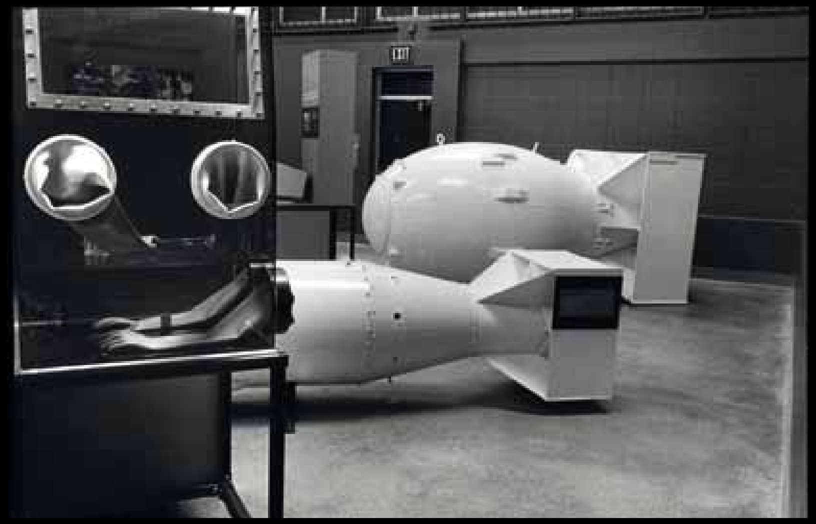
Photographs and Text by Robert Del Tredici

AT WORK IN THE FIELDS OF THE BOMB



Foreground: glove box for handling plutonium
Background: Hiroshima and Nagasaki duplicate bomb casings
Bradbury Science Museum, Los Alamos, New Mexico

The Cold War began on Day One of the nuclear age, for the atomic weapons that destroyed Hiroshima and Nagasaki were also intended to intimidate Stalin. But the secret of the Bomb would out. Within four years America and the USSR were locked in apocalyptic hostilities with no end in sight. Then, suddenly, that end came with the Soviet collapse.

During the last decade of the Cold War, for six years in the 1980s, I photographed in and around America's twelve principal H-bomb factories. Times were tense because the U.S. had been targeting the Soviet Union with Cruise and Pershing missiles in Europe, and the USSR had counter-targeted European launch sites. At this time writer Jonathan Schell published The Fate of the Earth in which he described humanity on the brink of nuclear self-extinction. I read the book and was convinced: we're doomed. What, I wondered, might I do while waiting for the end? I decided to document the source of

Terminal Guidance
A Goodyear sales representative displays Goodyear's contribution to the Pershing II missile system: the terminal-guidance all-weather gyroscopic radar/video synchronization unit. Pershing II is a medium-range missile; it can strike Soviet targets from bases in West Germany within 10 minutes. Terminal guidance enables the Pershing II to correct its flight path up to the moment of final impact.
U.S. Army Weapons Bazaar, Sheraton Hotel, Washington, D. C. October 15, 1986.

AT WORK IN THE FIELDS OF THE BOMBS

The Amount of Plutonium in the Nagasaki Bomb
This glass ball, 3.2 inches across, is the size of the plutonium core in the bomb that exploded over Nagasaki with a force equivalent to 22,000 tons of TNT.
Kansas City, Missouri. September 22, 1983.

the problem: the American complex whose 90,000 workers in factories and labs -- large and small, from New York to California -- collaborated to turn out three to six nuclear warheads a day. I crisscrossed the nation three times by car and felt more than once in my travels that I was coming from a future time down into that legendary era when nuclear weapons ruled the earth.

Some of the plants I visited had already exceeded their design life, and not long after I photographed them they got shut down. These closures developed a momentum that in time turned into a slow-motion system-wide collapse. Remarkably, the shuttering and demolition of America's Cold War infrastructure coincided with the collapse of the Soviet Union.

In the lengthy aftermath of this double breakdown an eerie quiet settled over U.S. nuclear weapons policy. Some observers dared to imagine that the United States might be coming close to seeing its way clear to ridding itself, and the world, of the Bomb. After all, the rationale for the Bomb, nearly as old as the Bomb itself, had just self-destructed. Was it not reasonable to expect the instrument identified with the rationale to follow suit? But what appeared to be an opportunity for transition to abolition ended up instead an incubation period from which the Bomb would be born anew as a symbol of sovereignty.

For half a century America's nuclear long sword had been plunged up to the hilt into its own body politic and that of its allies. But even though the Cold War was over and the U.S. Bomb complex was hobbled, the nuclear sword stayed put, its atoms quietly dissolving into America's bloodstream and migrating to the nation's brain where they reconfigured themselves into a Holy Grail of self-reliance that no longer needed any foe but rose, as it were, above politics, declaring, like Yahweh, "I Am That I Am."

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This Bomb showed serene indifference to earlier rationales that gave it once a place in the world; it no longer needed threats or targets to justify its existence. This new Bomb has made it possible for new generations of nuclear weapons from India, Pakistan, Iran, and North Korea to flourish.

Nuclear weapons have never been subject to the democratic process. After the Cold War, and during the stumbling of the U.S. nuclear weapons complex, America's addiction to the Bomb was unwavering. Without public debate, the Department of Energy set to work on a plan to consolidate and modernize its Bomb-making operations. It is currently putting finishing touches on a plan to convert its far-flung arc of facilities into a system "smaller, more responsive, efficient, and secure," according to The National Nuclear Security Administration, a branch of the U.S. Department of Energy. The agenda is called "Complex Transformation" and includes a crucial subset of facilities to research, develop, and test Bomb technologies, materials, and parts related to uranium, plutonium, tritium, and chemical high explosives in "centers of excellence" proposed for four industrial sites, three national laboratories, one test site, and one flight test range. Work with plutonium will go on in New Mexico at the birthplace of the first atomic bomb in Los Alamos – the national laboratory there will maintain the capacity to manufacture plutonium "pits", the trigger for a thermonuclear warhead, at a rate of several dozen per year, down from the hundreds per year that the defunct Rocky Flats plant in Colorado once made; small high-explosives charges will be tested at the Lawrence Livermore National Laboratory in California, which will also work with tritium, the radioactive booster for nuclear explosives; more tritium work will get done in South Carolina's Savannah River Site, which will also make neutron generators that start the chain reaction in plutonium pits; the Nevada Test Site will test large explosive charges; the Y-12 plant in Oak Ridge, Tennessee, will produce highly enriched uranium and canned subassemblies for the Bomb; and the Pantex Nuclear Weapons Final Assembly Plant outside Amarillo, Texas, will do what it has always done: test and manufacture high explosives and assemble and disassemble nuclear warheads. This Complex Transformation is a mere foot in the door, a vote of confidence in the day when the whole big complex will rear its head again, just like in the bad old days.

It is as true today as it was on the morning the first a- bomb exploded in the Alamogordo desert: that we who have created this Bomb have had to scramble like mad to keep up with it, for it has a life and logic all its own. Its status as a timeless icon in the mind contrasts with its rising costs on the ground and the burgeoning drums, tanks, and trenches of its everlasting wastes. The mirages it generates distract us from the de facto invisibility it enjoys. Mesmerizing hypocrisies cloak inflexible agendas. The Bomb backs up its pledge of security with the collateral of annihilation; but its security needs multiple hair-trigger upgrades, and the annihilation it offers comes wrapped in an abyss of imponderables. It seems the closer you get to the Bomb, the harder it is to see it. That may be why, in the end, we tend to let it have its way with us.

My aim has long been to give the collective imagination something accurate and graphic to hang onto as it tries to come to grips with the Bomb's reality. Its infrastructure may be in transition, but its own inner logic and the mindset of its acolytes, have been constant – and unrepentantly expansionist. I want the images I made in the 80s and 90s to alert viewers to the true nature of this thing -- that it is more than a brilliant instrument for annihilating enemies or enforcing fearful peace; it is more than a tool that favors those with the biggest, or the dirtiest or cleanest, or the most, or the street vendor with the little one inside a garbage can on wheels. The Bomb is not a weapon that favors the cunning or the strong; it is an affliction that threatens us all, and it will take the sustained effort of an awakened and aroused humanity to rid ourselves of it.

Robert Del Tredici, *Montreal February 3th, 2009*

Uranium Green Salt
Ten-gallon drums of uranium green salt line the floor of the Fernald Green Salt Plant. Uranium green salt, the product of a long chain of chemical transformations, is the base element for the transformation of uranium into metal.
Building 4, Feed Materials Production Center, Fernald, Ohio. December 16,1985.

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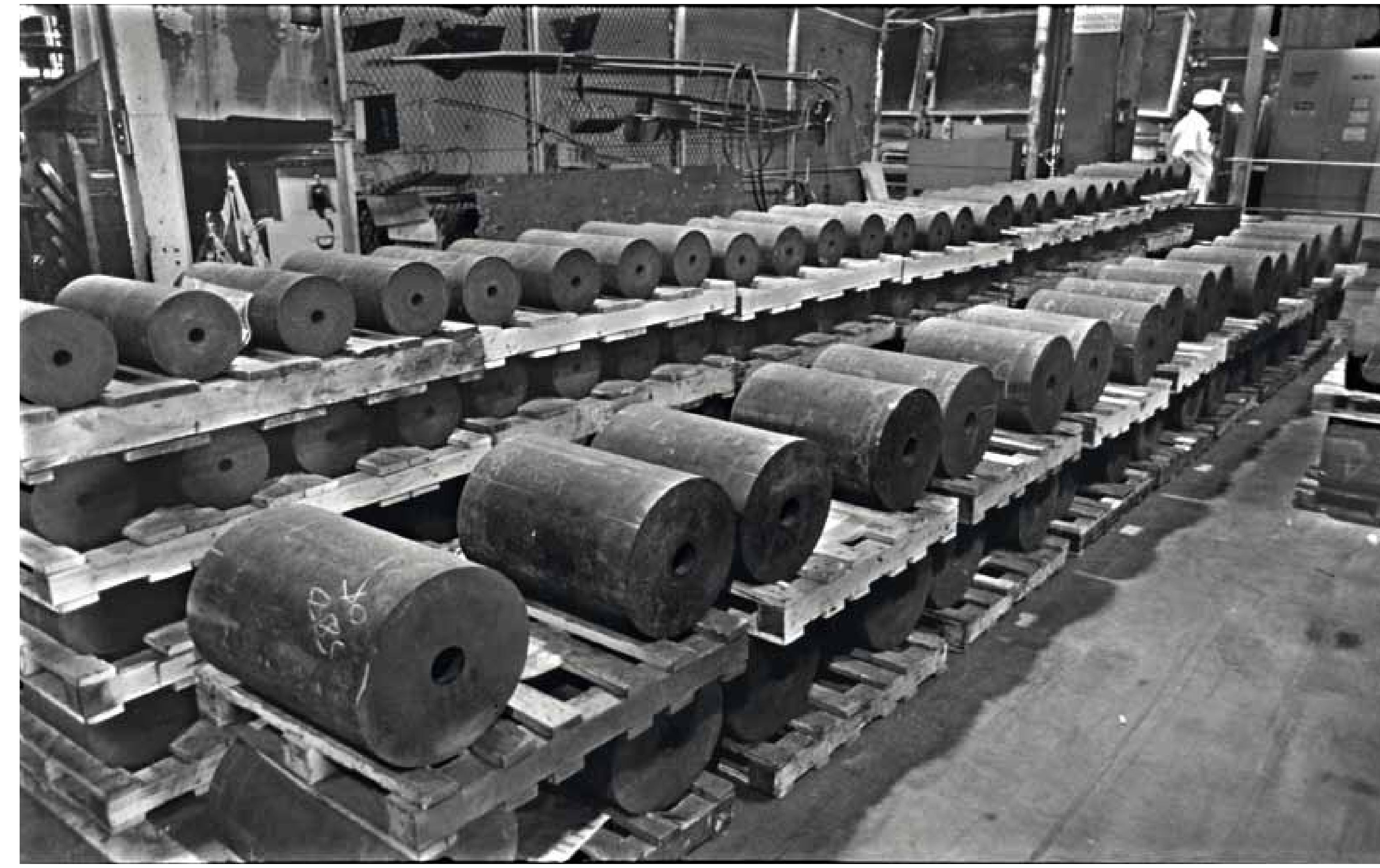
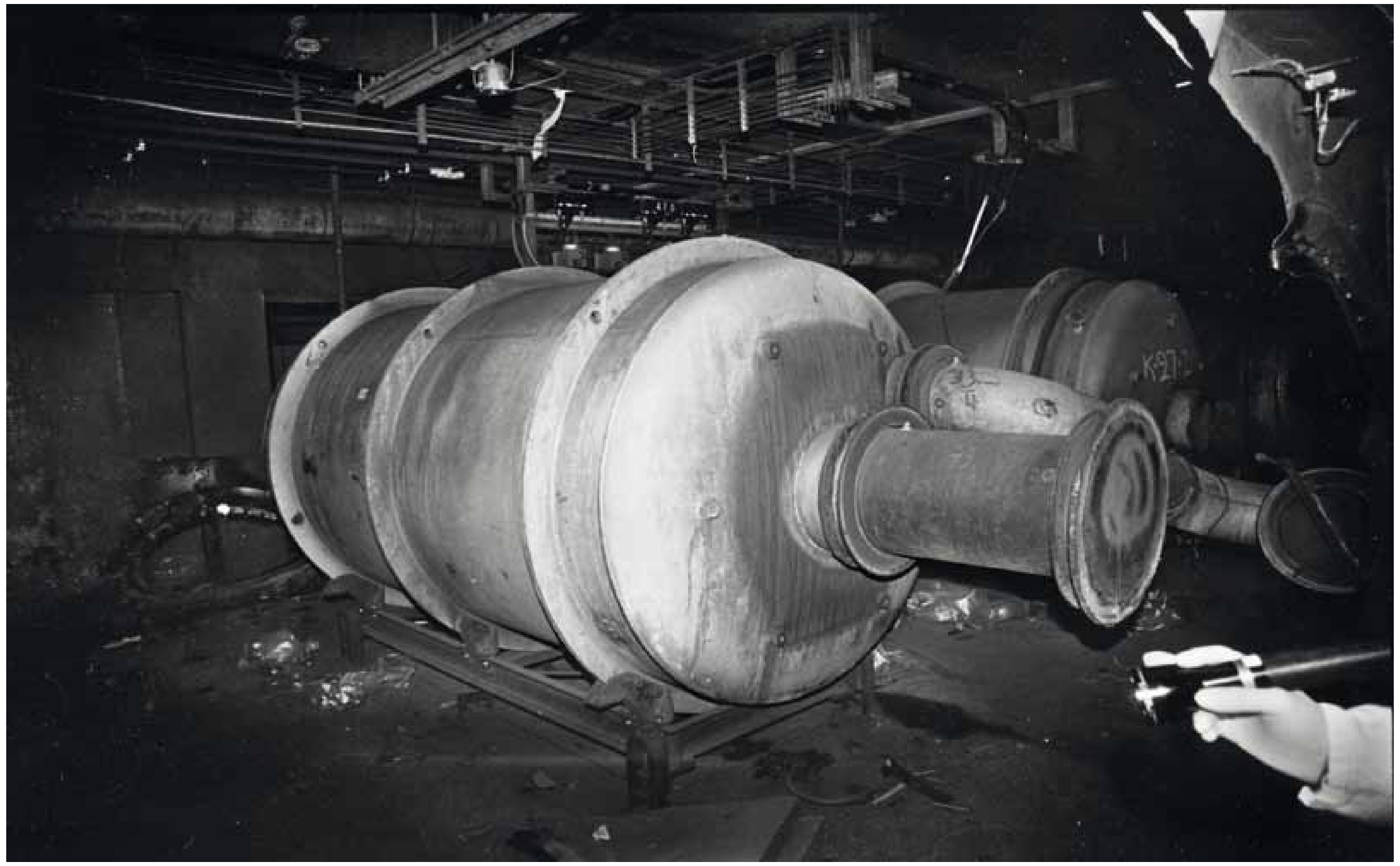


Ingots of Fernald at Ashtabula
These ingots, made at Fernald by remelting uranium metal derbies, have been trucked 300 miles northeast to Ashtabula, Ohio, for further processing. Here they will be submerged in molten salt until they reach a red-hot 1100°F Then they will be inserted into the Ashtabula uranium metal extrusion press.
The sign in the background reads “Caution: Radioactive Materials.”

The Back End of the Ashtabula Press
A worker waits for an extrusion of uranium metal to exit from the press.

Back to Fernald
Ashtabula returns uranium metal, in the form of long tubes, to Fernald. A worker stands by while a blanking machine cuts the metal into 14-inch segments, each weighing 28 pounds. These are Fernald's top product: Mark 31 Target Element Cores. They are called target element cores because at Department of Energy reactors elsewhere they will be bombarded with neutrons and transformed into weapons-grade plutonium.
Feed Materials Production Center, Fernald, Ohio. December 17, 1985.



Gaseous diffusion converter K-25

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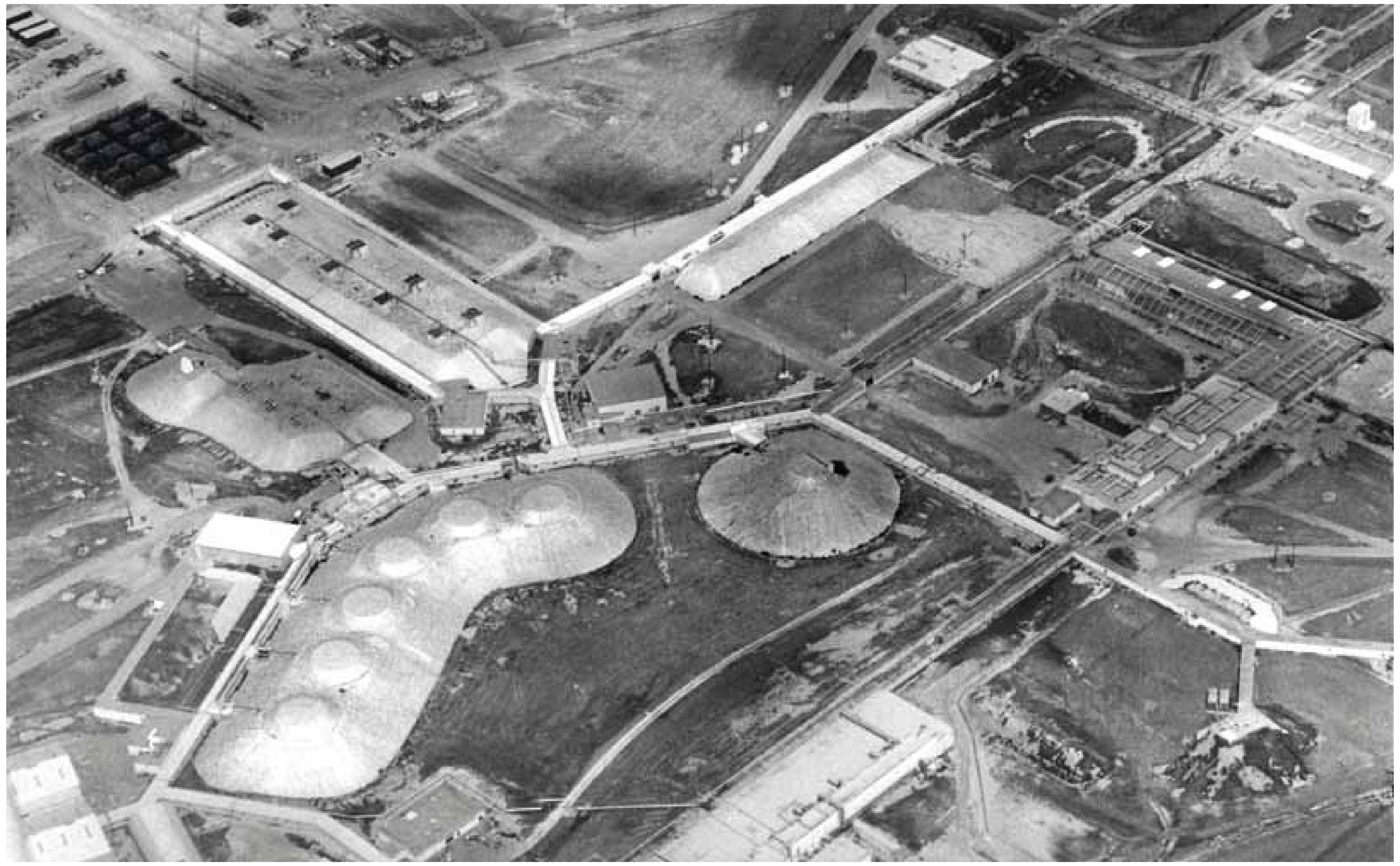
Reactor, Savannah River Plant
It is into this reactor that the Mark 31 Target Element Cores from Fernald are inserted. Here they are bombarded with neutrons and transformed into plutonium. The three dark pools in front of the reactor hold water for cooling. Like the Chernobyl reactor, the L-Reactor has no containment vessel. A total of five such reactors were built on the Savannah River Plant site. *Aiken County, South Carolina. August 6,* 1983.



Pantex Nuclear Weapons Final Assembly Plant
Pantex, America's only nuclear weapons final-assembly plant, receives parts from facilities throughout the U.S., in some 120 subassemblies made up of about 2,000 separate pieces. Pantex provides 2,700 jobs. It is Amarillo's largest employer. *Carson County, Texas. August 19, 1982.*

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Tapered Line-of-Sight Pipe, "N" Tunnel
This 875-foot steel pipe is dug into the side of Rainier Mesa in Area 12 of the Nevada Test Site. The tunnel tests the impact of radiation from a nuclear warhead on other nuclear warheads and on military communications equipment. At the far end of the tunnel is the "Zero Room," which contains the warhead that will be detonated. When it explodes, radiation comes down the pipe at the speed of light, followed by its expanding shock wave. But within 16 milliseconds, huge blast doors explode shut, trapping the shock wave in the Zero Room so that only radiation hits test equipment in the pipe. The pipe is being readied for the test code-named "Misty Rain.
Area 12, Nevada Test Site, Nye County, Nevada. October 29, 1984.

All the Warheads in the U.S. Nuclear Arsenal
This field of ceramic nose-cones represents, in miniature, all the warheads in the U.S. nuclear arsenal.
Estimates set the U.S. warhead total at about 25,000.
Amber Waves of Grain installation, Boston Science Museum, Boston, Massachusetts. February 13, 1985.

Interviews and Field Notes

Model of the Uranium Atom

Uranium is one of the heaviest naturally occurring elements on earth. It can be used in nuclear weapons or it can become the base from which plutonium, a more powerful nuclear explosive, is made. Uranium is unstable; when a single uranium atom breaks apart it releases, on average, two neutrons, one of which can smash into other uranium atoms and split them apart, releasing large amounts of energy - and two more neutrons. It is this geometric progression that makes a runaway chain reaction explosion possible. Uranium has a half-life of 4,468,000,000 years, which means that after that much time has elapsed, half of a given amount of uranium will have spontaneously decayed into other elements. Each one of these subsequent elements has its own half-life.

The Uranium-238 Decay Chain

Product in decay chain	Kind of radiation	Half-life
Uranium-238	alpha	4,468,000,000 years
Thorium-234	beta	24.1 days
Protactinium-234m	beta, gamma	1.17 minutes
Uranium-234	alpha	245,000 years
Thorium-230	alpha	80,000 years
Radium-226	alpha	1,602 years
Radon-222	alpha	3.823 days
Polonium-218	alpha	3.05 minutes
Lead-214	beta	26.8 minutes
Bismuth-214	beta	19.7 minutes
Polonium-214	alpha	.000164 seconds
Lead-210	beta	22.3 years
Bismuth-210	beta	5.01 days
Polonium-210	alpha	138.4 days
Lead-206	(stable)	non-radioactive

The Amount of Plutonium in the Nagasaki Bomb

The sphere of plutonium-239 in the Nagasaki bomb weighed 6,100 grams. One gram of plutonium, or one-third the weight of a penny, transformed its mass into pure energy to produce the explosion that destroyed Nagasaki's Urakami valley. The glass ball in the photograph is held by Richard Rhodes, author of *The Making of the Atomic Bomb*.

Howard Morland's Model of a Modern H-bomb Warhead

The modern thermonuclear warhead is termed a "physics package". This is the explosive fission-and-fusion core of a hydrogen bomb. A warhead this size would weigh about 270 pounds. Howard Morland was the first to make visible to the public the inner workings of the H-bomb. He pieced together its physics and internal design from unclassified literature and conversations with industry and government officials. In 1979 the U.S. government sued to prevent the publication of his article "The H-bomb Secret (To Know How Is to Ask Why)" in The Progressive. *Morland welcomed the lawsuit, maintaining that there are no longer any scientific secrets about H-bomb design. In court he demonstrated the public nature of his data, won the case, and published his article.*

Howard Morland
Washington, D.C., January 12, 1984

~ Howard, before most people were involved in thinking about weapons, you pieced together how a thermonuclear bomb works and you made a model of its insides for all to see. How long did it take you to do that and what is it that you discovered along the way?

- Well, it took six months to discover the H-bomb secret. One of the first places I looked when I began my research into thermonuclear devices was the *Encyclopedia Americana,* which is on public library shelves all over the country. In it was a very strange diagram - it showed a thermonuclear device with an atomic bomb inside one end of it, and a blob of something, lithium-6 deuteride, inside the other end. Other encyclopedias that I looked at had diagrams of H-bombs too, but this was the only one that had the stages separated, and it turns out that this "separation of stages" was the correct design concept. So in that one picture in one encyclopedia I found the essence of the H-bomb secret.

~ And what is that secret?

- Well, the federal government, when it tried to stop the publication of my article in *The Progressive* - and succeeded in doing so for six months - said that there were three elements to the H-bomb secret that I had revealed in my manuscript. The first element was the separation of stages - the fact that within the overall casing, the atomic bomb is physically separate from the hydrogen bomb. The second element was compression of the hydrogen fuel, which basically means that if you pack any kind of material together closely, reactions will take place within it more quickly. The third element, and this was the real secret, was called "radiation coupling" - the use of electromagnetic radiation produced by the exploding atomic bomb to ignite, or trigger, the nearby hydrogen component. These three design concepts were implicit in that *Encyclopedia Americana* diagram. But I had to do a lot of digging to realize what the diagram meant.

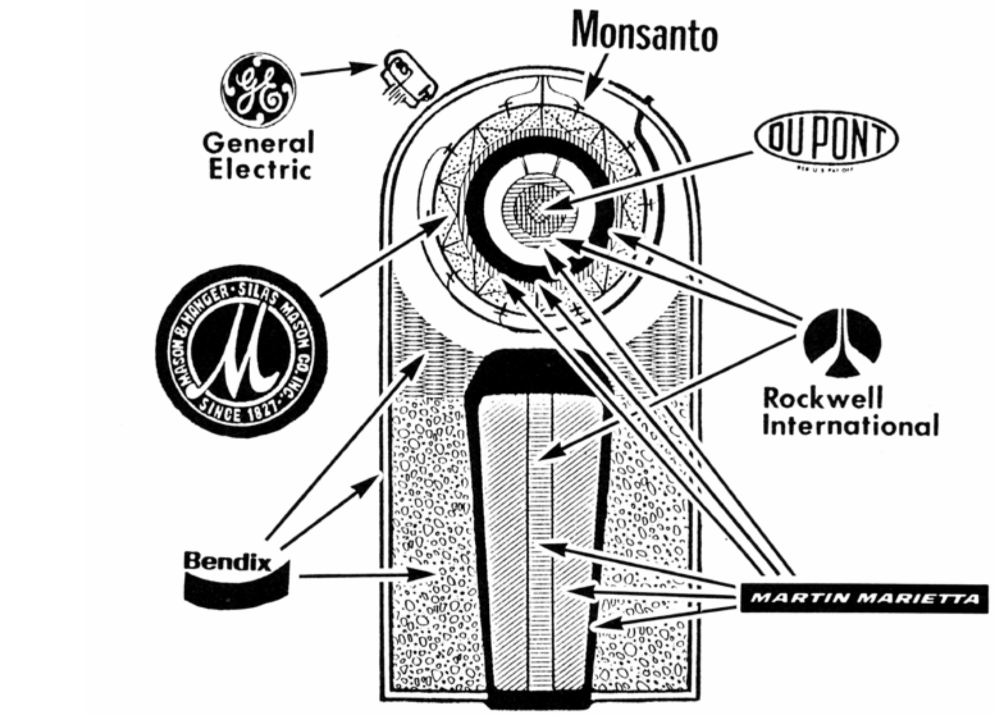
Excerpts from Howard Morland's article "The H-bomb Secret (To Know How Is to Ask Why)", published in the November 1979 issue of The Progressive:

"Paying attention to the details is also a way of reminding ourselves that these weapons are real. The most difficult intellectual hurdle most people encounter in understanding nuclear weapons is to see them as physical devices rather than abstract expressions of good or evil. The human mind boggles at gadgets the size of surfboards that can knock down every building for miles around. But these are devices made by ordinary people in ordinary towns. The weapons are harder to believe than to understand.

"The secret of how a hydrogen bomb is made protects a more fundamental `secret': the mechanism by which the resources of the most powerful nation on Earth have been marshalled for global catastrophe. Knowing *how* may be the key to asking *why.*

"The risks of proliferation of hydrogen weapons such as they are must be weighed against the public gain that may come from greater awareness of how and why they are already being produced.
"Whether it be the details of a multimillion-dollar plutonium production expansion program or the principles and procedures by which nature's most explosive force is being packaged in our midst, we have less to fear from knowing than from not knowing."

The following text and diagrams are Howard Morland's explanation of the inner workings of a thermonuclear bomb. Morland also traces the bomb's component parts to their corporate sources within the government-contractor system of the United States Department of Energy's nuclear weapons complex. This information updates Morland's original article published by The Progressive.

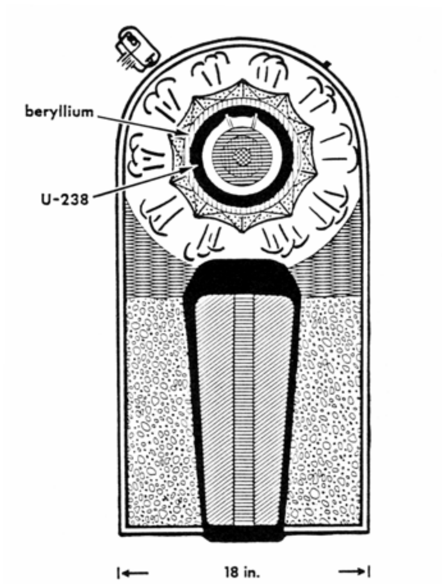


THE BOMB AND ITS MAKERS

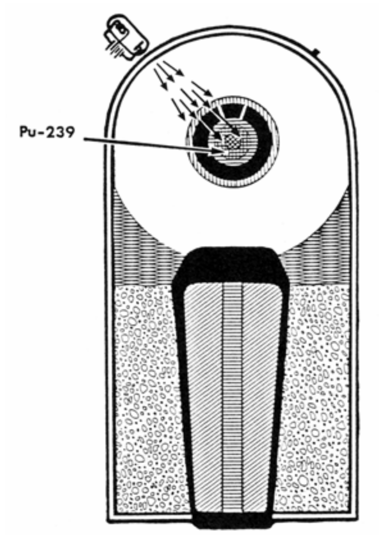
Western Electric, a subsidiary of American Telephone & Telegraph, does general engineering for the H-bomb at its laboratory at Albuquerque, New Mexico, in cooperation with two laboratories that conduct research at Livermore, California, and Los Alamos, New Mexico, under the auspices of the University of California. DuPont supplies small containers of tritium gas from its Savannah River, South Carolina, tritium loading facility. Martin Marietta contributes uranium, deuterium, and lithium parts made in Oak Ridge, Tennessee. Rockwell International fabricates plutonium and beryllium components at the Rocky Flats plant near Denver, Colorado. Monsanto manufactures explosive detonators at its Mound laboratory near Miamisburg, Ohio. The paper honeycomb shield and polystyrene foam which help focus pressure generated by radiation onto the H-bomb's fusion tamper are made by Bendix in Kansas City, Missouri. General Electric builds neutron generators at its Pinellas plant near St. Petersburg, Florida. Mason & Hanger-Silas Mason shapes the chemical explosive charges and supervises final assembly of the warhead at a plant near Amarillo, Texas.

HOW AN H-BOMB WORKS

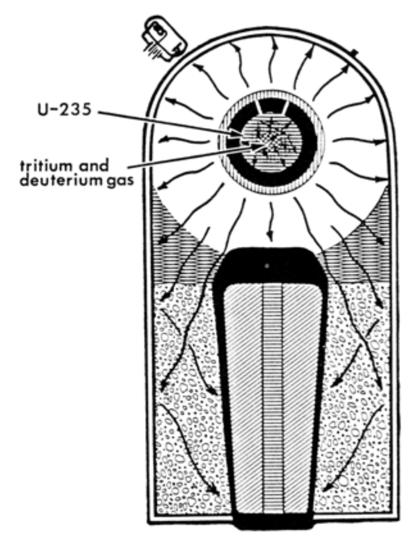
There are two discrete steps in the detonation of a modern hydrogen weapon: the explosion of the primary stage and, microseconds later, the explosion of the secondary stage. Each stage releases nuclear energy in a sequence of fission, fusion, and more fission. Although one event must follow another for the weapon to work, they happen so rapidly that a human observer would experience only a single event: an explosion of unearthly magnitude. The "primary" is a scaled-down version of the Nagasaki plutonium implosion bomb. It has roughly the same explosive power as the World War II weapon but measures less than twelve inches across. It is called the H-bomb's "fission trigger" because energy from its initial fission explosion triggers thermonuclear fusion between tritium and deuterium, the two forms of heavy hydrogen. This fission trigger resembles a soccer ball, with a soccer ball's pattern of twelve pentagons and twenty hexagons in a sphere. Each pentagon or hexagon is a high-explosive charge attached to a detonator; the spherical shell they form is one inch thick. A ball of plutonium and/or uranium-235 occupies the center, along with a small amount of tritium and deuterium in gaseous form. The primary stage could level a small city by itself, but in an H-bomb its explosion merely provides the preliminary energy needed to ignite the weapon's much more powerful secondary stage. After the primary has detonated, the secondary instantly manufactures its own tritium from solid lithium-6. This tritium then fuses with the deuterium already present, and the resulting fusion energy causes, finally, large amounts of uranium-238 to undergo fission.



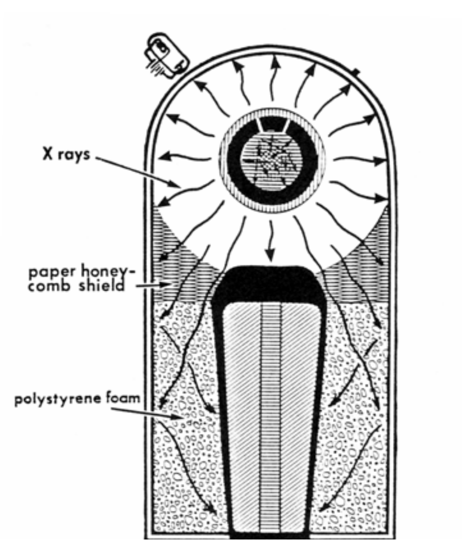
1. Detonators surrounding the primary system are electrically fired. These set off the chemical high-explosive charges that surround a hollow sphere, or "tamper," made of beryllium and uranium-238. This tamper is liquefied by the implosive shock wave and driven inward toward the plutonium core of the primary, imparting the high-explosive shock wave evenly to the sphere of plutonium. This inward-moving, symmetrical shock wave is the energy of implosion that creates the conditions for a runaway chain reaction in fissionable materials. This technology was used to explode the core of the Nagasaki bomb.



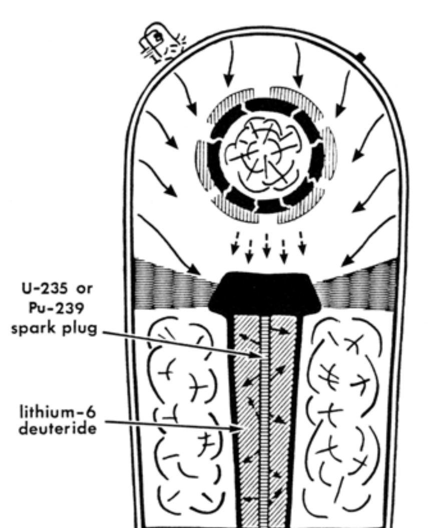
2. The symmetrical shock wave created by the high explosives compresses the plutonium to about twice its normal density (from softball-size to about the size of a hardball) for approximately one-millionth of a second, at which point it is hit with a beam of neutrons produced by a high-voltage vacuum tube called a neutron generator. The stream of neutrons from this generator initiates a fission chain reaction in the sphere of plutonium-239. Because the fission chain reaction has been initiated in the mass of plutonium while it is in its densest state, it will develop with the greatest speed.



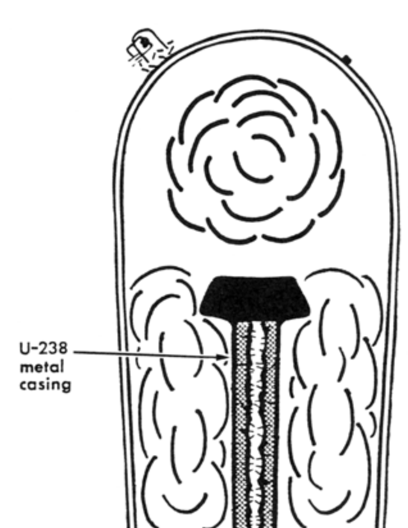
3. The chain reaction spreads outward to a layer of uranium-235 covering the surface of the plutonium sphere, and the heat and pressure of fission ignite a hydrogen fusion chain reaction in the "booster" charge of tritium and deuterium gas. Fusion adds neutrons to the fission reaction, speeding it up and raising its temperature. The primary system of a hydrogen weapon is in effect a tiny nuclear power plant that generates 20 million kilowatt-hours' worth of thermal energy in a few millionths of a second, all inside a lump of metal compressed to the size of a hardball.



4. The energy of the fission reaction races away from the primary system in the form of X rays traveling at the speed of light, or 100 times faster than the expanding debris of the bomb. The X rays are focused through a paper honeycomb shield and absorbed by a special polystyrene foam jacket surrounding the cylinder which makes up the "secondary." The polystyrene foam flashes into plasma that acts as a thermal explosive encasing the secondary system.



5. The exploding polystyrene foam compresses the secondary system, which is filled with lithium-6 deuteride. Running down the secondary's center is a "spark plug" of uranium-235 or plutonium-239. The exploding polystyrene foam compresses this spark plug to supercriticality, and it fissions. This fissioning, the second fission event in a thermonuclear bomb, supplies neutrons that convert the lithium fuel into tritium.



6. The fissioning spark plug and the exploding polystyrene foam form a double front of pressure which creates the conditions needed to make tritium fuse with deuterium. This tritium-deuterium fusion then showers the depleted uranium casing of the secondary system with high-energy neutrons that cause it to undergo fission and explode. This final fission produces most of the total energy-release of the bomb, as well as most of its deadly fallout.

Pantex Nuclear Weapons
Final Assembly Plant
Annual Budget: $198,100,000 (1986)

The mission of the Pantex plant is to assemble new nuclear warheads (approximately three to five a day); disassemble retired nuclear warheads; and fabricate the plastic high explosive that surrounds the plutonium in the fission "trigger" of a nuclear weapon. Assemblers of nuclear warheads work in pairs in thick-walled rooms called cells or bays. They wear blue coveralls, hard hats, safety shoes with rubber slip-over covers, and gloves of cotton or soft leather. One worker does the assembly; the other checks the proper procedure step by step in the Pantex Final Assembly Safety Manual. Assembly work goes on in thirteen bays. Assemblers constitute 15% of the Pantex work force and are among the highest-paid employees, earning in the range of $30,000 a year, compared to the average Pantex salary of $23,000.

The Nagasaki bomb was nicknamed "Fat Man" in reference, it is said, to Winston Churchill. The American government works with private contractors to build nuclear weapons. This is referred to as a "GO-CO" arrangement, a government-contractor agreement. The contractor working with the U.S. Department of Energy at Pantex is Mason & Hanger-Silas Mason, the Kentucky engineering firm that built New York's Holland Tunnel.

Paul Wagner, public relations manager for the Department of Energy at Pantex Amarillo, Texas, August 10, 1982

~ Mr. Wagner, how would you describe the function of the Pantex plant?
- Assembling nuclear weapons.

~ Do you make or shape or mill any parts for weapons here?
- We do not manufacture any components except the chemical high explosive.

~ What is the chemical high explosive?
- I won't say any more than that it's a necessary component in a nuclear weapons assembly.

~ They say you turn out three warheads a day here. Is that a fair average, or is that something you can neither confirm nor deny?
- I won't even answer that.

~ When you assemble the warhead, does that include the missile?
- That's the Defense Department's responsibility. The delivery vehicles belong to the Defense Department. They design 'em and build 'em and pay for 'em and operate 'em and shoot 'em.

~ Can you talk about how long it takes to assemble a warhead or how many parts are involved?
- No.

~ Here you also disassemble outdated warheads. - Can you say anything about what the average shelf-life of a nuclear weapon is?
- I can. But I won't.

~ Then let me ask you this: When they give the number of warheads in the U.S. arsenal as around 25,000, does that include the ones assembled but removed from service, or does it mean only those ready to go?
- I won't answer that.

~ Has there ever been more than one nuclear weapons final assembly plant?
- There was another one in Burlington, Iowa. It was closed in 1975.

~ How do you feel about this being the only one, then, with no backup?
- I have no comment. That's above and beyond any of us here.

~ Were there ever more than two plants like this?
- The Atomic Energy Commission from 1955 until 1965 had two smaller nuclear weapons assembly facilities, but there were only two just like this.

~ When you say "just like this," what makes this plant unique?
- The high-explosive manufacturing capability.

~ What goes on in that boomerang-shaped building with the circles on the roof
- Just assembly work.

~ Is that the building they call the "Gravel Gertie"?
- Right. A Gravel Gertie is a circular structure which has a gravel roof on it. If we have an explosion in the assembly area, that roof will vent the explosion and also act as a filter for any materials that are in the structure. It lets the gases of an explosion go out into the atmosphere, but it filters and traps any particulate radioactive material that's still in there.

~ Is there something about the gravel coming down on everything and burying it if there's an explosion? Is that part of the filtering process?
- Not really, no.

~ Does that happen?
- That happens, but it doesn't buy anybody anything.

~ I heard about the chemical explosives accident here that killed three workers. Have the procedures changed since then?
- Oh yeah, sure. The procedures change every time we get smart.

~ At Rocky Flats there's a lot of controversy about the quantities of plutonium that have escaped into the environment. Are there any problems like that here?
- No. All the plutonium we have is received in a finished form with a case of some benign material around it, like stainless steel or titanium. So there's no plutonium exposure. It's always contained.

~ You never handle plutonium as such?
- We handle it in a package. Now we take care to make sure we don't want the package to break. And there is radiation that comes through most material to some degree. But we don't have the open handling of radioactive material—none of it is cut, sawed, welded, or lathed. All of that is done at Rocky Flats.

~ How radioactive are the warheads?
- Very low, because people handle 'em all the time. I used to sleep on top of one.

~ You did? Does your wife know about this?
- Sure.

~ What were you doing, sleeping on top of one?
- I was tired.

~ Did your senior officer know about this?
- It didn't make any difference if he knew or not. I was on a ship that had nuclear weapons on it, and we had a bunk right over the top of these things. Big deal. I just say that to give you an idea of how much radiation is coming out of them.

~ How much is coming out of them? Did they monitor them to find out?
- Not back in those days.

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~ Do they monitor them now?
- I don't know what they're doing now.

~ Last week I opened up Life *magazine and found a two page spread on Bishop Leroy Matthiesen, who became famous for asking Pantex workers to examine their consciences; and on the next page was a picture of Eloy Ramos, the worker who quit Pantex for reasons of conscience after sixteen years on the job. How does this publicity affect workers here?*
- It doesn't. The only people it affects are Mr. Poole and me.

~ How does it affect Mr. Poole and you?
- We get people like you asking questions like that. It's a non-problem as far as we're concerned. As somebody said on television last week, it's the biggest non-issue of the twentieth century.

~ But when it brings a million people out to Central Park, isn't that a pretty big non-issue?
- It's still a non-issue. People go to Central Park for no reason at all.

~ I think they had a reason for going on June 12 .
- Charles Poole: Well, anyway, it doesn't bother us. We're speaking in terms of us, you know. There might be reactions in New York or West Germany, I don't know. . . . , but it doesn't really affect Amarillo.

~ I'd like to conclude by asking you a personal question. Do you ever get used to seeing the warheads? Do you have any particular feelings when you see them coming down the assembly line one after another?
- Wagner: Just like pickin' up a box of Silly Putty in a dime store. Hell, there's nothing to it. I don't react, and I've been in the business for years and years.

~ You don't think of the awesome forces?
- I've seen nuclear explosions in Nevada, and I've seen 'em in the Pacific. . . .

~ And what was your reaction?
- Big deal.

~ You mean, not such a big deal?
- Yeah. Sure, it's an awesome sight, but it didn't change my life. I'm very blasé about the whole thing. There's no hazard to it that particularly affects me. But you've got to realize, you know, where people are coming from. If they've been living a protected and uneventful and non-adventurous life, it might be a big deal. But I've done a helluva lot more dangerous things in my life than screwing around with nuclear weapons.

~ Name two.
- I was a deep-sea diver, for one thing. And I was an explosives demolition man in World War II. I had to defuse sea mines, and when that thing is right in front of you with 300 pounds of explosives, if you make one mistake you're gone. After that, this work at Pantex doesn't bother me a bit. And I'm fairly characteristic of people who have been in the business as long as the people around here have been around it.

Ashtabula Quench

Bud Schaeffer,
extrusion plant manager,
Reactive Metals, Incorporated—Ashtabula, Ohio, June 19, 1984

Okay. I'm plant manager at the extrusion plant. I have been with this operation since 1954, and associated with the Department of Energy contract since that time.

~ What goes on in this facility?
- Well, this plant operates as a conversion facility. That means we take customer-supplied billet and form it by the extrusion process to whatever shape the customer requires.

~ What is billet?
- Billet is a cylinder of solid metal, in varying diameters and lengths, which is put into the extrusion press and formed to a particular size and configuration.

~ What is an extrusion press?
- *(Laughs)* An extrusion press, as we have it, is a horizontal piece of equipment that operates under very high pressures, that takes billets or cylinders of metal and with this pressure and temperature forces the metal through a die to form it to the shape required.

~ How much pressure can the extrusion press at this plant exert on a billet?
- 3,850 tons.

~ How old is this press, and how old is the kind of design that this press represents?
- This particular press is a World War II–vintage Loewy hydropress. It was built in 1943. I guess extrusion presses must have come on board sometime in the twenties, and the design of extrusion presses is basically unchanged. This particular press belongs to the Department of Energy and was moved here from Adrian, Michigan, in 1961.

~ How does the Department of Energy figure in what you do here?
- Our primary purpose here is to extrude uranium under contract to the Department of Energy. Under that contract, when we've satisfied their requirements, then we're permitted to use the press for what we call commercial work.

~ How is it that you can do private work on the side?
- The press belongs to the government; the land and the buildings are my company; so, as part of the contract when it came down here, we were allowed to use their equipment for so-called commercial work.

~ Isn't this arrangement unique within the government's materials production side of the weapons industry?
- We pay them a fee for the use of this equipment, and while we're doing that, we're soaking up overheads that otherwise they would bear. So it's a benefit to them, and it's an advantage to us.

~ Let's talk a little bit about the primary purpose of the press, which is the extrusion of uranium. What kind of uranium are we talking about, and what happens to it?
- Well, we're involved in two streams here for the Department of Energy. The first stream is the Savannah River stream, which involves depleted uranium. Basically the Savannah River flow is the ingot, or billet material, which is cast at Fernald, and the billets are shipped here, where they are extruded to a tubular product. We then ship the tubes back to Fernald, where they're machined into fuel cores and shipped from Fernald to Savannah River for further processing.

~ What is the other stream?
- We're also involved in the N-Reactor stream at Hanford, Washington. It involves slightly enriched uranium.

~ When it comes out of the press here, which we'll see today, are they kind of like logs?
- Yes, they're a log sixty-seven inches in length and they're hollow. All of the billets going to Hanford are hollow.

~ When you said the N-Reactor stream used slightly enriched uranium, what is the level of enrichment we're talking about?
- It's 1.25 percent U-235. Normal is .711 U-235.

~ When we talk about depleted uranium, say, for the Savannah River stream, is that less than natural, then?
- That's less than .711. It's .2.

~ Is there a concern about health hazards when you're working with this material?
- The closest analogy I can draw is that you handle them more as a toxic material than as a radiation hazard per se. All of our employees have protective clothing, they wear film badges, and we monitor radiation. But there is no radiation hazard to our employees from this material.

~ You talked to me earlier this morning about something called uranium oxide. Is that a gas or vapor?
- No, it's a powdery substance. When uranium is heated to the forming temperatures that we use, which is somewhere up around 1100 or 1200 degrees Fahrenheit, as it cools, uranium has a tendency to flake off in the form of this oxide.

~ Is this oxide a potential hazard?
- It can be a problem if employees inhale enough of it. That's why housekeeping is very important here, to keep the oxides down and not let them get airborne.

~ How do you do that?
- Vacuuming, sweeping. And we quench a lot of the materials in water to inhibit oxidation.

~ And the workers all wear film badges because, I guess, there's some slight possibility of exposure to the uranium?
- The badges are to monitor radiation exposure. It's just good Health Physics practice to do this, and we've done it ever since I've been here. Everyone wears a film badge that works in the plant.

~ When we walked briefly through the plant this morning, the first things we saw were these red-hot billets in trenches of liquid salt. Why do you put the uranium into molten salt?
- It heats the metal to the right temperature for extrusion, and it prevents the uranium from oxidizing while it's being heated. As long as it's in a salt bath it won't oxidize because it's not in contact with air. If you were to heat uranium metal in a furnace, eventually it would completely become oxide.

~ The whole thing would just .. .
- You'd have a big pile of oxide.

~ Or a cloud of it?
- *(Laughs)* It's very heavy, you don't get clouds of it.

~ I mentioned that only because I thought that one of the hazards was breathing it.
- Yeah, that's true.

~ So it can become airborne?
- Well, it can become airborne.

~ Okay, so it's heated up to around 1200 degrees before it goes in the press. When it comes out of the press a few moments later, is it still 1200 degrees?
- It may even be a little higher than 1200 degrees at that point because of the force exerted on it.

~ How do you deal with these hot logs?
- These particular ones are taken from the press exit, or die-head area, and pulled over onto a cooling table where the pieces revolve for four or five minutes to make sure they cool down uniformly. Then we pick the extrusion up and quench it in water to get it down to where it stops oxidizing and our inspectors can handle it.

~ So when it's rotating, would that be the chief oxidation point, because that's where it's the hottest and it's in air?
- That's right.

~ Do you have fans over it?
- The whole operation is ventilated, yes.

~ I'm just curious, is that a billet sitting on the floor?
- That we would consider an ingot.

~ What's an ingot like that worth? What does uranium go for per pound?
- There's a standard transfer value between here and Fernald, I think it's about thirty dollars a kilogram, something like that. Don't quote me on that. It's, say, fifteen dollars a pound.

~ So the N-Reactor stream goes to Hanford. Where do you ship the Savannah River stream?
- The Savannah River product goes back to Fernald in truckload lots, by commercial, common carrier.

~ Does it have to have special safeguards when you truck it?
- Not really. The only thing we're doing is shipping it in sealed truckload lots. It's not at the strategic level of enrichment. I think it has to be above twenty percent U-235, then you get into all these escorted armed-guard shipments and this kind of thing.

~ How big a load of uranium metal can a truck take?
- It's whatever the highway limits are, and that's normally around 40,000 to 42,000 pounds a gross.

~ There is no radiological hazard with this material?
- It is radioactive, and there are very low levels of radiation involved, but not to the extent that you're talking about lead shielding and all this kind of thing. Generally the protective clothing that the workers wear is sufficient to virtually eliminate their exposures.

~ What is the special clothing that they wear?
- Just cotton coveralls is all it is. It's very, very low level, very little radiation. Nothing there, really.

~ In what way is cotton a protection? I know that lead is, I wasn't sure about cotton.
- It's the type of radiation that's emitted from this material. Usually when you're speaking of radiation people are thinking of gamma radiation, that's the stuff you get behind lead shields to protect yourself from. Alpha radiation, which I think mostly — again, I'm not a radiologist — but you're talking about a different type of radiation than gamma radiation, and it is such that simple cotton clothing is sufficient to block it, given the low levels that are involved.

~ I remember hearing that with alpha radiation a sheet of paper can stop it.
- Yes. Cotton acts the same way.

~ So that's non-penetrating radiation coming off the metal?
- Yes.

~ But the hazard with it is if you breath it in, right?
- Mm-hm. And the DOE [Department of Energy] furnishes to us annually a special machine that's in a semi-trailer and goes around to all these DOE sites. It measures the total body burden of radiation a worker might have, and we generally try to count everybody.

~ What's the average count that comes out of a person working around this material?
- I'd better not give you numbers, but there are established limits. There is a DOE requirement that you have to report anybody who's exposed at a rate of fifty percent of that limit, and we've never had to report anybody. I'd say the maximum body burden we've ever seen here is somewhere about ten percent of the acceptable limit.

~ And if you have ten percent you're still considered to be within the safety margin?
- Well within it, yes.

~ Okay, I think that covers it. I guess we should go on the tour now. I haven't been into a lot of factories myself, I've been dealing mostly with public-relations people and talking to people outside the factories, so this is an opportunity for me to really see something. But when I came out from this morning's short trip out onto the floor I had a little bit of a sore throat, and I figured there's all kinds of vapors there from all sorts of things going on, and I was wondering.... I bought a face mask in this welder's store. Would it be all right to wear that on the site? I'd feel a little bit better about having it.
- If you'd feel more comfortable, you're more than welcome to wear it.

Sam Cohen,
Father of the Neutron Bomb
Sam Cohen Beverly Hills, California,
December 6, 1984

~ I'm in the living room of Sam Cohen. . . .
- The day before Pearl Harbor.

~ Oh, that's right!
- A vicious time - that's what led to the Bomb. Which is why we're here.

~ I want to begin, Sam, by asking you to introduce yourself and say what it is you've been up to, what you've accomplished, and who you are.
- Nobody's ever asked me that before, so this is right off the top of my head: I'm a person, and I've led a somewhat normal life, as least as surface appearances go. Purely by accident I wound up at Los Alamos during the war. I became fascinated with it, and I've been at it ever since, which is now some forty-plus years.

~ What is the "it"?
- Nuclear weapons. That's been my profession over all these years. And it's always been my bent to move a step or two out into the future, which is why I got interested in advanced nuclear weapons concepts right after the war. And that's what led to my concocting the neutron bomb idea and any number of other schemes, none of which have had any impact whatsoever on the shape of things, but I've thoroughly enjoyed it. Again, trying to assess myself as a human being, I've never had any qualms. On a surface level, I've rationalized my fascination with nuclear weapons by saying it's important for the security of my country, and so there are no qualms to be had. If I went down another level in my psyche, I wouldn't know what to say—I've done it because I wanted to. So that essentially sums me up.

~ What did you do at Los Alamos?
- I was in the Efficiency Group at Los Alamos. Our job was to figure out the yield of the bomb that was burst over Nagasaki. To do that we had to learn how neutrons multiply once the chain reaction gets started. So this was my introduction to neutrons.

~ Was there a sense at Los Alamos that these weapons were the beginning of something new in terms of war fighting?
- On the evening of Hiroshima, when Oppenheimer was describing in very crude terms the catastrophe that had taken place over that city, the scientists who were listening to him were a bunch of howling savages, ebullient beyond imagination, as pleased as punch at what they'd accomplished. There was no consideration of what this might mean toward getting along with the Russians, or what the postwar complexion of the world might be, or anything like that. This was a fantastic day, our product had been used, apparently very successfully, and that's all they cared to know. There may have been a few who sat quietly while Oppenheimer was holding forth, but I don't recall seeing any.

~ I've always thought of Oppenheimer as the man who said, "We physicists have known sin."
- Well, that came later, and not too long after that, either. It had a very interesting result when it did come, I might add. Oppenheimer is rightfully called the father of the atomic bomb, but equally rightfully he could be called the father of the tactical nuclear weapon because he did the first conceptual spadework for using nuclear weapons strictly in a battlefield way instead of just decimating cities in a holocaust context.

~ So the father of the bomb that decimates cities is also the father of tactical nuclear warfare?
- He professed to be sufficiently guilt-ridden and aghast and appalled over the bombings of Hiroshima and Nagasaki that he never wanted that to happen again. So he recommended we design lower-yield weapons that wouldn't wipe out cities but that could strictly be confined to battlefield use.

~ And where were you in all of this?
- Well, my own personal addiction in all this has always been to tactical nuclear weapons for battlefield use.

~ Okay, then, let's talk about the thing you've come to be known for, Sam, the neutron bomb. You're called "the Father of the Neutron Bomb," one of those nuclear-paternity epithets. Is that an accurate description?
- I invented the concept. As to whether that deserves parenthood or even knighthood, God only knows. Take your choice.

~ What is the concept?
- The basic concept is to be able to have a battlefield nuclear weapon that won't have all these nasty side effects, like bringing down nearby cities and killing an awful lot of civilians and so on. It's something that can get at enemy personnel without causing what we call in the trade "collateral damage."

~ Let's talk about how a neutron bomb is different from the bombs used in Nagasaki and Hiroshima. Both those bombs were airbursts. Would a neutron bomb be an airburst?
- If it's going to be used to get what we call the "separation of effects," in other words, to get rid of the blast and heat, it not only has to be air-burst, but it has to be burst high, sufficiently high above the landscape so the blast and heat will not reach the ground.

~ How high up does the burst need to be?
- Depending on the yield, between 2,000 and 3,000 feet.

~ So roughly the same height as the Hiroshima and Nagasaki bombs?
- Right, not too much different, but the explosive yield is ten or twenty times less, so the blast and heat won't do much, but the neutrons will.

~ And what's the yield of a neutron warhead?
- Generally in the kiloton range, or ten to twenty times less powerful than the first atomic bombs.

~ Although it has ten or twenty times less explosive power than the first atomic bombs, the neutron weapon is still an H-bomb, right?
- Right, it's kind of a micro-mini hydrogen bomb.

~ And why is it that this type of H-bomb sends out so many neutrons? I heard H-bombs normally have an outer blanket of uranium that absorbs neutrons. Is the neutron bomb missing this blanket?
- Look, I can't go into too much technical detail or we'll start getting into things that are classified. But basically it has to do with the nuclear yield. The neutron weapon has this very low nuclear yield. The technology allows you to get most of the neutrons out if it is a low yield. In very large yields it doesn't allow you to do that. It's about that simple. There's no point in getting too technical.

~ How far do these neutrons travel in air?
- Neutrons are neutral particles, which means they can go a long ways in an un-dense medium like air, so you can have neutrons incapacitating people perhaps a thousand yards or so from the burst.

~ What can a neutron do to you?
- In a military sense it does two things. First, it really rips up the gastrointestinal system and causes all sorts of distressing symptoms, which the media has gone into galore, and I don't want to ruin your lunch by going into now. And then, for somewhat higher radiation doses, it affects the central nervous system and the brain.

~ What kind of a dose gives the gastrointestinal effect, and what kind of dose does it take to affect the nervous system and the brain?
- From a dose of several hundred rads on up to, roughly, a thousand rads, you get these gastrointestinal effects. Once you start going over a thousand rads on up to, roughly, 10,000 rads, you still get these gastrointestinal effects, but you also get a deterioration of the central nervous system so that the poor victim essentially is dysfunctional. He can't operate equipment.

~ What is a lethal dose?
- A lethal dose occurs roughly at 500 rads. At 500 rads, more than fifty percent of the people exposed will die.

~ Do they die on the spot, or does it take a while?
- No, they won't die on the spot. To have them die on the spot, a dose on the order of 10,000 rads or so is required.

~ At 10,000 rads does a person die right away?
- Chances are, at the 10,000-rad level, the trauma will be so great that unless medical attention is available immediately, the person will die from shock.

~ Is there something medicine can do for a person who has received 10,000 rads of neutron radiation?
- No. Nothing.

~ All right, so the bomb is detonated 2,000 to 3,000 feet overhead, and its yield is about one kiloton or less. What kind of a radius are we talking about for the bomb's deadly effects?
- We're talking about a radius of roughly a thousand yards where you will have these crippling effects on the central nervous system. These effects will be greater as you go toward Ground Zero. So if we had, say, several thousand rads at the periphery and we moved in toward the center, by the time we got to Ground Zero the doses could be tens of thousands of rads. Anybody in that area would be wiped out immediately.

~ What happens outside that area?
- Radiation intensity falls off with distance. So by the time you get out to, say, 1,500 yards, you're perfectly safe from the radiation.

~ Is there a dose out at that distance?
- Oh yeah, but it's probably less than 100 rads. And when one goes below 100 rads there are no really significant effects. You have a very small possibility that in the long run there may be an enhancement of such effects of leukemia, and other forms of cancer, but. . . .

~ . . .but that's not militarily significant, right?
- Right.

~ How did you come up with the idea for this weapon in the first place?
- I'd had the idea for the neutron bomb about eight years before I figured out how to put it together. I put together the actual concept in the summer of 1958. It came about purely by accident when I visited the Livermore Laboratory in the spring of 1958. I asked if anybody had any new ideas going around, and they said they really didn't, though they had begun work on some peaceful nuclear explosives. And the head of the division said, "Before you go home, you ought to take a look at these," and he showed me designs for some of the peaceful devices. And there they were: the neutron bomb characteristics. One of those designs was called Dove, by the way, for "Dove of Peace."

~ What was it about Dove that caught your eye?
- Well, there were two, Dove and Starling; both derived the major share of their energy from fusing deuterium and tritium. If the designs worked, there'd be an enormous outpouring of neutrons. But the designers weren't interested in capitalizing on them because they were bent on peaceful pursuits. I was the guy, see, with his Mars helmet on, that came up and said, "Well, what does this mean for war?" The question I asked was, "How many neutrons come out of this thing?" They made a few back-of-the-envelope calculations and the answer was: a hell of a lot. Then I took these calculations home and made my own calculations about the military effects of such a weapon, and, *voilà*, the neutron bomb! Then I put together the military concept of how to use this bomb and went off on a big sales campaign.

~ Was it easy to "sell" the neutron bomb idea?
- At first there was enormous resistance to the concept of a radiation weapon. The United States military has never been particularly enthusiastic about battlefield nuclear weapons in the first place, and in the second place, they think of nuclear weapons in terms of kilotons of TNT. It took a long time to convince them that a nuclear weapon doesn't have to produce a huge blast to be effective.

~ Why is that?
- Ever since day-one we've patterned our nuclear war-fighting strategies after Hiroshima and Nagasaki. But when you get both sides in a conflict slugging it out with nuclear weapons, then fighting a war with classical objectives like "winning battles" or "winning wars" becomes very, very fuzzy. I'd say the notion of using a nuclear weapon on the battlefield today still throws terror into the hearts of the military. And it's out of this terror that our whole nuclear war–fighting philosophy has come.

~ Can you explain that more?
- It's a circular argument: a nuclear war is too horrible to take place, so it won't take place, and to make sure it won't take place, we threaten that it will take place. So what we're basically proposing here to deter war is the threat of our own suicide. Now that's not a way for human beings to behave - that's lemmings! And it's all based on the premise that if we cross that nuclear threshold one more time we'll bring on the beginning of the end. So you get people like Jonathan Schell and Carl Sagan with this idea of nuclear winter and everything else. It's Armageddon. I don't find their ideas credible, and I'll tell you why: because in order to get these results from using nuclear weapons against cities, you have to have nations willing to use them that way. And I don't see any signs that either side, the United States or the Soviets, wishes to wage that kind of war.

~ But might not such a war happen because our thinking is so fuzzy on the subject? We've got so many of these weapons, and we're not thinking about them very straight.
- We're really not thinking about them at all.

~ So what would be a more realistic approach?
- *(Takes a long breath)* Well, now I'm going to make the most terrible statement of your entire interview by far and away. You know what the United States has to do if it wants to survive? It has to accept the fact that there will probably be a nuclear war, and it has to prepare to fight it and win it. It's a terrible, awful thing to say. But it's true, in my opinion.

~ What would such a nuclear war look like?
- I don't have the wildest idea. But we have to take certain basic steps that will enable us to fight one.

~ Are you saying we are not now ready to fight a nuclear war?
- If a nuclear war were to take place tomorrow morning, by tomorrow afternoon it would be all over. We'd be licked, militarily. And psychologically. The country would just fall apart at the seams.

~ But I thought we had enough weapons to destroy Russia a hundred times over. Or is it a thousand?
- It doesn't make any difference.

~ Why not?
- The only rational decision the president of the United States could make under such circumstances would be to throw in the towel. Unless he is going to be such a bestial, maniacal, immoral monster as to deliberately bring about the societal demise of the Soviet Union and kill tens of millions of Soviet civilians in revenge. And may God help us if we ever have a president like that. That's the fix we've gotten ourselves into!

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~ Where does that leave our almighty Triad, the command-and-control infrastructures, and the twenty-four-hour alert we've been on since 1960?
- It leaves all these things without a coherent strategy for use. If the war starts, we don't have the wildest idea of what to do. In the current predicament the best use that we can make of all these nuclear goodies is not to use them. Because the only way that we could use them would be in a morally obscene way. So our current strategy is not a strategy in the slightest. It's been U.S. national policy for more than a quarter of a century that nuclear weapons are actually unusable weapons. That's horseshit, and you can quote me on that.

~ The neutron bomb enables us to start a limited neutron-bomb war, but with the big ones still cocked and ready to go, that seems like a good recipe for global holocaust... .
- If we ever had to use neutron bombs it ought to be to defend U.S. terra firma, not the soil of allies. Let the allies develop their own neutron bomb. As a matter of fact, let's sell it to them! They should have discriminate weapons for their own defense. The United States doesn't need to take on the burden of defending all the rest of the world. That is in fact the best way of getting into a nuclear war, and that'll be the end. But it doesn't have to happen that way at all. A nuclear war can still be fought for political objectives, the way wars should be fought, and not for the extermination of the human species.

~ Sounds like a job for the neutron bomb .. .
- Well, let me put it this way: the neutron bomb offers a potential of waging far more discriminate warfare to avoid damage to the civilian fabric than any other weapon ever invented. If one wants to assume that fighting wars is basically immoral - let's assume that it is - then fighting neutron wars is considerably less immoral than fighting conventional-weapon wars, for all kinds of reasons.

~ And one of the reasons includes the fact that a neutron war generally stays away from a population and is intended to destroy only soldiers?
- That's a primary reason, after a neutron-bomb war you don't have this aftermath of towns and cities lying in ruins, or populaces desperately trying to survive, going hungry, diseases spreading around, and so on. To me that is a moral plus.

General Paul Tibbets
Columbus, Ohio,
February 25, 1985

I was notified in September 1944 that the United States was undertaking the development of the atomic bomb. My responsibility was to develop and train an Air Force organization capable of dropping the new weapon. Not too many people knew that the directive also said to be prepared to make simultaneous drops in Europe and Japan. This is what was meant when they termed it a "split operation."

~ The plan was to use atomic weapons on Germany and Japan at exactly the same time?
- That is correct.

~ With only two bombs available?
- At the time I'm talking about we didn't have any bombs yet. Production was only beginning. How many weapons would become available was not up to me. My job was to develop an organization and train it. I also had to work with the scientific element at Los Alamos and find out: What have we got? What does it look like? Where does it go? What do we do with it? I spent ten and a half months working with those people to get the weapon into a shape that it could be dropped with predictable accuracy from an airplane flying at 30,000 feet.

~ Is that what is meant by "marrying the bomb to the plane" ?
- Yes, that's what we called it.

~ What did marrying the bomb to the plane entail, exactly?
- First off, we had to get an aerodynamic shape to the bomb and one that would fit within our bomb-bay limitations. Additionally, we had to keep battery-operated heaters around the bomb because we didn't want the triggering mechanism to freeze up. Then next thing was, we had a weapon in there with critical material, and we had to monitor that as we were going along to be sure it wasn't starting to get active.

~ Did you have to learn any unusual things as the pilot of the plane that was going to drop this bomb?
- We hadn't been used to flying at 30,000 feet with our airplanes at that time. It presented a new bombing problem, because you had high-altitude winds aloft, "ballistic winds" they called them. Also, with this weapon, we knew that once it was released, we could not continue to fly forward as we did in Europe and the Pacific at that time. There was no way you could keep flying over this bomb and still survive. The question then became: how do you get away from it after you release it? The only answer is, you have to make a reverse turn - again, another flying problem at that altitude. You only had fifty seconds in which to make the turn, because that's the time it took for the bomb to fall and explode, the explosion to come to shock wave, and all of that.

~ And making that turn within fifty seconds was the most unusual thing?
- Absolutely. The rest of it was just flying, navigating, and bombing.

~ The plane was called Enola Gay, *and it's generally known that this was your mother's name. At what point did you name it after your mother?*
- I put the name on the airplane the afternoon before we took off the following day at two A.M.

~ Did you check with your mother on that?
- No, no. Because obviously I couldn't talk to her, and I didn't think that was really necessary.

~ How did she feel about being made relatively immortal as a result of that?
- Well, when I was able to get home, my father told me—he always called her "the old girl"—he said, "You ought to have seen the smile on the old girl's face when they said the airplane was *Enola Gay."*

~ I heard, General, that you were the one who sent the code to Washington that got the wheels rolling on the timing of the actual bombing. Can you explain how it fell to you to do this?
- We had started training in September 1944. By the following April I had a good outfit of people that had been driven hard and trained well. I put myself in a position of a football coach who knows that if you overtrain, it can cause you more trouble than you can imagine. So the question was, how workable was the bomb? I approached Dr. Oppenheimer and said, "What do you think the chances are of a failure to explode?" He said, "I don't really know, but I'm looking for that possibility of one in a million that it will malfunction." I said, "One in a million! Those are terrific odds. What are the odds right now?" I told him, "I really need to know." He said, "Well, if you need to know, I'm convinced that right now we're one in ten thousand." I said, "I'll take one-in-ten-thousand odds anytime." I was afraid we'd never get over there to get on with the primary purpose of the weapon, which was to stop the war. Now at that time any organization that had trained to go overseas had to be inspected. An Air Force or a Higher Command organization would do this, but the Higher Command in this case didn't know what we were doing, and I had been told you have to do all of this yourself. They gave me a code word, which today I don't remember, and that was my word to send to Washington when we were ready to go. I, arbitrarily on my own, independently, sent that word to Washington because I wanted to get that organization moving over to the Pacific theater.

~ There's all this talk of training the crew for Hiroshima. What about the crew for Nagasaki?
- I had fourteen separate crews. And I did the same thing with each one of the crews. It was all one organization, and I was commander of that organization. It was called the 509th Composite Group.

~ At what point did it become clear that you had two bombs rather than, say, one, or three?
- Well, put it this way: there were three bombs that could have been used. One on the island, one en route to the island, and one at Wendover. Now how long it would have been before there would have been a fourth one I don't know, but it wouldn't have been too long. Anyway, there were three that were readily available.

~ I always thought it was only two.. .
- There were three. And when Japan didn't surrender after the one in Nagasaki, I flashed a code word back to Wendover, Utah, and that bomb was loaded into an airplane and headed for the Pacific but got stopped at Moffett Field because the war was over.

~ What type of bomb was the third bomb?
- It was the Nagasaki type.

~ Can you describe what happened when you dropped the Hiroshima bomb?
- Well, as we came into the target my mind was really on the navigation of the airplane to the target, the stability of the airplane to furnish what we call a bombing platform. I wanted it absolutely tabletop smooth. And that's the way it worked. We worked that, all the way in from the target. We could see the city from seventy miles distant. And as we closed in on that distance we had certain procedural things we had to do. We had a check and recheck situation. First off, when the bombardier says, "I can see the city," the rule was that the navigator had to step up from his position, go up and look over the bombardier's shoulder, and say, "Yeah, I agree with you, that is - that is Hiroshima." The next thing is when we got much closer and the bombardier says, "I have the aiming point," that meant he put the cross-hairs of the Norden bomb-sight on that aiming point and the navigator then had to come up, look through the bomb-sight, say, "Yes, I agree with you, that is the assigned aiming point." I'm looking over the shoulders of both of them as they go, and, based on target study I had done trying to imprint the outline of this city in my mind, I couldn't do anything but agree also, because we had absolutely unrestricted visibility, it was just as clear as a picture. Now as we come in, there were some things that had to be done at the last moment. We had to activate a tone which was transmitted over the radio to the other two B29's accompanying us so that they would know we were only one minute away from the bomb release point. Now this tone was silenced when the bomb departed the airplane. That was the signal for those people to release their instruments and start this turn away from the bomb that I talked about.

~ What kind of instruments did they release?
- They were recorders to record the blast, and those recorders were attached to battery-operated radios to transmit that signal by radios to receivers back in the airplane.

~ Was the bomb dropped by parachute or did it just fall?
- It fell. The blast gauges were floating down by parachute.

~ What happened when the bomb went off? What did you experience?
- Well, nothing, strange as it may sound. The airplane had its back to the explosion, and it did not have a lot of windows in it. Now when the bomb exploded, the brilliance was such that even though it was a bright, sunshiny day, I could still see this silver light, it was kind of a bluish silver flash. So, fine. That is something that you didn't normally see. And the next thing I tell everybody is that I tasted it. And they say, well, how could that happen? I say, well, years ago when I was a young fella, the dentists, when they did work on your teeth, would fill your teeth with a combination of silver and lead, and when you would accidentally touch it with a fork or a spoon you would get a feeling of a pain going through. It's commonly called electrolysis. And that's exactly what happened. It was just a momentary flash and then it was over. I knew then that the bomb had exploded. Now at about the time I tasted it, my tailgunner, who is in the back with welder's goggles on so he wouldn't be blinded by the flash, he's looking for the shock wave. And he said, "Here it comes." He could see it coming up. A mirage like you see on the desert. Beautiful, ever-expanding circles coming right up to the airplane. We felt the first one with the force of two and a half g forces. It wasn't a scary, dramatic jolt, but it was one that positively got your attention. The second one was much lighter, and the third one wasn't strong at all.

~ And did you ever see the cloud from the blast?
- After the bomb exploded, I was still in a partial turn, and I kept the airplane coming right around to come back because we hadhand-held cameras, and we were instructed to take all the pictures that we could while we were in the air. So everybody got their cameras and they started taking pictures. We had gone in on basically a westerly heading, and when we came out I headed to the southwest. So I passed to the left of the mushroom cloud that was going up. By the time I could turn around and look at it, the mushroom cloud was higher than we were. And we were still at about 29,000 feet. The cloud was tumbling, rolling, and boiling, and, I mean, it was obvious that there was a tremendous amount of energy contained within that cloud.

~ What color was it?
- Well, dirty gray. That's the best color I could give you. And it was not the classic mushroom. This one was kind of strung out. Did you ever see a parachute come down that failed to open, what they call a straggler? That's what it looked like.

~ At what point did you see this mission from the point of view of the people on the ground? Did you ever feel that it had inflicted suffering that was beyond what anybody had experienced in a war before? Or did it seem to you similar to other kinds of bombings and simply what happens when wars start up?
- Well, I think you've basically touched on my philosophy. We had a famous old southern general who said, "War is hell." Sherman. And I couldn't agree more with him. It is. When I was dropping bombs in Europe, iron bombs and such, against the Germans and so forth, I knew that people were getting hurt on the ground, and when I realized that I was understanding people were getting hurt, I said to myself, "You gotta quit thinking about this. You can't be effective if you're going to be worrying about who's getting hurt down there. You're out to destroy a target. That's the name of the game, destroy the target." And on the basis of that, I must say that I never did dwell on it. Sure, I knew that there had been terrible loss of life. I knew all kinds of damage was taking place. But again, I took it objectively, not personally.

~ You mentioned the name of the game was hitting the target. What was the target in Hiroshima?
- The city was the target, period. We figured we'd wipe out most of the city. There was not much of a question about that. But the aiming point was a bridge right beside a Japanese temple. Don't ask me the name of the temple or the bridge, either one, but it was a positive geographical landmark that you couldn't mistake.

~ And how accurate was the drop?
- I think we were pretty accurate. The bomb exploded within 600 feet of where we intended to explode it.

~ Let me ask you, Mr. Tibbets, what would you say is the lesson or legacy of Hiroshima, speaking for today?
- The weapons available today make the ones we used look like miniature fire-crackers. Yes, we do have some weapons that we must do some serious thinking about. And I certainly don't advocate war. I would like to believe that nuclear weapons as such will never be used again, but I'm not that naive. I think they will be, just because we have them. The question is how to use them.

Dr. Edward Teller,
Hoover Institute Palo Alto, California,
December 14, 1984

~ Dr. Teller, my first question to you regards something you wrote in a book called The Legacy of Hiroshima. You stated there that we entered the atomic age with dirty hands. This was in reference to the fact that we bombed Hiroshima and Nagasaki without prior warning. How has this particular lesson of Hiroshima influenced our subsequent nuclear-war thinking?
- I think it is truly regrettable that a suggestion to demonstrate the atomic bomb before using it has not been put into practice. Imagine that we might have carried out such a demonstration, for instance, dropping a nuclear explosive over Tokyo without warning, but at such altitude that it would have lit up the evening sky for many miles and not done any damage whatsoever. In the end we dropped the bomb on Hiroshima, and the Japanese leaders were completely undecided what to do about it. The war was ended only by the personal and illegal intervention of Emperor Hirohito, who was God, and was not supposed to interfere with any military decisions. But I believe there was a very real chance that the demonstration over Tokyo with a subsequent demonstration of what it was, a demonstration that Hirohito would have seen, might have led to the same consequence. We could then have followed up with an actual bomb in two weeks if they did not surrender. But I think the chances are they would have surrendered. If we could have started the atomic age by having demonstrated the power of technology to end a dreadful war without killing a single person, I think we all would have a better conscience, we would be able to think more calmly about nuclear explosives, we would be more safe, and war would be less likely today.

~ Is there some way out of where we are today?
- What was done cannot be undone. But at least we can promote initiatives to use nuclear explosives in a defensive way. We should consider, as well, using all other means which in many cases may be more efficient and more appropriate, and not make distinctions between nuclear and non-nuclear weapons, but make a strong distinction between aggression and defense. That, I think, would lead us out.

~ You once stated, "For as long as I could remember I have wanted to do one thing: to play with ideas and find out how the world is put together." Could you describe, in your career, the role that playfulness, imagination, and curiosity have had in terms of your own major scientific breakthroughs?
- To apply imagination to pure science was what I wanted, and that's what I did. It is something wonderful in its day-to-day execution, and it brings people together. But as soon as the practical element enters, serious differences will unavoidably appear. Unfortunately, when the Second World War started we had reason to believe that the Nazis would work on an atomic weapon, and I was persuaded that we had to do likewise. And this needed an entirely different style of work. No more could we enjoy a completely free exercise of the imagination. That was not the kind of work I like. It's the kind of work I pursued because I understood it to be my duty. After the passage of almost half a century I still believe, unfortunately, that it is my duty, because the simple idea that technology must be developed and applied wherever it can be, but it must be applied by reason and limited by the decisions of a democratic society - that straightforward point of view is not accepted by the scientific community. Most scientists imagine they create weapons which then become independent of man, and, whether man wants it or not, these weapons will work destruction. Too few understand that technology for peace, technology for defense, cannot be separated in its technical origins from technology for destruction. These important differentiations have to be made, not by scientists, but by the public, which decides in a democratic society how technical advances should be used. There are too few spokesmen who continue to insist on the development of technology for defense and the welfare of the people, and not excluding arms because arms cannot be excluded in the present unstable political situation. Arms instability is caused by deep historical and ideological differences, and not by the arms race. This point of view needs people to defend it, and I happened to acquire at least an opportunity to be heard, which for me also is an obligation. From my own personal point of view, nothing would be more wonderful than if I could return to pure science, which I still am trying to do in my few free moments. That I'm not doing it full-time is simply due to the fact that among my colleagues the majority happen to look at nuclear war from exaggerated points of view. I find that the point of view which is for technology but also insists on its right application is underrepresented.

~ I' d like to ask you a question, Doctor, about the arms race. One disquieting aspect of it for many people is its mirror-like quality. It goes like this: if we can think of it, so can they, and we may as well build it, because if we don't they will. Yet if you have two parties who both think this way, it seems you have a situation that will never end. Is there a way out of such a mirror-like condition?
- You have mixed up in a most unusual and yet ingenious fashion what is correct and what makes no sense. If we can think of it, so can they - of course! The point is that one year before the hydrogen bomb debate started, before most people in our scientific community said, "If we don't do it, neither will the Russians," a year before that, Sakharov had already decided to work on the hydrogen bomb. The simple fact is true: we can think of it, they can think of it, but this does not need to lead to an impasse, because if we could work on defensive weapons, and we can prove, as I hope we can prove, that they are more effective than offense, then that will lead to two armed camps facing each other armed not with swords but primarily with shields. And that will be a much less dangerous situation than the present horrible balance of terror. Therefore, there is a way out. It seems to me to be a thoroughly worthwhile objective, and it should not be condemned as an element of the arms race. One should understand that any new development in technology can be applied to thoroughly peaceful purposes or to war and within war it can be applied to defense or attack. These distinctions will have to be made, quite obviously, by the public. But the technology must be made available to the public because otherwise the technology of attack, or of world domination, will develop in that country – Russia - which has applied suppression and pursued expansion for hundreds of years. That is why the situation is not mirror-like. The mirror does not exist.

~ Is weapons development in America a democratic process?
- The arms race is not a purely democratic process, as long as secrecy excludes the full participation of the public. But the arms race is deeply influenced by public opinion. To that extent it is a democratic process.

~ A final question, Dr. Teller, about what I sense is an underlying assumption throughout your writing, I would put it this way: man is here to stay, the human race shall survive. Today many people are full of fear and trembling over whether man shall be here to stay and whether the human race shall survive. Could you comment on this?
- I am afraid I have to contradict you, just in a flat and complete manner. That the human race will survive was never my basic assumption. It was my conclusion in every case where the question arose. I did not begin with any conclusion during the fallout scare, the scare connected with the depletion of the ozone layer, and now the scare connected with nuclear winter. In each case many of us, including me, have taken a careful look and tried to separate exaggeration and propaganda from fact. And in each case we came to the conclusion that the human race will survive as certainly as could certainly be stated at any time in the past. Without exception, those who object to war like to find additional reasons why war should be excluded. So we frequently are led to exaggeration, like picturing the end of the human race. Let me tell you, I am afraid that we may not survive. I am not very much afraid of this; I am somewhat afraid of it, in connection with biological warfare, which might get out of control. In nuclear warfare the extinction of the human race is much less likely. A nuclear winter is already an exaggeration, because the probabilities are for only a limited effect on temperature. It might get big enough to influence crops in the hemisphere, but it is practically certain not to lead to the extremely serious consequences that have been discussed. Actually, I believe that fallout, ozone depletion, nuclear winter - or, more properly expressed, nuclear temperature change - will cause possibly great additional suffering, but, with practical certainty, not as great as the suffering or slaughter that will occur in the nations that participate in the nuclear conflict. Nuclear war could result in probably more than a hundred million deaths, perhaps a thousand million deaths. Still - survival. But together with survival, the probability not only of immense suffering in the nations participating in the conflict, but destruction of all human ideals. German science, which used to be something really splendid before Hitler, never yet has recovered from what the Nazis did. A nuclear war will leave behind, I am afraid, no matter how it works out, some sort of madness, and some of my friends say that madness may turn out to be incurable. Of that I am much more afraid than of the end of the human race. The wish to avoid nuclear war need not be strengthened by fairy tales of the end of the human race. What is really to be expected should be sufficient to make us strongly determined to keep our ideals without a nuclear war. And I think it can be done, and the most hopeful approach today is the development of defensive weapons, non-nuclear or nuclear, as long as they defend the innocent. The way out of the present difficulties exists through increased emphasis on defense. I think a peaceful future can be secured only if those who want peace also develop technology to its limits.

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