The Doomsday Machine: Confessions of a Nuclear War Planner

by Daniel Ellsberg

HOW COULD I?

... On march 3, 1939, Szillard was the frst person to see that flashes of an oscilloscope screenin confirming his suspicion, ″that neutrons were emitted in the tission process of uranium and this in turn would mean that the large-scale liberation of atomic energy was just around the corner." He reports his reaction: "We watched them (the flashes] for a little while and then we switched everything off and went home. That night there was very little doubt in my mind that the world was headed for grief."

Nevertheless, later that year, expecting imminently the war he had long foreseen and fearing that Nazis might be first to exploit the potential of nuclear energy in a bomb, it was Szilard who induced Albert Einstein to send a letter, which he co-drafted, to President Franklin D. Roosevelt, urging what came to be the Manhattan Project. It was dated August 2, 1939. Hitler invaded Poland on September 1.

Almost three and a half years later, Szilard and Enrico Fermi constructed the first working nuclear reactor, which was necessary for the production of plutonium for a bomb. (The Germans never did get a reactor to work.) On December 2, 1942, Szilard recounts in his memoir, a chain reaction was actually initiated and controlled for a very brief period at Stagg Field on the University of Chicago campus. Someone brought out a scarce wartime bottle of Chianti and most present celebrated and congratulated Fermi. Szilard reports: "There was a crowd there and then Fermi and I stayed there alone. I shook hands with Fermi and I said I thought this day would go down as a black day in the history of mankind."

Yet despite this extreme, and fully justified, foreboding, Szilard was playing a critical role in bringing this ominous explosive power into the world. How could he? The answer is that he believed, even before others, that they were racing Hitler to the attainment of this power. It was German scientists, after all, who had first accomplished the fission of a heavy element. There seemed no reason to suppose that Germany could not stay ahead of any competitors in harnessing this unearthly energy to Hitler's unlimited ambitions for conquest. The specter of a possible German monopoly, even a temporary one, on an atomic bomb drove the Manhattan Project scientists --above all the Jewish emigres from Europe like Szilard (Fermi had left Italy in 1938 because his wife was Jewish)- until the day of Germany's surrender.

In reality the race was one-sided. **At virtually the same time, in June 1942, that the American team of theoretical physicists was tackling the problems of bomb design, Hitler had decided against a bomb effort, not for moral but for practical reasons: the unlikelihood that it could be delivered during the several years he had scheduled for the war. Nevertheless, ignorant of this German choice, the scientists in the United**

States focused single-mindedly on achieving a usable weapon as quickly as possible.

Some of them saw it exclusively as a means for deterring Hitler from using such a weapon, if he got it. To possess such a deterrent seemed an

urgent necessity, raising no moral issues for them. One of these scientists, Joseph Rotblat, after learning from a British associate in the fall of 1944 that there was no German program to deter, promptly resigned from the Manhattan Project. The only scientist to do so, Rotblat was induced, by threat of deportation, not to reveal his reasons for leaving, lest he inspire others to emulate him.

Others, including Szilard, remaining uncertain whether Hitler might unveil this war-winning weapon at the last moment, were prepared to use the weapon against Germany if it became available before Nazi surrender. But prior to that event, there had been almost no consideration or discussion within the Manhattan Project itself of what to do with or about this capability if it were not needed either to defeat Germany or to deter a German bomb. Only after this was unmistakably clear with the German surrender did Szilard and some of his colleagues turn to urgent efforts to avert unilateral U.S. test of the bomb, or to refrain from dropping it on Japan --thus, hoping to avert an inevitable U.S.-Soviet nuclear arms race. But it was too late.

We come at last to the issue with which I began this chapter. The reasons for my own lower-level involvement in shaping nuclear policy - despite my early feelings of dread about the very existence of nuclear weapons -- were strikingly similar to those of Joseph Rotblat and Leo Szilard. In the late fifties, I was given what seemed good reason to believe --on the basis of highly classified official information-- that we were again in a desperate race with a powerful, totalitarian opponent comparable to Nazi Germany, working to deter a nuclear Pearl Harbor attack or to avert unanswerable nuclear blackmail. As we'll see, once again this apprehension was based on illusion. But the fears were real, and they seemed to have a plausible basis. How I came to share these fears and to act on them is a story with two parts.

First, like my older colleagues at that time and like so many among my generation in America, I had become a Cold Warrior over the preceding decade. I had taken some note when Churchill, one of my heroes since the Battle of Britain, proclaimed in March 1946 that an "ïron curtain" had descended across the continent, dividing free Europe from tyrannical rule in the East. ...

CHAPTER 17
Risking Doomsday I
Atmospheric Ignition

As we have seen, the creation of a nuclear Doomsday Machine depended on a willingness to regard cities as legitimate targets for mass destruction; that was fully accepted by our ally, Britain, as early as 1942, and by our own leaders and air force by 1945. But the construction and maintenance of such a machine also drew on a willingness, at least on the part of certain human beings, to undertake vast, even incalculable risks that went far beyond the potential of "killing a nation." This propensity was demonstrated before the first atomic bomb was tested on living targets.

In the late winter of 1941, Enrico Fermi passed on to Edward Teller his thoughts about the possibility of a fusion bomb a thousand times more powerful than the fission bomb they were about to consider. To cause atoms of the lightest element, hydrogen, to fuse together, thereby releasing a vast amount of energy, would require extraordinarily intense heat. Within the heart of the sun, fusion of hydrogen was self-generated by the ongoing heat and pressure of the sun itself. On earth, if it were possible at all, the fusion of hydrogen would require a fantastic amount of heat and pressure to start the process. But an atom bomb -which depended for its energy on splitting, or fissioning, the atoms of the heavy element

uranium - might do the job.

This discussion with Fermi lighted a fire in Teller's mind that never subsided. The pursuit of this obsession so consumed him during the Manhattan Project that he was shunted aside by Robert Oppenheimer

to a subproject on "future superweapons" and didn't contribute much to the actual project of developing an atomic weapon before the end of the war.

It was on the second day of the first meeting of the proto-Manhattan Project, July 7. 1942, in a locked classroom at the University of California, Berkeley, with heavy wire screens on the windows to keep out intruders, that Teller covered a blackboard with his calculations on the process that might lead to the ignition of a thermonuclear fusion weapon. First, he laid out the process understood in principle by all those in attendance, starting with the fission by a single neutron of one atom of U-235, which, in splitting, would emit two or more neutrons. That would in turn start a chain reaction of successive fissioning and emissions that would, in milliseconds, cause an explosion a thousand times more powerful than the blast of a ton of TNT. That was supposedly the end result their main project was aiming for.

But the point of Teller's presentation, triggered by his conversation with Fermi, was a calculation of the heat that would be built up in this process. It would be enough, he proposed to show, that the resistance to the fusion of two or more atoms of hydrogen would be overcome, leading to the emission of energy another thousand times greater (a million times that of TNT). His figures on the board did show that.

But to these assembled minds it also showed something else, something Teller himself quickly pointed to. The scientists looked at the blackboard scribblings with a wild surmise. Heat that intense, greater than that at the center of the sun, would not only fuse hydrogen atoms. It would break the Coulomb barrier between atoms of hydrogen in water and nitrogen in the air. It would ignite virtually instantaneously all the hydrogen in the oceans and set the air around the globe afire. The earth would blaze for less than a second in the heavens and then forever continue its rounds as a barren rock.

None of them, coming together in Berkeley, had doubted the theoretical feasibility of an atomic explosive. The problems, possibly insurmountable at least in time for practical use in World War II, were technical: for example, could the mass be held together long enough for the fission chain to generate a full explosion? Now it appeared that the practical challenge of making the bomb was not the only issue. Making it workable might not be such a good idea.

They began to go over the stages of Teller's calculations. Before long they discovered a mistake. He had omitted consideration of one part of

the process that bore, critically, on the speed of cooling: the transmission of heat to the atmosphere. Still, these corrections did not eliminate the possibility that the feared reaction might still occur.

Among those present for this presentation was Hans Bethe, who was the greatest theoretical physicist among the group, and whose later Nobel Prize was precisely for his work on the thermonuclear reactions in the sun. His initial instinct was that this result was "impossible."

However, others didn't come out with that result. ("Certainty" Nuel Phar Davis wrote in his account of this episode, "is a state of mind based on not having to depend on someone else's calculations.") Fermi, in

particular, the greatest experimental physicist present, did not agree with Bethe's assurance of impossibility. Eventually Oppenheimer concluded that Arthur H. Compton, in charge of the whole project, needed to be told of this danger at once. Meanwhile, everything had to be put on hold. But Compton was on vacation with his family at a lake in Michigan. Oppenheimer managed to reach him by phone and, in an anxious voice, told Compton that he must come to see him immediately. He couldn't tell him why. They agreed that Oppenheimer would take the next available train. (Scientists essential to the project were forbidden by government orders to travel by plane, for safety reasons.) What happened next was recounted by Compton in his memoir:

I"ll never forget that morning. I drove Oppenheimer from the railroad station down to the beach looking out over the peaceful lake. There I listened to his story. What his team had found was the possibility of nuclear fusion -the principle of the hydrogen bomb. This held what was at the time a tremendous unknown danger. Hydrogen nuclei, protons, are unstable, for they could combine into helium nuclei with a very high temperature. But might not the enormously high temperature of an atomic bomb be just what was needed to explode hydrogen? And if hydrogen, what about the hydrogen of sea water? Might the explosion of an atomic bomb set off an explosion of the ocean itself?

Nor was this all. The nitrogen in the air is also unstable, though in less degree. Might it not be set off by an atomic explosion in the atmosphere?

These questions could not be passed over lightly. Was there really any chance that an atomic bomb would trigger the explosion of the nitrogen in the atmosphere or of the hydrogen in the

ocean? This would be the ultimate catastrophe. Better to accept the slavery of the Nazis than to run a chance of drawing the final curtain on mankind!

Let's step back for a moment and consider that last proposition. It seems sensible enough, one might even say obvious. Yet in the countless books about the Nazis and World War II, I don't believe that there is a comparable statement to be found anywhere, in any official record, memoir, or scholarly history. Nor in a newspaper editorial or letter to the editor. Something worse than Nazi occupation?

Being enslaved by Nazis was actually not a near-term danger for Americans, but it was for their wartime allies, the British and Russians. In June 1942, just before the six-month battle of Stalingrad was to begin, a Nazi victory in Russia looked more than possible, on top of their success in occupying all of Europe. And at the time of Compton's judgment, the Nazis had begun the process of murdering two million Polish and six million Jewish civilians in their occupied lands, along with twenty-seven million Soviet soldiers and civilians. Could there really be something worse, something so bad that a chance "of it was worse than accepting the slavery of the Nazis"?

Well, yes. Compton's instant judgment was that what they might be bringing about --the possibility of ending life on earth- was such a prospect, one they should not risk at any cost.

Strikingly, Adolf Hitler's own reaction to this possibility was not different. Just weeks prior to this, in June 1942, his minister of armaments, Albert Speer, was confirming Hitler's view that there was "not very much profit" in pursuing an atom bomb project during the war, mainly because it would not be successful within Hitler's two-year dead-

line for victory, but also for another reason:

Actually, Professor Heisenberg had not given any final answer to my question whether a successful nuclear fission could be kept under control with absolute certainty or might continue as a chain reaction. Hitler was plainly not delighted with the possibility that the earth under his rule be transformed into a glowing star.

Following this discussion, Speer reported, "*on the suggestion of the huclear physicists we scuttled the project to develop an atom bomb ...*

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after I had again queried them about deadlines and been told that we could not count on anything for three or four years."

In ignorance of this German decision that month against a bomb project, and facing the possibility that earth might become forever a barren rock after a very brief glow, Compton and Oppenheimer "agreed there could be only one answer. Oppenheimer's team must go ahead with their calculations. Unless they came up with a firm and reliable conclusion that our atomic bombs could not explode the air or the sea, these bombs must never be made."

Facing, indeed, possibilities that no human being had ever confronted before, one would like to think that this was an inevitable judgment. It turns out, that was far from being so. In fact, Compton didn't entirely hold to it himself.

The Manhattan Project did continue, at full blast (so to speak), but not because further calculations and partial tests proved beyond doubt that there was no possibility of what became known as "atmospheric ignition." Some scientists may have come to trust Bethe's calculations, or really, his initial gut feeling, that this result was "impossible." But many others did not.

As months went by, with the work having resumed on a crash basis, no one, including Bethe, was able to convince most others that the ultimate catastrophe was "not possible": which Compton, in charge of the project, had laid down, seemingly reasonably, as the definite condition for pursuing the work. Very unlikely, yes. But not impossible.

Just how unlikely? Was the risk, in some sense, "negligible"? How low was it? And just how low would the risk have to be -of killing everybody, every living thing- to be acceptable? In a later interview with the novelist Pearl S. Buck, Compton recounted the story above (in almost identical words) and then added, according to Buck, that while the work went on for the next three months,

scientists discussed the dangers of fusion but without agreement. Again Compton took the lead in the final decision. If, after calculation, he said, it were proved that the chances were more than approximately three in a million that the earth would be vaporized by the atomic explosion, he would not proceed with the project. Calculation proved the figures slightly less- and the project continued.

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Say what? How does one arrive at a precise upper limit of "three in a million"? What is it derived from, and what does it mean? In this case, it meant: "Small, very small. We don't know exactly." Most of the senior theorists did believe the chance was very small, but not zero. When Compton had been assured that the risk was not more than the "three in a million" chance (which he had more or less pulled out of the air as the upper limit to be accepted for continuing the work), he decided, contrary

to his initial reaction, that although it was not "no chance," it was low enough to resume research. All the others went along with that. As Peter Goodchild puts it, "Once Bethe's calculations had relegated atmospheric ignition to a remote possibility -at least for the time being- the group returned to the issue at hand [designing a fission bomb]."

"For the time being"-meaning, awaiting further calculations, hopefully that would prove the possibility was zero (as Compton had initially demanded of Oppenheimer), prior to conducting an actual explosion. But calculations before the test never did demonstrate that.

Nearly every account to be found of the problem of atmospheric ignition describes it, incorrectly, as having been proven to be a strict non-problem -an impossibility-- soon after it first arose in the initial discussion of the theoretical group, or at any rate well before a device was actually detonated.

I know this to be untrue because I heard that from the lips of the official historian of the Manhattan Project, David Hawkins, who had been hired to write an ongoing, highly classified account of the process from its earliest days. When I questioned him at the University of Colorado in 1982, he elucidated an often-quoted statement from his own eventually declassified 1945 history: "The imposibility of igniting the atmosphere was thus assumed by science and common sense."Impossibility" in that passage, he explained to me, "didn't mean no possibility" It meant "for practical purposes" a "negligible" chance: "enough assurance to proceed with the work."

He told me that he had "done more interviews with the participants on this particular subject, both before and after the Trinity test, than on any other subject" in his research. What the problem did become, he said, was a nonsubject for further discussion by the project's leaders with the other researchers. "They had to keep batting it down. Younger researchers kept rediscovering the possibility, from start to finish of the project." When they brought it up privately to a senior theorist, with

considerable anxiety, they would be told, "We've looked into that; it's been taken care of; don't worry about it."

Prior to the detonations at the Trinity site, Hiroshima, or Nagasaki, Hawkins told me firmly, they never confirmed by theoretical calculations that the chance of atmospheric ignition from any one of these was zero. Even if they had, the experimentalists among them would have recognized that the calculations could have been in error or could have failed to take something into account. That was very much in Enrico Fermi's mind, and even Edward Teller's, on the eve of the first test.

Most accounts of the Trinity test on the early morning of July 17, 1945. recount that Fermi offered to accept bets the night before as to whether atmospheric ignition would occur. He said, "I feel I am now in a position to make book [that is, to accept bets at fixed odds] on two contingencies: 1) that the explosion will burn New Mexico; 2) that it will ignite the whole world."

Too bad that the actual odds Fermi offered that night on these events are lost to history. Whether anyone placed money with Fermi and what odds he did offer seem never to have been reported. There are strong hints that his odds for total atmospheric ignition were much higher than three in a million. He would hardly have offered to "make book" on the basis of odds like that.

Accounts agree that when General Groves, the military officer in charge of the Manhattan Project, heard about this offer, he was angry;

he feared it would upset the enlisted men. He had himself prepared a draft news release in case the explosion was larger than expected and destroyed Oppenheimer and the other observers. It mentioned simply an "accidental explosion." He was disconcerted that Fermi's reported bets would imply to some that he might need a different press bulletin: "We've lost New Mexico." (If Fermi had won the second bet, about the end of life on earth, no bulletin would be necessary.) But on second thought, Groves concluded that Fermi was joking.

As a consequence of his reaction, many accounts describe Fermi's offer as "a joke, intended to relieve the tension." It's unclear how anyone's tension could have been relieved by this particular jest. But as William Laurence of the New York Times, permitted to chronicle the whole process and the testing of the bomb, put it at the time and in a retrospective later, "many of the scientists did not believe he was joking." Indeed not: numerous accounts mention how anxious many of the participants were that night, especially the younger ones. That probably included

those who had hit upon the possible phenomenon themselves and whose concerns had been met simply with formulaic assurances.

As Peter Goodchild recounts, Fermi's expression of uncertainty about the occurrence of atmospheric ignition had been neither a joke nor a last-minute tremor:

In the final weeks leading up to the test Teller's group were drawn into the immediate preparations when the possibility of atmospheric ignition was revived by Enrico Fermi. His team went to work on the calculations, but, as with all such projects before the introduction of computers, these involved simplifying assumptions. Time after time they came up with negative results, but Fermi remained unhappy about their assumptions. He also worried whether there were undiscovered phenomena that, under the novel conditions of extreme heat, might lead to unexpected disaster.

As the test approached, Teller himself, Goodchild reports, "searched for and tested out hypotheses about such phenomena on anyone who would listen." He was still doing this with Oppenheimer's aide Robert Serber in the evening hours before the test. (Serber advised him to deal with the possibilities by bringing along a bottle of whiskey.)

In 1982, Thomas Powers reported an interview with Stan Ulam, who in 1951 was the progenitor of the H-bomb along with Teller, that finally gives a sense of the measure of Fermi's uncertainty that night. According to Ulam:

Before the Trinity test, the physicist George Breit was given the job of estimating the chances that a nuclear bomb would ignite the carth's entire atmosphere. The chance of this was very small, but after all, said Ulam, "the stake is infinite.... Fermi did the same calculations too." He wanted to be sure. Theoretically, if the temperatures created by a nuclear explosion were high enough, the nitrogen in the atmosphere might spontaneously ignite. Fermi confirmed Breit's calculations: such temperatures don't exist in nature. On the long drive to Alamogordo for the Trinity test, Fermi joked about his conclusions. "It would be a miracle if the atmosphere were ignited," he said. "I reckon the chance of a miracle to be about ten percent."

As Sam Allison, a physicist who had been assigned to "ride herd" on the final stages of the project, was counting down the last seconds over a loudspeaker, "Ten, nine, eight.." Davis reports that another young

physicist had the responsibility of deciding whether to push a button that would abort the process. In those last seconds, he turned to Oppenheimer and said, "What if I just say this can't go on and stop it?"

Oppenheimer looked at him coldly and said, "Are you all right?" As Allison continued his countdown, "...five, four..." he was thinking partly, he told Davis, of "Fermi's qualms," which he shared. It had been his job, asigned by Oppenheimer, for the past six months to make sure that the project was moving ahead on schedule. But now, "for him it was no justification to say he had done what someone had told him to do; what right had he to participate in an experiment that might kill off the human race?" Seconds later, as the great light was followed by a blast wave that shook the bunkers and eventually subsided, Allison was musing, "Still alive.... No atmospheric ignition."

Others watching ten miles away from ground zero had the same feeling of relief, for the same reason, having spent seconds before that fearing the opposite. One of these was James Conant, the president of Harvard who had oversight over the Manhattan Project as chairman of the NDRC. As Allison's final countdown was echoing over a loudspeaker Conant whispered to Groves that he "never imagined seconds could last so long." In his words:

Then came a burst of white light that seemed to fill the sky and seemed to last for seconds. I had expected a relatively quick and light flash. The enormity of the light quite stunned me. My instantaneous reaction was that something had gone wrong and that the thermal nuclear transformation of the atmosphere, once discussed as a possibility and jokingly referred to a few minutes earlier, had actually occurred.

His thought at that moment was, "The whole world has gone up in flames."*

"I was told by the daughter of a scientist who had experienced the test lying near James Conant that when the preternaturally intense white light first enveloped them, Conant's first thought, he said later, was, "Fermi was right." It was my hearing this comment at a reception at the University of Colorado Boulder in 1982 that first attracted my attention to his issue and led to my talk with David Hawkins a few days later.

In short, the first Trinity test at Alamogordo constituted a conscious gamble by the senior scientists at Los Alamos and their immediate superiors: a gamble with the fate of every sentient being on the face of the planet and in the atmosphere and the depths of the oceans. It is noteworthy that it was the scientists alone who took on themselves the esponsibility for this gamble. On the basis of any documentation that has survived or any recorded memories, there is no evidence that the possibility of atmospheric ignition was ever made known to the president or anyone else in Washington, D.C., outside the Manhattan Project, either in 1945 or in the three years since it had first been raised to Compton by Oppenheimer in July 1942.

If it had been made known to top civilian offcials -as it was exposed to Hitler, that same month in 1942, by Speer- how would they have reacted? Would President Roosevelt have sided with Compton's first reaction: that "no chance of this event was acceptable, no matter how small the probability? Or with his judgment shortly after that the risk was suficiently small that continued development work was appropriate?

Probably the latter, since only the research was in question at that point, and for the next several years. After all, in June 1942, the scientists had every reason to fear that the Germans might develop the bomb before we did, and for the policy makers there was still a lively concern that Germany might win the war without a bomb. But none of that was

still true in July 1945, when the effort had come to the point of actually detonating a test device without having put entirely to rest the possibility of atmospheric ignition.

Might President Truman or Secretary of War Henry Stimson --if they had been aware of the possible loss of all life on earth, forever!-- have demanded odds better than three in a million, let alone Fermi's "ten percent"? As it was, in ignorance of any reason for anxiety as they awaited reports at the Potsdam Conference in Germany, hoping for news that would strengthen their hand in negotiations with the Soviets, they learned of its success without Sam Allison's sense of relief. And they were equally ignorant of some scientists' continued cause for apprehension about the longer-term effects of this result, and still more about the experiments on humans that lay just ahead in Japan.

Part of that concern --for some the smaller part-- had to do with the people who would be killed by those further explosions. Allison had qualms about that prospect within minutes after the test, as soon as his fears of burning everyone on earth had dissipated. "Oh, Mr. Conant," he said, in anguish, "They're going to take this thing over and fry hundreds of Japanese." His estimate was low by three orders of magnitude, a thousand times.

At the May 31 meeting, Oppenheimer had estimated that the first bomb would kill about twenty thousand people. It immediately killed four times that many, but that was still fewer than the hundred thousand who had been burned alive in one night by the Tokyo firebombing. The readiness of the highest civilian and military officials to allow General Curtis LeMay to multiply that scale of civilian death several times over had been thoroughly tested in the months since. They had all passed that test. Likewise, by late July the scientists had demonstrated their own readiness to take a sufficiently small chance (for Fermi, not so small) of burning up all life on the planet.

According to Albert Speer, this would not have surprised Adolf Hitler. In June 1942, Hitler occasionally "joked that the scientists in their unworldly urge to bare all the secrets under heaven might some day set the globe on fire. But undoubtedly a good deal of time would pass before that came about, Hitler said; he would certainly not live to see it." Actually he died, by his own hand, only ten weeks before the Trinity experiment.

Those who undertook that gamble in July 1945 did not appear to fit the stereotype of the "mad scientist": though in the light of this long-unknown history, the notion is not so far removed from reality. But though they did expect to win that particular bet, with high probability, they were also aware -again more so, it seems, than their civilian superiors- that they were simultaneously engaged in a longer-term gamble imperiling the survival of humanity.

First, some of them (not all) were convinced that even a unilateral U.S. test, still more the unwarned use of the bomb on cities in wartime - in the absence of collaboration with the Soviets and of international controls- virtually assured a desperate postwar nuclear arms race with the Soviets. Second, nearly all understood that such a race would probably lead in a few years' time to the production of thermonuclear weapons on both sides. Bombs with a million times the evplosive power of the

largest blockbusters of World War II; thousands of them. These two deselopments together -the latter recognized in July 1942 at the same moment as the possibility of atmospheric ignition-- foretold the distinct possibility of destroying the whole of human civilization. Total incineration of the world of cities of the last four thousand years. And with a

probability of a lot more than three in a million.

Back in Washingtoa, James Conant wrote up his notes on the Trinity test for his boss, Vannevar Bush. Conant concluded by suggesting that his first few seconds' sense that they had participated in the destruction of hurmanity might have been prescient. "My first impression remains the most vivid, a cosmic phenomenon like an eclipse. The whole sky suddenly full of white light like the end of the world. Perhaps my impression was only premature on a timescale of years!"

George Kistiakowsky's reaction to the flash was much the same as Conant's. He told the New York Times reporter who had witnessed the spectacie from ten miles farther away that it was "the nearest thing to Doomsday one could possibly imagine."

That was mistaken. More than three years earlier, Enrico Fermi had stirred Edward Teller to imagine and for the next nine years, obsessively to pursue an explosion a thousand times nearer to Doomsday than the one they witnessed at Alamogordo:

"The yield of the frst droppable H-bomb tested by the United States in 1954 was fifteen megatons. That is a million times more explosive power than the largest blockbusters in Wocd War II.(The largest warbead ever tested, fifty-eight megatons, was detonated by the Soviets in 1961.) The yield was 250 percent greater than the largest yield that had been predicted for it, six megatons, resulting -along with an unexpected shift in wind- in heavy radoactive fallout contaminating inhabitants of the Marshall Islands and the crew of the distant Japanese fishing boat Lucky Dragon, one of whom died. The reason for the great underestimate of yield, with its serious human consequences, was precisely the kind of scientific error or unforeseen reactivity that Fermi had feared in connection with the possbility of atmospheric ignition from the Trinity test. Los Alamos bomb designers had neglected (or greatly underestimated) the contribution to the production of neutrons and to the yield from one of the isotopes included in the hydrogen fuel, lithium-7, which had been thought to be relatively inert but proved not to be under the unprecedented conditions of the dry-fuel thermonuckear detonation. (See Alex Wellerstein, "Castle Bravo Revisited," Restricted Data, June 21, 2013, and comments: blog .nuclearsecrecy.com/2013/06/21/castle-bravo-revisited/)

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