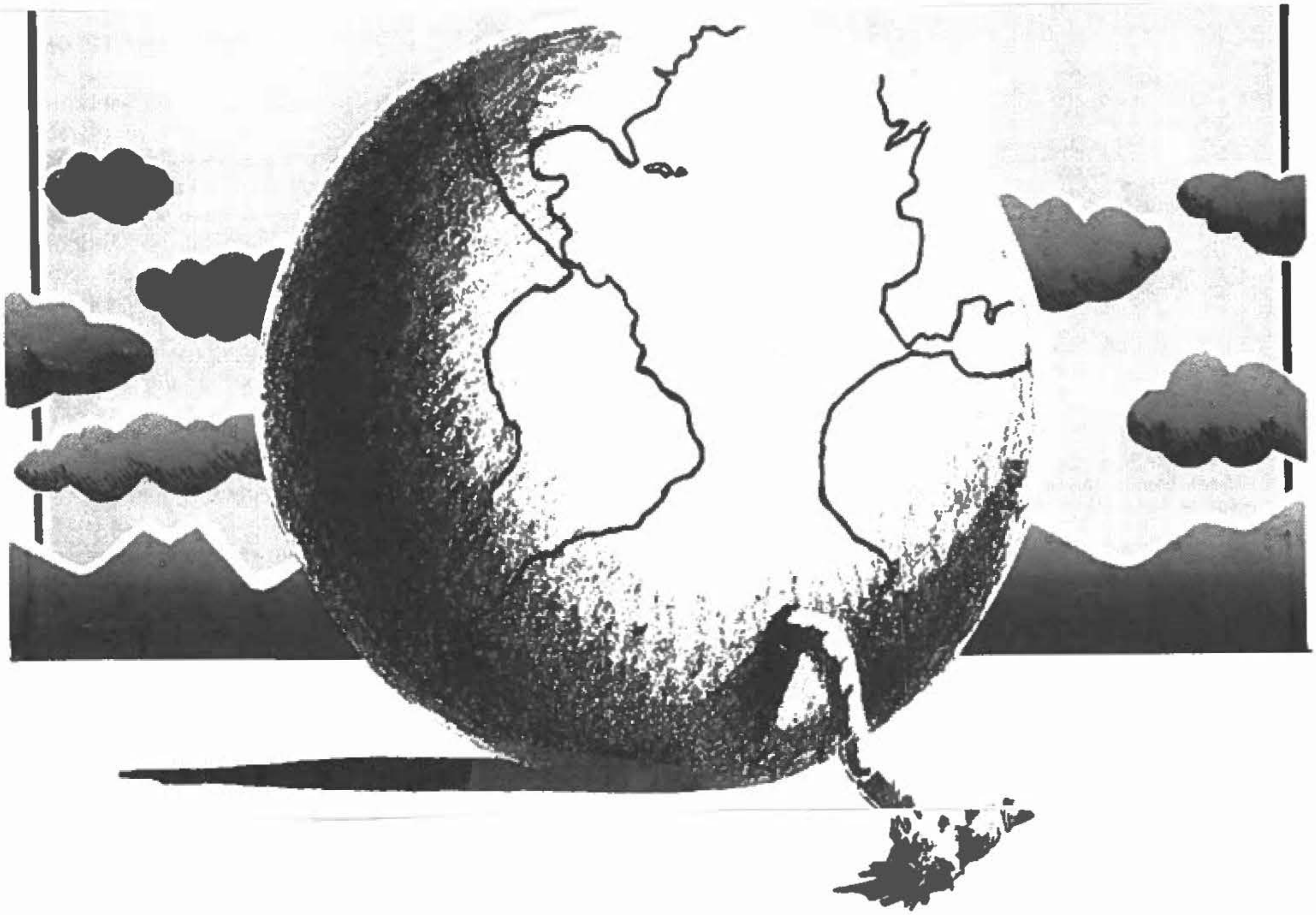

H. C. Dudley

The ultimate catastrophe

It's time someone ran a computer calculation on the chances of a high order fusion explosion inducing a runaway chain reaction

In the many excellent historical and autobiographical papers which have appeared in the *Bulletin* during the past two years, little or no mention is made of the nervous strain under which the personnel of the Manhattan Project labored during the years 1941-45. Time has apparently dimmed such memories. Compare the equanimity of those in high places who now consider plans for detonating 100,000 fusion devices *annually* for alleviating the growing energy crisis.[1]

During World War II the eminent scientists of that era offered two options to President Roosevelt: accept the possible slavery of the Nazis or develop and explode atomic bombs. There was a third option, however, that was kept under wraps, *top secret*, discussed only behind closed doors, though sometimes guardedly by the lower echelons of *the* Project. This was the possibility of triggering a vast nuclear accident when and if a fission device was detonated.

The tension under which the leaders of the project were working during the developmental period was discussed by the writer Pearl Buck in

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After studying rats for 30 years I realize why people are so horrified by them. They're the animal species that comes closest to duplicating human social behavior.

an interview with Arthur H. Compton published in 1959:[2]

"And if hydrogen, what about the hydrogen in seawater? Might not the explosion of the atomic bomb set off an explosion of the ocean itself? Nor was this all that Oppenheimer feared. The nitrogen in the air is also unstable, though less in degree. Might not it, too, be set off by an atomic explosion in the atmosphere?"

"The earth would be vaporized," I said.

"Exactly," Compton said, and with what gravity! "It would be the ultimate catastrophe. Better to accept the slavery of the Nazis than to run the chance of drawing the final curtain on mankind!"

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 to one 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.

The first trial of a high order fission explosion, the first atomic bomb (code name "Fat Man"), was set for Monday morning, July 16, 1945, 5:30 am at the Trinity site in New Mexico. The mental state that morning of those who had made the calculations of the probability of the 'ultimate catastrophe' was described as follows by Stephane Groueff some 22 years later:[3]

On arrival [Lt. General Leslie] Groves immediately sensed the tremendous excitement in the air. Everyone was overtired, and tension was mounting visibly as zero hour approached. Groves was particularly worried about Oppenheimer, who seemed to be reaching the limit of his endurance. Groves wanted the laboratory's director to be as calm as possible when making the final command decisions. There were altogether too many excited people around giving him advice on what he should do. Groves was annoyed, too, with Fermi, who was making bets with his colleagues on whether the bomb would ignite the atmosphere, and, if so, whether it would destroy only New Mexico—or the entire world. Fermi was also saying that, even if the bomb failed to go off, it would still be a worthwhile experience—it would prove, in that case, that an atomic explosion was probably impossible.

So the Fat Man bomb was successfully detonated at Trinity, two more over Japan (1956) and two at Bikini (one under water) (1946). Between 1948 and 1958 there were about 50 more fission and fusion devices exploded in the far reaches of the Pacific. Several other nations have developed and tested these devices, thus, notifying the world of their nuclear capabilities. Isn't this sufficient evidence that such a vast nuclear accident can not occur? NO!

In 1945 the probability of such an accident was calculated to be about three in a million. This simply means that the chances of such a holocaust occurring are not numerous, but certainly *not* zero. And by the well-established principles of statistics and probability each detonation is a fresh new event, not predictable from a few previous rolls of the dice.

One may drive an automobile for years and never have so much as a scratched fender. But the likelihood of a serious accident can be measured by the ever increasing auto insurance premiums. That such events do occur all too frequently is well documented in the junkyards that are scattered on the outskirts of our cities. There we can see the workings of probability—possibilities becoming reality.

The knowledge that nuclear explosions have the potential of triggering a vast nuclear accident has been in the hands of scientists for more than 30 years. It is not known to this writer whether Presidents Roosevelt and Truman were made aware of these calculations. Nor is it known from any published material whether those who were instrumental in developing fusion devices (1948 to 1958) ever seriously considered the ultimate potential or the unexpected results of fusion explosions that were a 1,000 times as powerful as the fission device of 1945. In any case, they were all rolling dice for high stakes and the rest of us did not even know that we were sitting in the game.

The criteria in 1945 for assessing the danger of an 'ultimate catastrophe' being triggered by an atomic explosion consisted of (1) the laboratory data on fission available since 1939; (2) the theoretical assumptions and concepts developed since about 1905; and (3) the assumptions of the applicability of the mathematical systems used in developing the basic theories from which the safety projections were made.

As a result of the success of the Manhattan Project and other wartime technological developments, major governments of the world and industry have poured about 3 percent of their Gross National Product into all types of research and development. These vast expenditures have generated what is well-called the 'information explosion.' Over the last 30 years new laboratory information on the interactions of the atom have become available, new theoretical concepts are developing. The old order changeth. These studies show that fission and fusion can be triggered by lasers; that the rate of radioactive decay can easily be altered; that half-lives once thought to be constant are easily varied; and that the energy yields of fusion devices are not accurately predictable.

The theoretical foundations of the whole of nuclear science are being questioned as the result of reexamining a concept that was taught as basic in all physics textbooks pre-1920: the necessity of the presence of an all-pervading gas-like medium

Taking up where Bethe left off

In 1939 Hans Bethe published a theory that explained the source of the Sun's energy. He worked out a six-step process, a possible way, by which four ordinary hydrogen atoms (H^1) could be converted to form one helium atom (He^4). If four hydrogen atoms fuse together, they liberate large amounts of energy—conversion of mass to energy—since the mass of four H^1 atoms is greater than the mass of one He^4 atom. Inasmuch as the Sun consists largely of hydrogen, it is able to generate energy at a high rate. Bethe received the Nobel Prize in 1967 for his contribution to the theory of nuclear reactors, and especially his discoveries concerning the reactions which supply energy in the stars.

One of Bethe's six steps required the presence of the same kind of nitrogen atoms that make up 80 percent of the Earth's atmosphere:

$$N^{14} + H^1 = O^{15} + \text{energy} \quad (1)$$

For such a reaction to start, the temperature in the interior of the Sun must be about 100 million degrees. For such a reaction to continue, the energy released must be retained near the site of its production, with containment pressure measured in tons per square inch. These are the conditions which exist in the interior of the Sun. According to Bethe, other reactions are

$$H^1 + H^1 = H^2 \text{ (deuterium, D)} + \text{energy}. \quad (2)$$

$$D + D = He^3 + \text{neutron} + \text{energy}. \quad (3)$$

$$D + D = H^3 + H^1 + \text{energy}. \quad (4)$$

with reactions (3) and (4) being more probable under the conditions of containment and high temperature.

A probable secondary reaction following the formation of hydrogen by reaction (4) is

$$H^3 + D = He^4 + \text{neutron} + \text{a large energy yield}. \quad (5)$$

Reaction (5) produces more than four times the energy per atom as do reactions (3) and (4), with a much higher probability of occurrence of (5), once the H^3 is formed by reaction (4). Under the conditions of a hydrogen-rich mixture, containing some nitrogen and deuterium, it seems logical to predict that reaction (5) may provide the means of sustaining a chain reaction as a result of the high energy yield being contained by a high pressure environment.

As indicated, the interior of the sun provides the required hydrogen-rich high pressure-high temperature environment necessary for all five of these reactions to continue for billions of years. The seas also provide a hydrogen-rich environment, with containment pressure measured in tons per square inch under millions of square miles of water. The explosion of a conventional fission or fusion device would provide the 100 million degree temperature necessary to initiate reactions (1) through (5).

Another theoretical approach is through the examination of "nuclear binding energy," which is a measure of the energy stored within the nucleus of an atom. By plotting the binding energy against the mass of the atoms one generates a curve which has marked discontinuities at that section where the lighter elements lie (hydrogen, helium, boron, beryllium, lithium). From these data one can predict that such reactions as (2) through (5) will take place. Extending this, one finds that in the segment of the curve at N^{14} and O^{16}, constituents of our atmosphere, there is another break in the curve. This is not so marked a break as lower down with the lighter elements, still it is sufficient to explain the N^{14} reaction in Bethe's solar sequence. Thus, one can conclude that both N^{14} and O^{16} may be caused to undergo fusion with the hydrogen in atmospheric moisture. The probability of a sustained chain reaction in the atmosphere does not appear as great as in the sea since there is no high pressure containment mechanism. However, as Fermi, Oppenheimer, Compton and others calculated, this probability is by no means zero.

To add weight to the above comments, it is necessary to have experimental data. But nuclear explosion research is of course classified *top secret*, since this is definitely an area of weapons research.

There is, however, some published data on those reactions that offer the greatest promise for electric power generation through fusion, namely, reactions (4) and (5) shown above.* Using this information—following in the footsteps of Bethe since he too had little data to go on in 1939—we should for safety's sake apply the information available in 1975.—H.C.D.

*S. Glasstone and R. H. Loveberg, *Controlled Thermonuclear Reactions* (Princeton, N.J.: Van Nostrand, 1960), and D. J. Rose and M. Clark, Jr., *Plasma and Controlled Fusion* (New York: Wiley, 1961).

called 'ether' or 'aether,' which fills all space. The calculations of 1945 assumed that the ether does not exist, yet in 1975 astronomy and cosmology are beginning to define this earlier ether as the 'neutrino sea,' an energy-rich subquantic, particulate medium which fills all interstellar space. In fact, it now appears that there is more unseen mass between the stars than there is present in all the stars and their planets.

Another result of the vast expenditure of R&D funds over the past three decades has been the development of weapons and their delivery systems that stagger the imagination. Men have literally found the way in 30 short years to send a few survivors back to the caves. Given the present nuclear overkill capability both of the United States and Soviet Union, we can cause our culture to follow the route of the Mayans and Aztecs. Yet, the world's leaders, and the people too, accept this state of affairs with equanimity.

These weapons systems include intercontinental ballistic missiles with an accuracy of ±1 mile and satellites armed with multiple warheads that can spew out H-bombs like confetti. Submarines are on the prowl, each armed with H-torpedoes and long-range H-rockets. Similarly armed SAC planes are flying constant patrol. And what is the probability of some *accidental* goof-up that will cause a high order fusion detonation in seawater? Note what Compton had to say about Oppenheimer's concern in 1945 with the probabilities of a *fission* device inducing a chain reaction in the sea, not forgetting that the Earth's surface is about 85 percent water. Remember, too, that there is plenty of hydrogen and oxygen down there, along with some nitrogen, even deuterium to act as the trigger. The obvious question: What is the probability of a *fusion* device initiating a sustained chain reaction in seawater?

Because of the complexity of modern warfare, there is among the rank and file of the U.S. military a spoof on this called Murphy's Law: "If any thing can go wrong, it will." And proof of the validity of this Law is the U.S. submarine at the bottom of the South Atlantic, crew long dead, but H-bomb rocket heads intact. A Soviet sub met the same fate more recently in the mid-Pacific. Same results. A cruising SAC plane, off the coast of Spain a few year ago dropped or jettisoned its H-bomb as it made ready for a crash landing. Fortunately, the bombs did not detonate, but the fissionable material was scattered over the landscape.

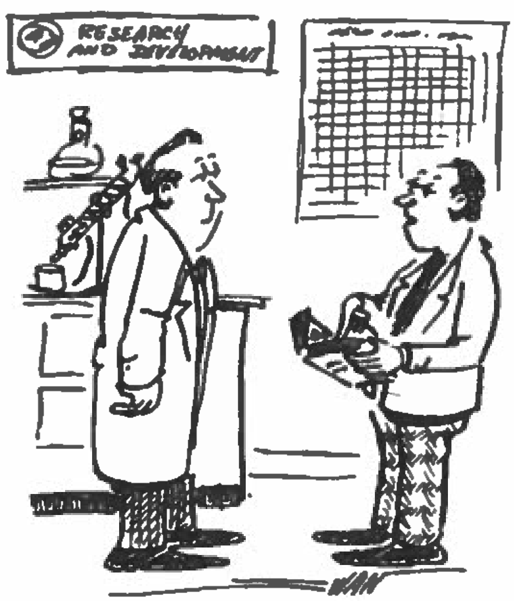
Proponents of fission power visualize the near-exponential increase in the number of fission power reactors to alleviate the coming energy shortage. Others study the 'China syndrome.'* They are asking such questions as:

- Can a uranium or plutonium reactor, going supercritical, melt down to a seething white hot mass? Then what?
- Under what conditions will such an accident generate a self-sustaining metallic fire ball which will melt its way to the center of the Earth, or perhaps entirely through the Earth?

Will someone please use modern computer techniques to repeat the calculations of Oppenheimer, Compton and Fermi as to the probability of a vast nuclear accident being initiated by fission explosions. Then revise the computer program by plugging in the 1,000 times greater energy yields often derived from 1975 fusion devices.

Reprogram the problem in order to include the parameters of a high order fusion explosion inducing a sustained chain reaction in the presence of seawater, at a containment pressure of 5 tons per square inch at a depth of 4 miles. Repeat the program using pressures at 1, 2, and 3 miles depth.

In view of the information explosion, 1945-1975, generating a scientific revolution of unprecedented proportions, can we afford the luxury of waiting a generation or two before this new information seeps into our textbooks of physics, or is fed into our computer banks and, *then*, incorporated in the estimates of the State of the Union Message?



What's this simple declarative sentence doing on page 39 of your report?

Notes

1. William D. Metz, "Energy: Washington Gets a New Proposal for Using H-Bombs," Science, 188 4184 (April 11, 1975), 136.
2. Pearl Buck, "The Bomb—The End of the World?" American Weekly, March 8, 1959.
3. Stephane Groueff, *Manhattan Project: The Untold Story of the Making of the Atomic Bomb* (Boston: Little, Brown and Co., 1967), p. 352.

*If the core melts, existing reactor safety systems would be unable to cool it and a core *melt-through* would follow. The molten core would melt through the pressure vessel, containment building, and sink into the earth below, the 'China syndrome.'