would have forgone the development of the Super but that the Russians would have ignored this American restraint and would have proceeded at first just as they did in the actual world. I also assume that the U.S. would have vigorously followed the positive elements of the Oppenheimer committee's advice; thus the booster project and other ideas for improving fission bombs would have been accelerated. The difference between the most probable alternative world and the worst plausible alternative world lies in the timing of the test of the first Russian superbomb. In the worst plausible world I assume that this test would have come on the same date that it did in the actual world. In the most probable alternative world, however, I assume that the test would have been substantially delayed.

In both of the two hypothetical alternative worlds, then, the Russians in August, 1953, would have exploded Joe 4, a large bomb deriving part of its explosive energy from a thermonuclear fuel and yielding a few hundred kilotons. Such a device, however, would have had no real effect on the "balance of terror." In both alternative worlds the U.S. would surely have already tested the 500-kiloton all-fission bomb in November, 1952 (or probably earlier, since the timing of Operation Ivy was determined by the availability of the much more complicated Mike device). Therefore the explosion of Joe 4 would have meant that the U.S.S.R. had caught up with but not surpassed the U.S. insofar as the capability of producing enormous damage in a single explosion was concerned.

Then what would have happened?

From that point the Russians might conceivably still have gone on to produce their multimegaton explosion in

November, 1955, but I think it is ...y probable that they would not have done so until much later. In the actual world they had the powerful stimulus of knowing from our November 1952 test that there was some much better, probably novel way of designing hydrogen bombs so as to produce much larger explosions than the one they demonstrated in their August 1953 experiment. A careful analysis of the radioactive fallout from the Mike explosion may well have provided them with useful information concerning how to go about it. In the hypothetical world where the U.S. would have followed the Oppenheimer-Lilienthal advice that stimulus and information would have been absent. Moreover, a comparison of the way nuclear-weapons technology advanced in the U.S. and the U.S.S.R. during that period makes it seem likely there would have been a much longer delay—probably some years—before they took that big and novel a step without such stimuli and information. Therefore in the most probable alternative world the first Russian superbomb test would have been delayed until well after the first American superbomb test (in other words, delayed until 1957 or 1958), whereas in the worst plausible alternative world it would have occurred just when it did in the actual world: in August, 1955.

What would the U.S. have done in the meantime?

It would have been known immediately that the Russian explosion of August, 1953, was partly thermonuclear and that this test was many times as big as the Russians' previous explosions. If one assumes that following this Russian test the American program in the worst plausible world would have gone along just as it did in the actual world following President Truman's 1950 decision, then the U.S. would have set off the Mike explosion in April, 1956. A simple duplication of those earlier events at this later time, however, would have been unlikely. Any analysis of U.S. reactions to technological advances by the U.S.S.R. shows that the detection of the August 1953 event would have resulted in the initiation of a very large, high-priority American program to produce a bigger and better thermonuclear device. Such a program would undoubtedly have had broader support than the one actually mounted in the spring of 1950. Moreover, the general scientific and technological situation in which a hydrogen-bomb program would have been embedded in 1953 would have been significantly different from the actual one in 1950. For one thing, the kind of theoretical work in progress on the Super before President Truman's decision would have continued and would have provided a solider base from which to launch a crash program. In addition the booster program would presumably have continued along the path already set for it in 1948 (which included a test of the principle in 1951), and therefore in 1953 there would have been available some real experimental information concerning thermonuclear reactions on a smaller scale.

Last but not least, there had been great progress in computer technology between 1950 and 1953. When the real Mike test was being planned, fast electronic computers such as MANIAC and the first UNIVAC either were not quite operating or were in the early stages of their operating career. By a year or so later they were in full running order and much experience had been gained in their utilization, so that they would have been much more effective in connection with any hypothetical post–Joe 4 American crash program. For all these reasons it is plausible to assume that the U.S. would have arrived at something like the Teller-Ulam design for a multimegaton superbomb either in the same length of time or, even more likely, in a somewhat shorter period, say sometime between September, 1955, and April, 1956.

These dates bracket the actual date when the Russians arrived at roughly the same point in the actual world. A few months' difference either way at that stage of the program, however, would not have been meaningful. It takes quite a long time, typically several years, to go from the proof of a prototype to the deployment of a significantly large number of weapons based on it. Differences in production capacity would have played a much more important role than any small advantage in the date of the first experiment, and such differences as then existed surely favored the U.S. Hence even in the worst plausible alternative world the nuclear balance would not have been upset. Moreover, in the most probable alternative world the date the Russians would have arrived at that stage would have been delayed until well after the first large U.S. Mike-like explosion had showed them there was a better way; thus in this most probable case the U.S. would still have enjoyed a substantial lead.

J. ROBERT OPPENHEIMER AND EDWARD TELLER met at a Washington reception in 1963. Behind the two men is Glenn T. Seaborg, who was then chairman of the AEC. At the left is Oppenheimer's wife. Oppenheimer had just received the Fermi Award of the AEC. Ten years earlier, in the aftermath of the secret debate over whether or not the U.S. should proceed with the development of the hydrogen bomb, he had been banned from all Government work by virtue of the fact that his security clearance had been removed. Teller had been a leading advocate of the development of the hydrogen bomb from the early 1940's. The General Advisory Committee of the AEC, of which Oppenheimer was chairman, had recommended in 1949 that the U.S. not initiate an "all-out" effort to develop the Super.

In short, the common notion that has persisted since late 1949 that some sort of disaster would have resulted from following the Oppenheimer-Lilienthal advice is in retrospect almost surely wrong. Moreover, even if by some unlikely quirk of fate the Russians had achieved the Superbomb first, the large stock of fission bombs in the U.S. arsenal, together with the 500-kiloton all-fission bomb for those few cases where it would have been appropriate, would have adequately ensured the national security of the U.S.

This history and the conjectures about possible alternative pasts show that Op-

no further part in original.