Hans in War and Peace

Hans Bethe spent a lifetime enhancing the security of his adopted homeland—initially designing its nuclear bombs, but ultimately warning presidents and the public to guard against the hazards of such bombs.

Richard L. Garwin and Kurt Gottfried

Freeman Dyson likes to recall that when he first came to Cornell University, he was pleasantly surprised that everyone called the famous Professor Hans Albrecht Bethe "Hans." So shall we.

Hans often recalled his pre-war years in America as "the happy thirties" (see Silvan Schweber's article on page 38). They were indeed happy times for the elite physicists who had been able to flee the Nazis and find positions abroad. But Hans knew better than most Americans that the 1930s were anything but happy. Like many refugee scientists, he believed that Adolf Hitler's ambitions made war almost inevitable, and he worried whether the Western democracies had the will and the resources to survive.

So, after the fall of France in the spring of 1940, Hans did not wait for an invitation to participate in military work; for an enemy alien who had lived in the US for a short five years, such an invitation was unlikely. In characteristic fashion, he took the initiative.

From nuclear theory to nuclear weapons

Hans first worked on armor penetration with George Winter, an engineer and fellow refugee at Cornell. Then he and his close friend Edward Teller visited Theodore von Kármán, the great aerodynamics expert at Caltech, to ask for an unsolved practical problem. The homework assignment, whose ultimate purpose was not explained, soon led to the Bethe–Teller paper[1] "Deviations from Thermal Equilibrium in Shock Waves," which Hans considered to be one of his best. It was mostly written in a Colorado mountain cabin during one of the Bethes' annual summer treks out West and, once submitted, was immediately classified as secret by the government and thereafter inaccessible to the authors.

After Pearl Harbor, and on becoming an American citizen, Hans joined the radar project at the MIT Radiation Laboratory. There he invented the Bethe coupler, a simple device with a small round hole in the common wall between two metal waveguides, which provides a way to make separate measurements of the power flowing forward and backward in the main waveguide. In typical style, Hans worked out a new and exhaustive theory of the coupler, extending it far beyond the immediate need.[2]

For months Hans resisted entreaties to join the nascent atomic bomb project; he thought it was a boondoggle because the difficulty of acquiring sufficient weapons-grade uranium meant that it would not be possible to produce a weapon in time to contribute to the war effort. He changed his mind after witnessing Enrico Fermi's progress toward a self-sustained chain reaction at the University of Chicago. Fermi's research held out the prospect of also using plutonium as the fissile material for a bomb. Hans went on to the University of California, Berkeley, to participate in the 1942 summer study organized by Robert Oppenheimer. Participants quickly concluded that there was, in principle, no problem facing the realization of a fission weapon once the highly enriched uranium or the plutonium was in hand. They spent much of their time exploring the possibility of a fusion weapon triggered by a fission primary.[3] Here Hans's understanding of stellar energy production was invaluable.

Soon after the government created the Los Alamos Laboratory in March 1943, with the inspired choice of Oppenheimer as its director, Hans was appointed head of the lab's theoretical division. It was to carry heavy responsibilities because many of the facts and processes required for developing the bomb and assessing its explosive yield were not yet adequately known or understood, or accessible to experiment, even in principle. At that time the problems could only be attacked with the mathematical techniques of theoretical physics—without the help of automated computing. Giving a problem to a computer meant handing an accountant's spreadsheet to a person or team equipped with mathematical tables and motor-driven desktop calculators for addition, subtraction, multiplication, and (if inevitable) division.

The mix of new and old scientific knowledge, technical invention, educated guesswork, and brute-force computation constituted a new form of sophisticated engineering, an art in which Hans became a virtuoso. His technical mastery and tranquil but powerful personality made him a highly effective leader of a crew that was more habituated to questioning authority than to disciplined teamwork. The role of the theoretical division grew to be even more crucial after plutonium became available as the fissile material, for plutonium had an unanticipated property that called for a much more sophisticated weapon design than did uranium.

When highly enriched uranium is used as fissile material, as it was in the untested bomb dropped on Hiroshima, two slightly subcritical masses are combined by firing one against the other in a short artillery gun barrel. This concept would not have worked with the newly available plutonium from the Hanford, Washington, reactor because that material, in contrast to uranium, had so many neutrons due to spontaneous fission that the chain reaction would be initiated long before assembly could be completed using the gun technique. The result would have been an explosive yield far below what was actually achieved at the Trinity Test site and Nagasaki, where a

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Skiing at Los Alamos. (Standing, left to right) Emilio Segrè, Enrico Fermi, Hans Bethe, Hans Staub, Victor Weisskopf, and (seated, left to right) Erika Staub and Elfriede Segrè enjoy the mountains at Los Alamos in 1943. (Courtesy of AIP Emilio Segrè Visual Archives, Segrè Collection.)

ball of plutonium was imploded by the detonation of a surrounding shell of chemical explosives.

Throughout the Manhattan Project, Hans did more than lead and manage others. He worked personally on critical problems. Late in life he still spoke proudly of having designed a neutron initiator that Niels Bohr, during a visit to Los Alamos, thought was superior to Fermi's. And with typical candor, Hans told many that John von Neumann solved a problem that had defeated him—the arrangement of explosive lenses that transform multiple expanding detonation waves into a single spherically converging detonation to compress the plutonium core.

The hydrogen bomb

The idea that a fission bomb could ignite a thermonuclear explosion in liquid deuterium was first voiced by Fermi to Teller in 1941.[4] But at wartime Los Alamos, work on a thermonuclear weapon was sidelined because a fission trigger was a prerequisite for that project, and only programs that could affect the war effort received high priority. Furthermore, it was evident from the first that there would be many serious problems with a thermonuclear (hydrogen-bomb) design.[5]

As relations between the US and the Soviet Union deteriorated during the early post-war years, the issue of whether the US should develop a thermonuclear weapon became increasingly controversial. The arguments were complex, with technical, political, and moral facets. Hans was deeply involved in all of them. His commitment to both morality and pragmatism often put him under great stress, and led him to follow a path through this minefield that was not simply connected, to use a mathematical term. As Hans, on recalling his journey, once put it,[6] "It seemed quite logical. But sometimes I wish I were more consistent an idealist."

The participants in the 1942 Berkeley study had already realized that the H-bomb posed far more serious technical problems than a fission weapon, because the temperature reached by even an efficient fission bomb would be rather low compared to what is needed to produce fusion of deuterons. Furthermore, the complex processes involved could not be analyzed reliably until powerful electronic computers became available between 1950 and 1951. Nevertheless, during the war Teller had become fixated on the "classical super," in which a long cylinder of liquid deuterium was to be brought to sufficiently high temperature by a nearby fission explosion. Teller's preoccupation with the idea had already led to tension between him and Hans during the war, long before the well-known controversies surrounding the post-war H-bomb project and the Oppenheimer hearing:[7]

> At the start I regarded Teller as one of my best friends and as the most valuable member of my division. Our relation cooled when Teller did not contribute much to the work of this division.

Before the Soviets conducted their first test of a fission weapon in August 1949, there was a broad, though hardly universal, consensus among former Manhattan Project leaders, many still senior advisers to the US government at the time, that an H-bomb should not be

The American delegation signs an agreement at the 1959 Geneva Conference on the Discontinuance of Nuclear Weapons Tests. (Left to right) Frank Press, Anthony Turkevich, Hans Bethe, and John Tukey sit in back behind Wolfgang Panofsky, James Fisk, and Doyle Northrup in the front row. (Courtesy of AIP Emilio Segrè Visual Archives.)

developed. That position was fundamentally a moral one. In contrast to fission weapons, thermonuclear devices could, in principle, produce essentially unlimited yield and become far more powerful weapons of mass destruction and genocide. However, after the Soviet test, a great deal of pressure developed both inside and outside the government in favor of rapid development of the "super." That pressure resulted in President Harry S Truman's public announcement on 30 January 1950 that the US would mount a crash program to develop an H-bomb. An order forbidding further public discussion of the matter by government officials and staff followed the decision.

Truman's decision did not end the controversy, however. Not being a government employee, and having dissociated himself from work on the H-bomb, Hans could speak out, and did so:[8]

> I believe the most important question is the moral one: Can we who have always insisted on morality and human decency . . . introduce this weapon of total annihilation into the world? . . . It is argued that it would be better for us to lose our lives than our liberty, and with this I personally agree. But I believe that is not the choice facing us here; I believe that in a war fought with hydrogen bombs we would lose not only many lives but all our liberties and human values as well.

Nevertheless, Hans soon decided to work on the project in the hope of demonstrating that the H-bomb was a practical impossibility. Indeed, many had doubted that Teller's classical super would ignite and propagate fusion reactions efficiently. Later in 1950 Stanislaw Ulam and Fermi demonstrated as much.

In the spring of 1951, Teller and Ulam sidestepped the technical problem by inventing the radiation-implosion mechanism. As one had to assume that the Russians would also discover this way of detonating an H-bomb, Hans and others who had initially opposed development of the super turned to making it a reality. Hans became head of the theoretical megaton group at Los Alamos and spent more than a year there between 1951 and 1953.

Hans would always be tormented by the H-bomb. He ended his 1954 initially classified, personal account of the project with this statement:[9]

> I still believe that the development of the H-bomb is a calamity. I still believe it was necessary to make a pause before the decision and to consider this irrevocable step most carefully. I still believe that the possibility of an agreement with Russia not to develop the bomb should have been explored. But once the decision was made to go ahead . . . I cooperated to the best of my ability.

Advising presidents

The possibility of preventing the creation of thermonuclear weapons by means of a negotiated and verifiable test ban had been proposed by Fermi and I. I. Rabi in a secret 1949 report to the Atomic Energy Commission, and at an even higher level by Vannevar Bush in 1952, but the idea was still-

born.[10] From Andrei Sakharov's memoirs, we later learned that the Soviet authorities would never have considered such an agreement.

In 1957, President Dwight D. Eisenhower established the President's Scientific Advisory Committee (PSAC) and Hans was among its first members. Both the US and USSR had conducted successful thermonuclear tests by then, but some committee members hoped to constrain development of ever more powerful weapons, especially for the missiles that were coming on line.

From his position on PSAC, Hans advocated that the technical feasibility of a test ban be studied by the US, and then explored with the Soviets.[11] An interagency committee was formed, with Hans as chair, and in 1958 the first in a series of expert conferences with the Soviets and British was held in Geneva. Due to objections from test-ban opponents, Hans was only an adviser to the US delegation; nonetheless, he became an influential participant.

Presidential adviser Hans Bethe, accompanied by previous winner Glenn Seaborg, receives the Enrico Fermi medal from President John F. Kennedy in 1961. (Courtesy of Abbie Rowe, White House, John F. Kennedy Presidential Library and Museum, Boston.)

The original goal had been a ban on all tests—in the atmosphere, in space, at sea, and underground—above a threshold of several kilotons yield. But Teller and his associates foiled that goal when they discovered that an underground explosion in a large cavity could be decoupled from its surroundings to muffle the seismic signal by as much as a factor of 70. Initially skeptical on hearing the argument advanced in Geneva, Hans did his own technical analysis and concluded that cavity decoupling was, in principle, valid. The upshot was that the atmospheric test-ban treaty as signed in 1963, although banning tests of any yield in the sea, the atmosphere, or space, did not forbid underground tests, and thus did little to slow the nuclear arms race. This outcome prompted Hans to write the following:[12]

> sometimes insistence on 100 percent security actually impairs our security, while the bold decision—though at the time it seems to involve some risk—will give us more security in the long run.

Missile defense

Throughout history, every new weapon has provoked the search both for improved versions and for a defense. The invention of ballistic missiles is no exception. The German V-2 rocket used against England in World War II had a range of about 300 km and inspired major programs in the US and the Soviet Union to produce first medium-range and then intercontinental ballistic missiles. Those ICBMs were first fielded in 1960.

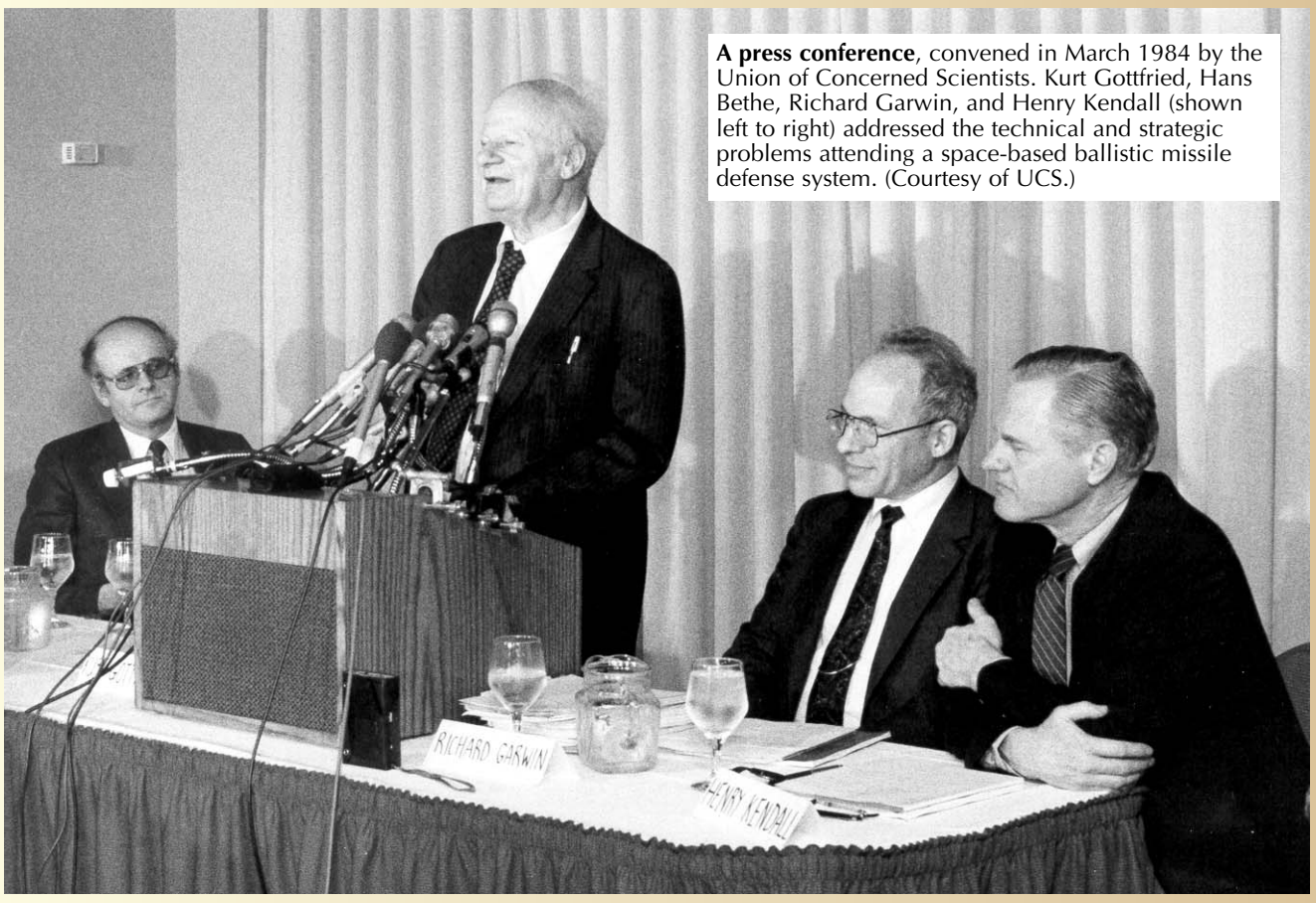
And yet, to this day, no effective defense of cities against nuclear-armed ballistic missiles has come into view, let alone been deployed, because it is relatively easy and inexpensive to overwhelm the defense with a variety of disguises for warheads, fake warheads, and other stratagems. The PSAC Strategic Military Panel recognized that problem early on, along with the inevitable consequence that deployment of a missile defense would merely provoke a buildup by the adversary.

Despite the predictable ineffectiveness of city defense against an attack by nuclear-armed ballistic missiles, the Soviets committed the blunder of deploying a nuclear-armed missile defense for Moscow. The US then targeted additional missiles on Moscow, a reaction that demonstrated in the most graphic terms how ballistic missile defense would accelerate the arms race. Robert McNamara, President Lyndon B. Johnson's secretary of defense, fully understood the problem. But Johnson ultimately yielded to domestic political pressure and decided in 1967 to deploy the *Sentinel* antiballistic missile system, with McNamara explaining that it would be a "light" defense against China—which was to have no ICBMs for the next 11 years.

Hans, a longtime member of the PSAC Strategic Military Panel, had decided before McNamara's announcement that he would make public his opposition to such a decision. Gerard Piel, the publisher of *Scientific American*, urged Hans and one of us (Garwin), who had also been involved in relevant PSAC and Defense Department panels, to publish our analyses, and we did so after a security review.[13]

The Bethe–Garwin article became the basic document in the campaign against deployment of the *Sentinel* ABM system. Both authors testified to the House and Senate committees responsible for the program, and Hans also privately advised several senators who had concerns about the Johnson and Nixon administrations' ABM policy. The Union of Concerned Scientists (UCS), soon after it was founded at MIT, featured Hans in its first public event on 3 March 1969. Addressing a standing-room-only crowd at a Cambridge high school, Hans began tongue-in-cheek: "I know you are against ABM, and I'm here to tell you why!"

Of course, logic and physics do not suffice to convince true believers that defense against nuclear-armed ICBMs remains ineffective, even in principle, except under exceedingly limited circumstances. But the allure of that



A press conference, convened in March 1984 by the Union of Concerned Scientists. Kurt Gottfried, Hans Bethe, Richard Garwin, and Henry Kendall (shown left to right) addressed the technical and strategic problems attending a space-based ballistic missile defense system. (Courtesy of UCS.)

mysterious belief in missile defense was not properly appreciated in 1983, and President Ronald Reagan's "Star Wars" speech that March came as a surprise to all of us who thought we were in the know. Reality suddenly intervened while one of us (Gottfried) was working with Victor Weisskopf in his Cambridge home, when, out of the blue, a call came inviting Weisskopf to the White House for a dinner that evening. The explanation of the gathering's purpose was obscure, but speculations that it would be related to missile defense were suddenly in the air.

Weisskopf and Gottfried flew to Washington and met Hans, who had flown in from a briefing at Livermore National Laboratory on the x-ray laser by Teller and colleagues. The text of a presidential speech that was making the rounds did not mention missile defense, but included a sentence stating that a paragraph remained to be inserted. Viki and Hans trooped off to the White House, where Teller lobbied for their support. The president's televised speech then aired. Hans declined to appear on Ted Koppel's television show *Nightline* that night and convinced us at UCS that we should not hold a press conference the next day. He was wondering whether the x-ray laser, which was supposed to intercept missiles in their boost phase, would be immune to countermeasures, and beyond that, whether it would make defense cheaper than offense—and thus undo the argument that had led to the 1972 US–Soviet ABM treaty.

At the 40th anniversary of the Los Alamos National Laboratory in early April 1983, a month after Reagan's speech, Hans and Garwin reminded the packed auditorium (and CBS-TV) that the claimed intercontinental lethality of the x-ray laser against enemy ICBMs in boost phase depended on the laser's ability to reach sufficient altitude to "see" over the curve of the earth to a distance of perhaps 6000 km while the ICBM booster was still burning. Consequently, interception by the x-ray laser could be foiled simply by launching hostile warheads with "fast-burn" boosters. That strategy would give the enemy two advantages over the defense. First, to reach the laser's firing position in time would require the interceptor missile to carry the laser at double speed, a far more costly proposition for the defense than for the offense, which needed only to reach ICBM speed in half the time. Second, if enemy boosters burn out before leaving the atmosphere, even a still-burning booster would be immune from attack, because x rays can penetrate only a short distance into the atmosphere, as Hans had realized shortly after returning to Cornell from the White House dinner.

At Cornell, Hans and Gottfried explored a suite of countermeasure concepts against the various high-tech intercept techniques proposed by the Star Wars advocates. These began in what we called countermeasure lunches, occasionally followed by a phone call from Hans to Garwin; or as Hans would playfully put it, "I'm going to call the wizard."

This work culminated in a UCS report[14] that had considerable impact in the press and in Congress—sometimes held up and pointed to by members of Congress as they questioned administration witnesses. Unfortunately, the report had a serious error that greatly overestimated the number of satellite-based interceptors required to fully cover the required ground targets. Gottfried discovered the

error, which was then immediately disclosed and eliminated from our slightly later journal article.[15] Moreover, correct estimates of the required number of lasers still supported the same conclusion: Even if the proposed Star Wars technologies functioned as advertised, such a system would not be "cost-effective at the margin," to use Paul Nitze's formulation; that is, it would be defeated by a much cheaper buildup of the offense.

Naturally, that study, like any argument based solely on logic, physics, and common sense, did not settle the matter. Pentagon officials and their supporters roundly attacked the report. Hans, Carl Sagan, and Gottfried spent part of their 1984 Christmas break drafting one of several rebuttals.[16]

One encounter with critics brought out a wonderful side of Hans. A press conference was scheduled to convene following a debate at Cornell between Hans and a Reagan administration spokesman. Only three members of the press showed up, representing the Cornell student daily, the university's radio station, and a small local newspaper. The event's student organizers were clearly embarrassed by the small turnout. But Hans launched into his presentation with the same care and formality that he displayed with the Washington press corps or at congressional hearings. He always treated students that way. Once he told Senate staff that he would be unable to testify if the hearing time was delayed; what he didn't tell them was that his unbreakable appointment was for dinner with one of his former graduate students.

The end of the cold war did not end Hans's deep concerns about the ongoing threat posed by nuclear weapons. He believed that we had been lucky to get through that conflict without a catastrophe, and fortunate that nuclear proliferation had been much slower than he had feared in 1945. And he was dismayed that the end of the very conflict that had stimulated the grotesque accumulation of the means for mass annihilation had left those means and their hazards largely untouched.[17]

On the 50th anniversary of Hiroshima in 1995, Hans issued what is his testament on the nuclear predicament:[18]

> Now, at the age of 88, I am one of the few remaining senior [leaders of the Manhattan Project] alive. Looking back at the half-century since that time, I feel the most intense relief that these weapons have not been used since World War II, mixed with the horror that tens of thousands of such weapons have been built since that time—one hundred times more than any of us at Los Alamos could ever have imagined. . . . But in some countries nuclear development still continues. Whether and when the various Nations of the world can agree to stop this is uncertain. But individual scientists can still influence this process by withholding their skills.
>
> Accordingly, I call on all scientists in all countries to cease and desist from work creating, developing, improving and manufacturing further nuclear weapons—and for that matter, other weapons of mass destruction such as chemical and biological weapons.

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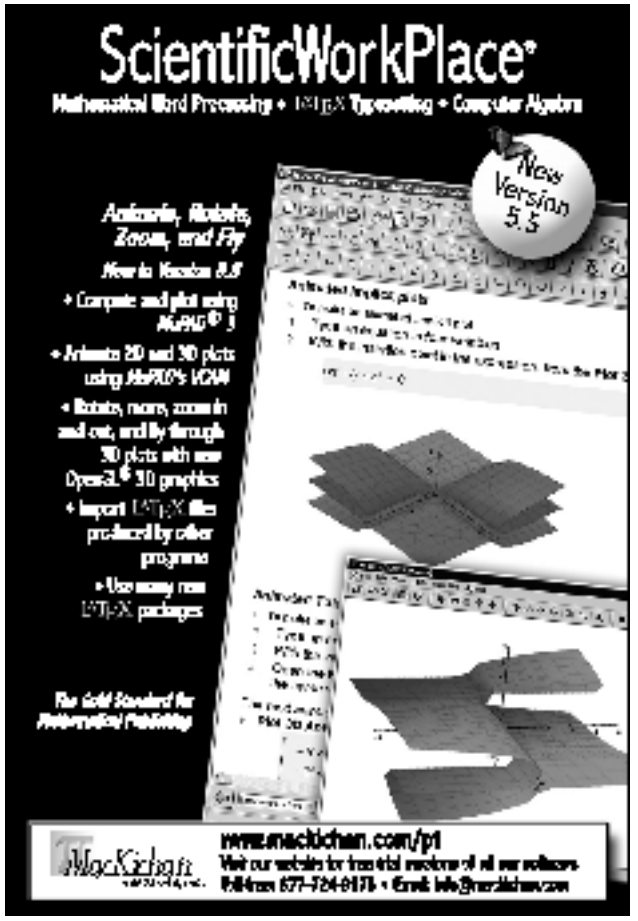

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