Footnotes

for

ATOMIC ADVENTURES

Secret Islands, Forgotten N-Rays, and Isotopic Murder - A Journey into the Wild World of Nuclear Science

By

James Mahaffey

While writing ATOMIC ADVENTURES, I tried to be careful not to venture off into subplots, however interesting they seemed to me, and keep the story flowing and progressing at the right tempo. Some subjects were too fascinating to leave alone, and there were bits of further information that I just could not abandon. The result is many footnotes at the bottom of pages, available to the reader to absorb at his or her discretion. To get the full load of information from this book, one needs to read the footnotes. Some may seem trivia, but some are clarifying and instructive.

This scheme works adequately for a printed book, but not so well with an otherwise expertly read audio version. Some footnotes are short enough to be inserted into the audio stream, but some are a rambling half page of dense information. I was very pleased when Blackstone Audio agreed wholeheartedly that we needed to include all of my footnotes in this version of ATOMIC ADVENTURES, and we came up with this added feature: All 231 footnotes in this included text, plus all the photos and explanatory diagrams that were included in the text.

I hope you enjoy reading some footnotes while listening to Keith Sellon-Wright tell the stories in ATOMIC ADVENTURES.

James Mahaffey
April 2017

Author's Note
Stories Told at Night around the Glow of the Reactor

Always striving to beat the Atlanta Theater over on Edgewood Avenue, the Forsyth Theater was pleased to snag a one-week engagement of the world famous Harry Houdini, extraordinary magician and escape artist, starting April 19, 1915.[1]

It was issued an operating license, no. R-97, by the Atomic Energy Commission on December 29, 1964, and proceeded to entertain with its own form of magic, doing tricks that would have baffled Houdini on a daily basis, doing everything from driving a LASER cavity with neutrons to investigating Legionnaire's Disease.[2]

Orren Williams, a grad student working as a reactor operator, leaned back, put his feet up on the console, and described the beautiful, highly intelligent woman he was seeing and the house he was going to buy as soon as they were married.[3]

He was the type who would eat a roach off the floor on a dare or decide to test the emergency escape tunnel after lunch.[4]

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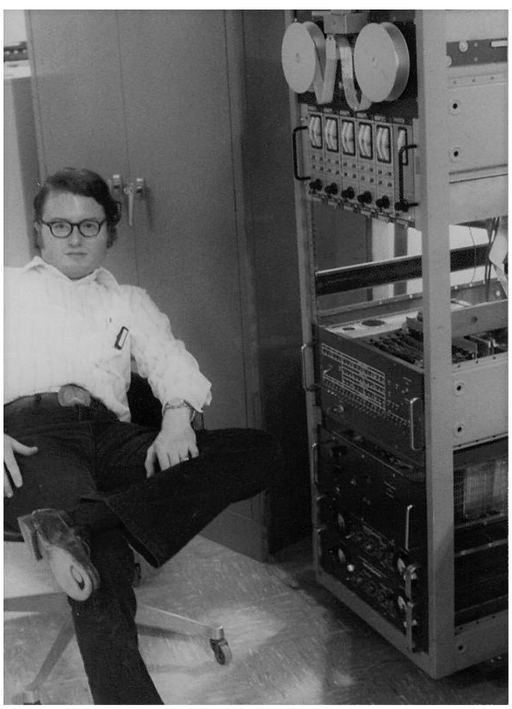
[1] This was actually Houdini's second show at the Forsyth Theater. The first was announced in late December 1911, and his engagement was January 1-6, 1912. To have him appear in Atlanta was still a world-class novelty in 1915. Working back from the original story, I believe that the 1915 show is the one depicted here.

[2] The Houdini story was first told by Georgia Governor Lester G. Maddox. Upon his election in 1967, Maddox was treated to a tour of the Georgia Tech campus, and he was particularly intrigued by the nuclear reactor. He was invited to the control room, located high and overlooking the reactor bio-shield in the containment building. The operations crew encouraged him to sit at the control panel, where he put his feet up on the console and spun his tale about what had been on this spot back in the day. The Governor didn't know anything about nuclear research, but he knew a lot about Atlantic Drive. He had grown up in a house right down the street, and he quit high school to work in the steel mill.

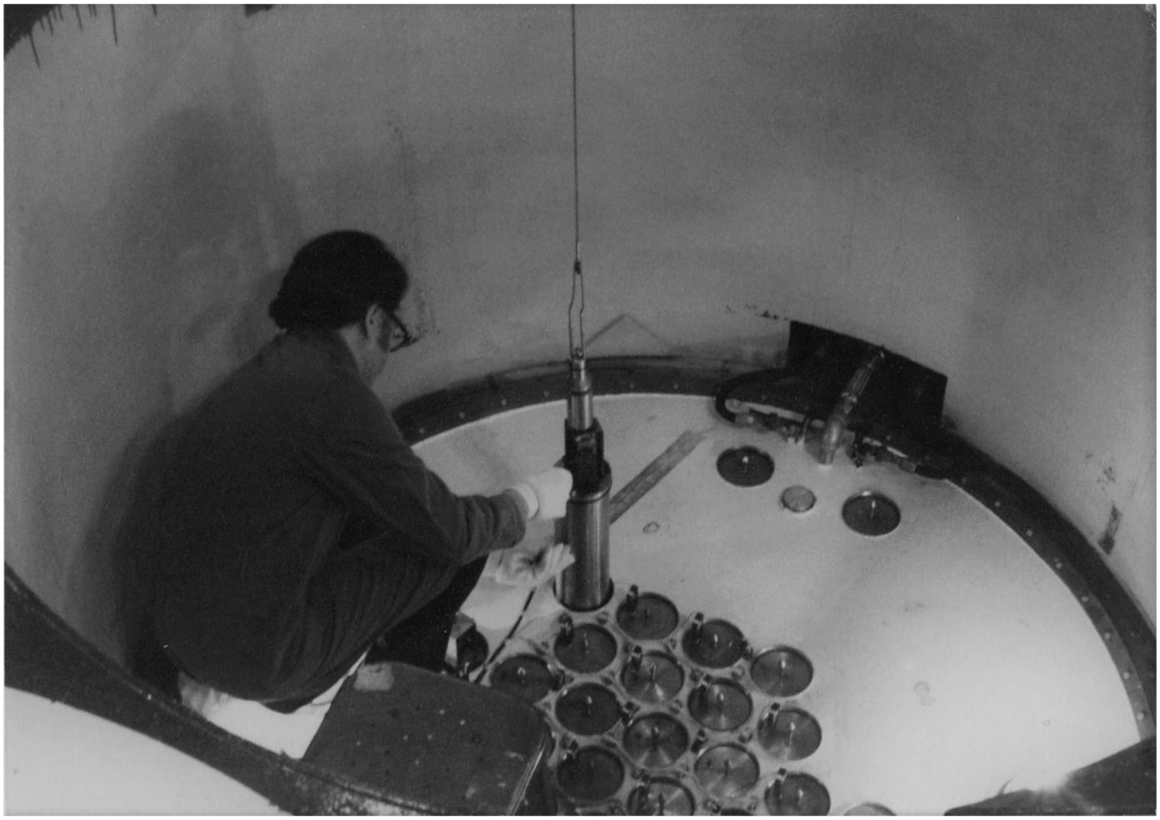
[3] Williams' description of his beautiful, highly intelligent love interest, who was working downstairs in the reactor complex for a nuclear medical research foundation, sounded so irresistible, immediately upon graduation I married her, following a brief courtship. Our 38th anniversary is coming up in 2017. Orren Williams never talked to me again.

[4] Moon's favorite stunt while idling at the control console was to ask a fellow operator, in this case Dean McDowell, did he know that bees can only sting you through open pores, and further that pores open only as you take a breath? If you simply hold your breath, a bee cannot sting you. McDowell found this claim difficult to believe, but Moon just happened to have a bee right here, under an inverted urine specimen cup. He took a deep breath, held it, and slipped his palm under the cup. The bee, mad as hell, tried repeatedly to stab him, to no success. See? "Let me try that!" McDowell enthused. He took his breath, slid his palm under the lip of the cup, screamed, and flung the bee-cup combination ceilingward. Moon collapsed with laughter. His palm was so heavily callused, there was no way for a bee to stick a stinger in him. The escape tunnel was at GNAL, not at Georgia Tech. It was a steel pipe, 3,600 feet long, just wide enough for a man to crawl through, leading from the underground control room of the Radiation Effects Reactor to the main gate at the "lethal fence."

The control room of the Georgia Tech Research Reactor with Dave Cox at the console.



The author, sitting on top of the reactor with his neutron counting equipment. The computer in the rack at right was built from scratch in the electronics shop downstairs. Notice the hole in his shoe.



The author on top of the reactor core, with the shielding removed, installing his axial instrument thimble in V-14.

No, young man, the reactor glow is a lovely shade of blue.[5]

[5] The Georgia Tech Research Reactor was shut down and de-fueled in 1996, for fear that international athletes would storm the building and steal the 97% enriched metallic uranium fuel during the 1996 Summer Olympics in Atlanta. The facility was decommissioned in 1999. It took a few years to knock it down and haul away the remains. Atlantic Steel was down to 400 employees by1997, but they were still turning out Dixisteel barbed wire. The mill was bought by Jacoby Development in 1998, erased from the old farmland, and replaced with a residential/commercial development named Atlantic Station. Neither facility, the reactor nor the steel mill, will ever be built again.

Introduction
The Curious Case of the N-Rays, a Dead End for All Times

Your measurement or detection must rely on the objectivity of physical equipment and not on the wishful impressions of a person.[6]

These incidents were noted as degrees of deflection, and each could then be mapped into an atomic weight using a simple chart.[7]

T. Galen Hieronymus applied for a patent of his device, "Detection of Emanations from Materials and Measurement of the Volumes Thereof," on October 23, 1946.[8]

The Air Force wanted to talk to him about detecting human presence on the ground from a high-altitude airplane.[9]

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[6] But, science is flexible. Alessandro Volta was a professor of experimental physics at the University of Pavia, Italy, in 1800, when he invented the electric battery. The first voltmeter, used to determine that electricity was indeed being produced by the new device, was Volta's tongue. He would place the two wires, anode and cathode connections, against the tip of his taster and feel the burn. This important experiment, by definition, employed the Heironymus effect. Some people could definitely taste the "metallic" flavor of electricity, and, over a spectrum of response sensitivity, some could not. How Volta thought to stick the wires in his mouth is not written down.

[7] I am writing this description from T. G. Hieronymus's literal description of his device. I think that he meant to say "atomic number." Given only the atomic weight, one could derive only a vague idea of what the element is. Finding, for example, an atomic weight of 14, the specimen could be either oxygen-14 or carbon-14. An atomic number, the number of protons in an element's nucleus, corresponds only to a specific element.

[8] The title of this patent, no. 2,482,773, is misleading. Nowhere in the patent does this device claim to measure the volume of anything. It is supposed to measure the element composition of materials.

[9] Hieronymus gladly stepped up to this challenge, but instead of mounting his machine in the downward-looking bombsight window of a high-altitude plane, he instead requested *photographs* of the ground where soldiers were hidden. The Air Force complied, Hieronymus scanned the pictures with a psionics device, and he found evidence of people all over the photographs. When told that people were only in a few locations, Hieronymus explained his analysis saying that the soldiers had obviously been urinating on all the trees and had left their essence scattered hither and yon. The Air Force decided not to pursue this inquiry.

He had successfully measured the extremely rapid response speed of a Kerr cell under electrical excitation using an ingeniously modified rotating-mirror apparatus from Léon Foucault's speed-of-light measurements.[10]

The high voltage was not exactly steady, but was produced in a ragged, pulsed alternating current using a buzzer operating off the iron core of the transformer.[11]

New data piled up, and On May 11, 1903, he submitted another paper, "On the Existence, in the Rays Emitted by an Auer Burner, of Radiations which Traverse Metals, Wood, etc."[12]

His fellow research physicists, 120 of them, mostly of Gallic origin, would collectively publish almost 300 notes, articles, and papers on the subject.[13]

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[10] The Kerr cell, invented in Scotland in 1875 by the physicist John Kerr, consists of two parallel electrode plates separated by a layer of nitrobenzine. Apply electricity across the electrodes, and the liquid develops interesting optical properties. It becomes birefringent to polarized light, refracting it off in two directions. The effect will switch on and off with incredible speed on the nanosecond scale. This property was exploited in the rapatronic camera, invented by Harold Edgerton of MIT, for use recording motion pictures of atomic bombs exploding at the tops of steel towers. These movies, only 10 frames long, break an event that lasts a few milliseconds down into a slow-moving sequence, with the rapidly evolving explosion frozen in time. Watching it, you can see the fireball erupt from the bomb as the over-running x-ray shock waves travel down the guy wires of the tower and cause them to evaporate. The tower has no time to be blown out of the way as it reduces to plasma under the spherical shock. It's a rare spectacle of two divergent theories operating in the same photograph. Quantum mechanics eats the tower, while Newtonian mechanics (inertia) makes it stand still.

[11] Blondlot would later employ a "rotary interrupter" to modulate the primary coil in his Ruhmkorff setup. This was a disc made of an electrically insulating material having a conducting stripe of copper foil adhered to the surface. The disc was spun at a high, constant speed by being fastened directly to the axle of an electric motor. As the disc spun, two spring-loaded electrical feelers would bear against the surface, and make a periodic on/off connection through the copper strip to the battery driving the Ruhmkorff. The rotary switch setup may have improved the sputtering, inconsistent quality of the high-voltage spark.

[12] The "Auer burner" was invented by Carl Auer von Welsbach, an Austrian scientist, in 1890. It was a new way to use a gas flame for light, employing a mantle made of a mixture of thorium dioxide and cerium oxide. Instead of a dim, yellow flame, an Auer burner glowed brilliant white from the fluorescence of the thorium-cerium combination, and it turned out to be a strong source of N-rays. Think Coleman lantern. Carl went on to invent the cigarette lighter flint.

[13] It has been said, as a slur attributed to Robert W. Wood, that "only Frenchmen could observe the phenomenon." This is an exaggeration. J. S. Hooker and Leslie Miller, both Englishmen, and F. E. Hackett, a student at the Royal University of Ireland, reported N-ray observations. Miller was the first to exploit N-rays for profit, selling a manufactured device for finding them and advertising it in *Lancet*.

The assistants were unable to guess correctly when he had his hand in the beam and when he had withdrawn it.[14]

[14] This is obviously a case of the "Hieronymus Effect" taking the place of objective instrumentation, and the attributes of N-rays corresponded with the Hieronymus "eloptic" rays. The researchers at Nancy had even confirmed that the "physiological rays" to and from living things could be collected by a metal plate and conducted along a wire. Blondlot may have been deluded by his experimental results, but he was not a complete fool. He had, in fact, recorded many of his spark-gap brightness measurements on photographic plates, correctly thinking that eyes could be fooled, but not photographs. The extent that a photographic emulsion is exposed by the light from a spark over a fixed unit of time should be an unimpeachable recording. Wood saw it differently. Watching a demonstration of Blondlot's photo-recording techniques, he could see how subtle biasing of the exposure time or processing duration could throw the measurement to a consciously or even subconsciously desired outcome. There was a troubling possibility of skullduggery at work in this laboratory. It was traditional to split the monetary proceeds of a research award with the lab assistants, and if they would score a Nobel with this discovery, the reward would be substantial. The assistants, who have never been named, could have thrown out any photographic evidence that there was no N-ray effect, and kept only those that confirmed what Blondlot wanted to see.

Chapter 1
Cry for Me, Argentina

The waste products of fusion are only slightly more complex than the hydrogen used in the reaction, and they are not radioactive.[15]

One D-T fusion yields a respectable 17.6 million electron volts (MeV) of energy.[16]

Patents were filed in Germany and the United States for the fusion neutron generator, and at the Langley Memorial Aeronautical Laboratory in Hampton, Virginia, the first "tokomak" fusion reactor was built by Arthur "Arky" Kantowitz and Eastman Jacobs.[17]

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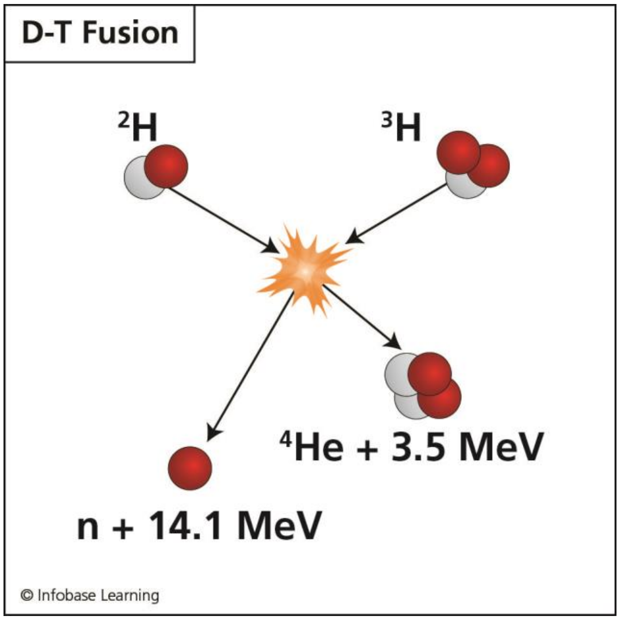
[15] There are, of course, exceptions, and, in the interest of full disclosure, I must mention them. The free neutron released in three known fusion reactions is technically a radioactive particle, because it decays into a proton and an electron (beta-minus decay) with a half-life of 10.23 minutes. Free neutrons can also activate other nuclides to radioactivity upon capture. Tritium (hydrogen-3) is another possible fusion product, and it undergoes a very low-energy beta-minus decay with a half-life of 12.32 years. These scant radiation sources do not hold a candle to the high-energy, million-year, mixed-mode radiation from fission products and from the immediate fission process.

[16] That energy yield, 17.6 MeV, is only 6.7×10^{-13} calories per fusion. True, you would have to fuse 1×10^{16} times to equal the 7,000 calories of energy produced from burning a gram of ethanol, but those fusions only involve 8.3×10^{-8} grams of deuterium-tritium mix. That's not much. If you "burn" a gram of deuterium-tritium using fusion, which weighs about as much as a single raisin, you are given 8.0×10^{10} calories. That's the equivalent of 84 megawatt-hours of electricity. In the hypothetical fusion transformation of that gram of material, 0.0000000037 grams of mass mysteriously vanish.

[17] The Kantowitz-Jacobs fusion device was way ahead of its time. Kantowitz, a recent physics graduate of Columbia University, read in a magazine article that Westinghouse had bought a very powerful Van de Graaff high-voltage machine, and the buzz was that they were going to use it to build a jumbo-sized Oliphant fusion reactor. Although working on aircraft wing design, he had no trouble spinning up his boss, Jacobs, with the idea of one-upping Westinghouse with a better fusion reactor design. He proposed using a toroidal (donut-shaped) electromagnet to compress ionized hydrogen inside and cause it to fuse. This was hardly the mission of the Aero Lab, so they had to cloak it with a name, "diffusion inhibitor," in order to wrangle a budget of $5,000. The plasma was heated by a 150-watt radio transmitter, and the power-draw from the water-cooled magnet windings was enough to dim the lights in the neighborhood. Kantowitz held the circuit breaker closed as they watched the smoke rise from the building's wiring, but they were never able to make the simple hydrogen fuse. It was a brilliant idea, and Soviet scientists would gain fame fifteen years later with their version of the tokomak. The tokomak reactor concept is still in play in the twenty-first century. Kantowitz drifted away and founded the Avco-Everett Research Lab in Everett, Massachusetts, and Jacobs opened a restaurant in Malibu, California.

Although it is far less efficient than the D-T fusion, one does not have to own a tritium source to make it work.[18]



Mark Oliphant's D-T fusion reaction. The free neutron, traveling at very high speed, 14.1 MeV, is a bonus that can be exploited as a neutron generator. The helium-4 is four times heavier than the neutron and is moving more slowly, but together the two kinetic energies of the product particles are 17.6 MeV.

It was a start, but it did not explain where the helium comes from, nor did it explain how heavier elements, which were detected by spectral analysis of larger stars, could be built up by solar fusions.[19]

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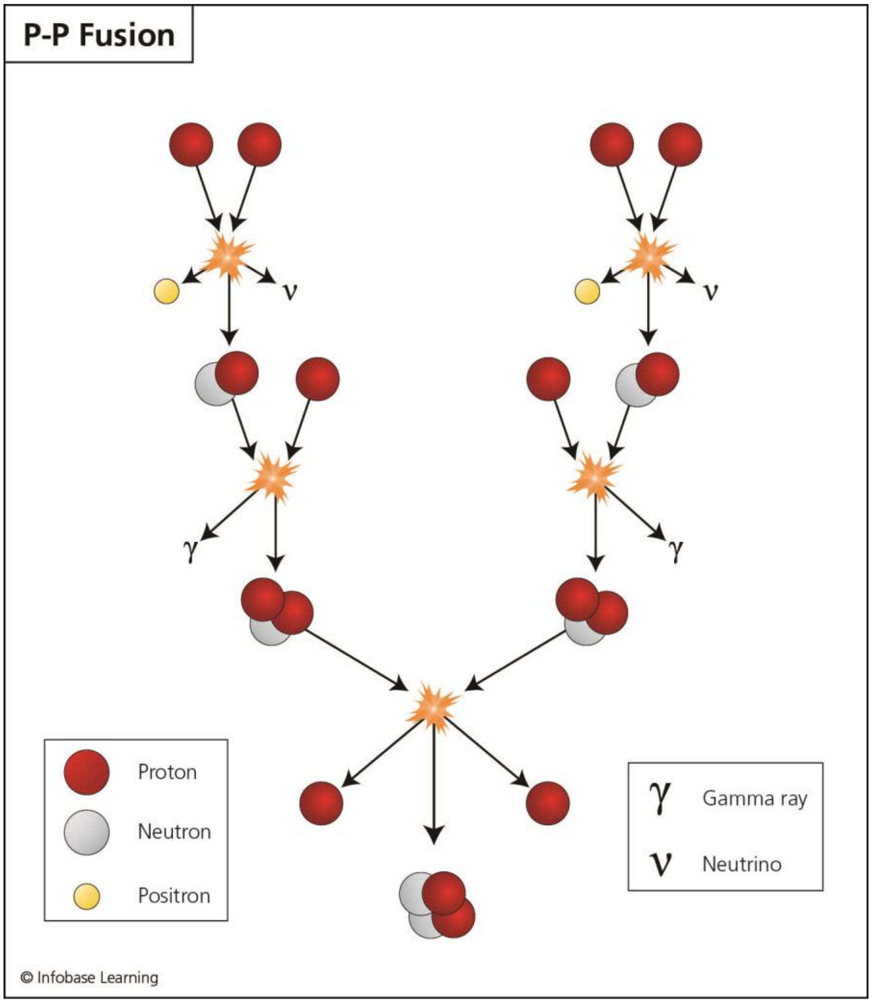
[18] The amateur scientist was encouraged to make his own radioactive sources by bombarding various materials with neutrons generated in his home-built "machine to produce low-energy protons and deuterons." As an after-message, the article encourages the experimenter to stay out of the way of the "x-rays of substantial intensity," shield the apparatus with a double layer of solid, 18-inch thick concrete blocks and boxes of paraffin surrounding the stationary target, wear a dosimeter and a film badge, and keep a Geiger counter turned on. Back in '71, amateur science ran wild and free.

[19] George Gamow, a theoretical physicist who did pioneering work on the Big Bang theory of the creation of the universe, was born in Odessa, Russia, in 1904 and defected from the Soviet Union to a professorship at George Washington University in 1934. He was a major consultant at the Los Alamos National Lab in the 1950s during the H-bomb development. He died of liver failure in Boulder, Colorado, in 1968, probably as a result of processing too much ethanol through the weakened organ. Carl Friedrich von Weizsäcker, German theoretical physicist born in 1912, collaborated on the proton-proton fusion concept. They lost touch as World War II started, and Weizsäcker joined the ultimately unsuccessful German atomic bomb development project. He died at age 94 in Starnberg, Germany, in 2007. His German patent for a nuclear weapon, filed in the summer of 1942, was not granted.



The fusion of simple hydrogen to form helium requires a complicated process that involves five steps. First, two sets of two protons combine to form two deuteriums, just as Gamow had worked out, but then another pair of protons fuse with the deuteriums to form tritiums. The two tritiums crash together and make helium-6 for only an instant, and it blows apart, leaving a helium-4 and the two secondary protons given back into the process. The total energy produced is 26.72 MeV.

It would take as long as the next 30 years to build commercial fusion power stations.[20]

[20] There is some question as to how many of the detected neutrons coming out of a Z-pinch device are actually the result of fusions. The Z-pinch effect was thoroughly studied by British scientists in 1957-58 at the ZETA (Zero Energy Thermonuclear Assembly) experiment in Hangar 7 at Harwell. (Half the hangar, which was quite large, was used to house the capacitor bank.) After initial announcements of success in creating a "sun in a bottle," further tests indicated that most of the detected neutrons were not due to fusion, but were neutrons bounced out of the plasma stream by energetic protons. In the short duration of the lightning bolt, there simply was not enough time to build up a temperature high enough to produce hydrogen fusions.

The fusion reaction with the highest probability (5.0 barns), is the one that Oliphant achieved in 1932, the deuterium-tritium reaction.[21]

The next best, at 1.2 barns, is the proton-boron-11 reaction, and the deuterium-deuterium fusion is down on the list, at a maximum 0.11 barns.[22]

Further work on this topic was continued by another student, Hans Felsinger.[23]

Given the freedom of being solely in charge and with his mind amped up with the post-doctoral buzz, his ideas and research were original and breaking some new ground.[24]

Turn up too much power, and the well-behaved electron stream breaks down into a sudden mini-explosion and blows out the arc.[25]

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[21] The reader is reminded that the probability of a nuclear reaction is expressed as the effective cross-sectional area of the involved nucleon. The bigger something is, the easier it is to hit with a projectile. The unit is a cross section of 1×10^{-24} square centimeters, which, in sub-atomic terms, is "as big as a barn."

[22] Having been given the cross section for the deuterium-tritium fusion reaction, you may expect me to cite a cross section for the proton-proton fusion occurring in the Sun and stars. At this writing, that cross section has yet to be measured. In fact, a proton-proton fusion has not been accomplished in a laboratory setting. A definitive paper that explains this cross section, "Solar Fusion Cross Sections" in *Reviews of Modern Physics*, Oct. 1998, has 36 authors and is 57 pages long. Suffice it to say that this cross section is "terribly small," to quote the principal author, Eric G. Adelberger. If you must have a number, then use 4.5×10^{-24} barns. With a probability that low, one wonders how anything ever gets done in the Universe, and the "Sun in a bottle" concept of fusion is truly impossible. The proton-proton fusion does not scale down, and an Earthbound fusion power reactor will depend on some other reaction mode, such as tritium-deuterium.

[23] Heavy rumors have it that Richter never published his thesis, and his work was found to be erroneous and riddled with "spurious evidence" by Felsinger. I find these allegations hard to believe, but I must admit that Richter himself could not cite his own paper, but he could point to Felsinger's article in *Annalen der Physik* in 1937. If he managed to graduate with no publication and a seriously flawed series of experiments, it was the fault of Reinhold Fürth and the University of Prague and not his.

[24] One of Richter's projects in 1935 was a scanning microscope using electrons, protons, or deuterons looking for fine surface details of a specimen held in a hard vacuum. I have found no confirmation of this claim, but, if true, then Richter's scanning electron microscope (SEM) work beat Manfred von Ardenne's SEM prototype by one year. Richter referred to his setup as an "image-converter activity contrast microscope." The first commercial SEM was built by the Cambridge Scientific Instrument Company thirty years later, in 1965.

[25] At least two popular applications for the carbon arc remained in place through the 1960s: search-lights and motion picture projectors. These two uses for the arc have now disappeared, taken over by xenon lamps. In World War II, carbon arc search-lights were used all over Europe to illumine the bottoms of night bombers and allow the visual aiming of anti-aircraft artillery. The carbon arc was first demonstrated in 1802 by Sir Humphrey Davy.

He, along with every other physicist in the academic world, was well aware of Mark Oliphant's fusion experiment using deuterons hitting tritium.[26]

Tritium was hard to come by, but he bought a vial of Norsk Hydro heavy water and spritzed an aerosol of it into the electrode gap.[27]

A deuterium-deuterium fusion has a lesser cross-section than Oliphant's deuterium-tritium reaction, but it is still a fusion. It worked as planned, and it was an excellent idea.[28]

He was supposed to be working on hydrogen storage systems, but most of his time was consumed investigating ways to measure the temperature in his plasma shock waves.[29]

Sometime in the autumn of 1942, while he was travelling by train to another aircraft factory, the Gestapo arrested him on charges of spying for the British, which probably would have paid better than what he was actually doing.[30]

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[26] Before we leave this subject, Oliphant's experiments were remarkable in that there was no commercial source of deuterium in 1933. He was given a few drops of it by American physical chemist Gilbert N. Lewis, who had expended great effort to separate it from tap water. Oliphant discovered tritium, a byproduct of his particle accelerator experiments, and then used countable atoms of it in his fusion setup. Tritium, an artificial nuclide not occurring in nature, was first manufactured in minute quantities a year later at the Cavendish Lab by Earnest Rutherford and Paul Harteck. Harteck and Johannes Jensen invented the ultracentrifuge isotope separator in 1943, working in the German atomic bomb program. Thousands of these devices are now used by the Iranian government under suspicions of a nefarious agendum.

[27] The year before, in 1934, the Norsk Hydro-Elektrisk plant in Telemark, Norway, began purifying and selling 99.6% pure deuterium oxide taken from water in the Rjukan Waterfall. The plant, built in front of a nitrate fertilizer factory, had a production capacity of 12 metric tons per year. The product came in flame-sealed glass vials. Each vial contained 5 grams of heavy water.

[28] I should say, it was an excellent idea if this really happened. Unfortunately, no dated notebooks from these experiments seem to exist, and we are relying on Richter's written account given to the U S Air Force in 1957 (AFR 190-16, declassified April 26, 1999). If true, it's a grand story, and it is a perfectly logical setup for Richter's post-war work in Argentina.

[29] Remember this sentence when we get to Chapter 3. There is a coincidental cross-linkage here, and a possible missed opportunity by Ronald Richter.

[30] It is interesting to note that at this juncture, August or September 1942, Richter finally reported success in his fusion scheme to measure plasma shock wave performance. This project had been following him from job to job, and the fact that he was working on it in Braunschweig may indicate less than 100 percent performance on assigned tasks. In his unpublished memoir, he claimed to have invented a three-stage lithium-6/neutron reaction cycle to be used in a hydrogen bomb, a neutron bomb, and a gamma-flash bomb at around this time. No mention of these inventions has been discovered in war-time documentation.

"We have a war to win here! Get back to work at Alderhof, or the Gestapo will make an ashtray out of your skull."[31]

Allied bombing raids by this time, 1944, were making life in Berlin extremely unpleasant, and AEG had bigger problems than Ronald Richter.[32]

At the end of World War II, as the world collapsed in debris around Focke-Wulf, he was working on the radical design of a jet-powered, swept-wing fighter plane, the Ta-183 Huckebein.[33]

This and having the lovely, wildly popular Eva "Evita" Duarte Perón on his arm all but guaranteed his election.[34]

He had picked up some work at the French Petroleum Institute, 2 Rue de Lubeck, in Paris, but it was not hard to break the contract and disappear.[35]

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[31] Or something to that effect. The use of lithium and boron in a fusion reactor is not as loopy as it may sound. The Z-Pulsed Power Facility at Sandia National Laboratory in Albuquerque, NM, uses an electromagnetic pulse vaguely similar to Richter's setup to generate X-rays. The purpose of this device is to simulate the X-ray environment generated in a thermonuclear explosion, and it does so by fusing small amounts of deuterium. Seeing a possible application of the "Z Machine" as a pulsed power production reactor, Sandia is considering using lithium and boron fusion to enhance the effect.

[32] This account of Richter's employment history during World War II is based on his detailed, written application to the U S Air Force for a research grant in 1956 (declassified in 1999). Richter probably believed that USAF Air Intelligence had ways to check up on everything he claimed, so this information is probably as correct as can be found. His unpublished memoir, written decades after the war, paints a different picture. According to this document, Richter was heavily involved in the German atomic bomb development program, and he was the only scientist who argued that graphite should have been used as a moderator in the nuclear reactor experiments, instead of the hard-to-produce heavy water. He claims that in 1944 he was called to Adolf Hitler's headquarters in Berlin to state his case for an immediate change in the reactor design, for which he had personally argued with everyone from Walther Bothe (the scientist who declared graphite unusable) to Karl Brandt (Hitler's personal physician). After the war, the Germans blamed a lack of heavy water moderator for their having no success in achieving a working fission reactor, while the Americans enjoyed spectacular success with using graphite instead of heavy water. There is no other evidence to support Richter's claims of involvement in or knowledge of the German atomic bomb research.

[33] *Huckebein*, Kurt Tank's advanced jet fighter, was named for a Nazi-era cartoon character; a trouble-making raven. Think "Woody Woodpecker" in German.

[34] Eva was the best thing that ever happened to Perón. A former actress of questionable reputation, she moved into Juan's house in the Polermo Chico neighborhood after kicking his 14-year-old futon-mate, known only by her pet name, "Piranha," to the curb. They were married in a civil ceremony on October 18, 1945, followed by a flashy, very public church wedding on December 9.

[35] Richter had been striving furiously for a transfer to the United States as a nuclear physics asset, exchanging letters with a Colonel Peters in the USAF, but he was having trouble starting a fire under the Americans. The offer from Argentina was urgent and solid, and Richter had to abandon his shot at America for the time being.

The group then travelled by train to Rome through Milan and Genoa, eventually meeting Ivo Omrcanin, a former Ustasha official who spoke flawless German and knew Krunoslav Dragonovic, a Croation war-criminal/priest with solid Vatican connections and headquarters in the pontifical College of San Girolamo degli Illirici.[36]

The plane rolled to a final stop on August 17, 1948, and the weary travelers were met at the airport by Nazi-spy/ glad-hander August Siebrecht, welcoming them to Argentina.[37]

He gave Richter the corner of a building at the aircraft factory in Córdoba, an open budget, and a salary of $1,250 (US) per month.[38]

Obviously, the blob of plasma would have to be suspended in midair.[39]

Still, Richter seemed strangely fearful of espionage and technical interference.[40]

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[36] The Utasha was the Nazi-controlled puppet government in war-occupied Croatia, famous for efficiently cleansing the country of Serbs, Gypsies, and some 30,000 Jews. There remains much mystery and controversy as to what happened to the Utasha treasury, believed to have been $80 million in gold confiscated from murdered Serbs, Gypsies, and Jews, transferred to the Vatican for safekeeping after the war. Vatican authorities deny any connection.

[37] I have found no indication of how Richter's wife, Ilse, joined him in Argentina. She may have had no travel restrictions and simply waited until he sent her travel money from Argentina and flew down on a commercial flight. Richter could not speak a word of Spanish, the official language of Argentina, but Ilse spoke several languages, and she often acted as his interpreter.

[38] In 1948, that was a movie-star salary.

[39] Due to extreme secrecy, Richter's scheme for isolating the plasma from nearby solids is not clearly known, but a letter he wrote to the editor of *Scientific American* (unpublished) contains a clue. In his brief period of activity in Córdoba, he investigated ball lightning, a rare atmospheric electrical phenomenon that causes a glowing sphere to float in the air for several seconds, then disappear, often with an explosion. There are some excellent theories, but the nature of ball lightning remains unknown at this time. Richter could have spent the rest of his life trying to figure out ball lightning, and considering its use in a fusion reactor is an impossibly long stretch. A 10-minute film of one of Richter's over-driven arcs, erupting violently between two cross-pole electrodes, separated by about 10 centimeters of air, and reigniting several times, was made in the Cordoba laboratory. Unfortunately, the film is considered lost.

[40] Richter and Ehrenberg had killed time together in von Ardenne's lab back in 1943. They tried bombarding mercury fulminate, the highly explosive chemical used in cartridge primers, with protons rapidly exiting von Ardenne's Van de Graaff particle accelerator. One asks, "Why?"

After scouting over the desert landscapes, which did not appeal to the demanding and autocratic semi-German, as they were running out of places to look, Richter gazed down at the freezing waters of Lake Nahel Huapi in a majestic landscape near the Chilean border.[41]

Here, on the secluded place a half mile from the shoreline, Huemul Island, he would establish his atomic laboratory and build the world's first fusion power reactor, and his headquarters would be in Bariloche.[42]

He hoped to further devise a way to achieve a self-sustaining fusion process, in which the energy produced by a momentary start-up would create enough temperature and pressure to keep the fusion process going as long as it was fed with lithium and hydrogen.[43]

Finding a "resonance" on this curve means that there is a sudden, upward jump, or a large blip, that makes the probability of interaction very favorable at the energy associated with the resonance.[44]

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[41] I have found out a great deal about Ronald Richter and his fusion experiments, but there is simply not room in this chapter to reveal all. As a demonstration of the depth of my research, I propose the following Trivial Pursuit question: German scientist Dr. Ronald Richter built a nuclear fusion laboratory and reactor in Argentina in 1950. What was the name of Richter's beloved Siamese cat? Answer: Epsilon.

[42] The place-name *Huemul* is said to mean "antelope" in a few references, but in researching this topic I found it not to be true. When laborers were clearing the right-of-way for a trail to the first plateau on the island in 1949, they found a wooden box containing human remains and marked "Chief Huenul 1902." Huenul, later changed to Guenul, was a Chilean fruit-grower who had lived on the island with his family since the 1880s. His canoe, also marked with his name, was found later at the bottom of the lake, and it now rests in the *Parques Nationales.* Huemul is a misspelling of the name Huenul.

[43] What we know about Richter's work comes from a long paper written by Wolfgang Ehrenberg and published eight years later, "Problems and Possibilities in Nuclear Fusion." Dr. José Antonio Balseiro's report to President Perón on September 15, 1952, concerning Richter's experiments, completes the picture. The only scientific result to be published in connection with the Huemul project was a paper concerning the use of fractional distillation for heavy water enrichment, written by Ehrenberg and Jaffke. It was published in 1953 in an obscure German magazine, "Z. angew. Physik 5." Richter's later reminiscences dwell on political impediments and instances of sabotage and offer very little to describe his experimental setup.

[44] Resonances are common in nuclear cross sections. One of the first found is on the very low-energy scale of the uranium-235 fission cross section curve, indicating that there is a huge probability of fission at room temperature. Otherwise, the curve gradually increases up into the MeV range (thousands of KeV). This resonance makes light-water fission reactors possible.

To achieve this effect, a static magnetic field of specific strength had to be established through the electric arc, with a continuous short-wave radio signal of specific frequency bearing down on it.[45]

It took about half an hour to charge the capacitor bank, using a kenotron rectifier and a big, high-voltage transformer.[46]

The gap and magnet were surrounded by a heavy shielding of lead and concrete.[47]

The magnetic field surrounding the gap was monitored using two crossed coils of wire, with each connected to a Tektronix 511 oscilloscope.[48]

The scaler connected to the Geiger-Müller counter recorded, indirectly, the total number of fusions.[49]

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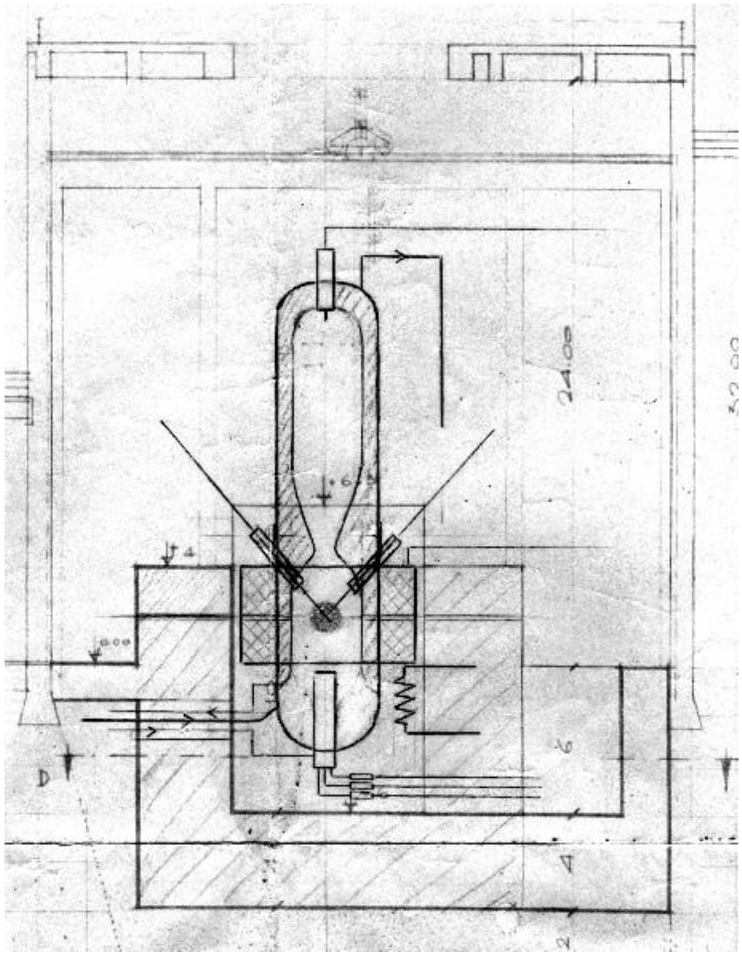
[45] If you have ever been subjected to an MRI scan in a hospital, then the hydrogen atoms in your body have experienced Larmor precession, the existence of which was predicted by the Irish physicist Joseph Larmor. The presence of the wobbling is detectable by perturbations in the radio-frequency radiation used to cause it, and the frequency required to make the atoms precess is dependent on the value of the magnetic field. The MRI, Magnetic Resonance Imaging, machine used for medical diagnostics scans through your body in a straight line, detecting the concentration of hydrogen at places along the line, then rotates the angle of the magnetic field and takes another scan. After having taken many scans through different angles, an image of the cross section of your body can be constructed using a tomographic algorithm. The magnetic field intensity varies with the depth of the scan, so the hydrogen detection can be mapped into a depth measurement by noting the radio frequency at which the hydrogen concentration is detected.

[46] Richter’s kenotron was almost surely a General Electric KR-3. It was a long, glass thermionic diode tube with a bulge in the center and a Bakelite base at both ends, commonly used to make DC current in X-ray machines. At the time, it cost a budget-tweaking $248.

[47] Richter claimed that the shielding of the gap was to protect the research staff from X-rays. There was no way, however, for an electrode gap operating at atmospheric pressure to produce X-rays, regardless of the voltage used to ionize the air. The only way to accelerate electrically charged particles to a speed that will produce X-rays is to do it in a hard vacuum. Oddly, the circular, 12-foot-thick wall surrounding the reactor in the building that he had torn down was not a radiation shield. It was to protect personnel and sensitive equipment from destruction due to ultrasonic sound developed by the spark gap.

[48] The 65-pound Tektronix 511 DC-coupled oscilloscope cost $795.00 f.o.b Portland, Oregon. That is the equivalent of about $10,000 in 2014 money. Richter ordered an even dozen of them. He cried sabotage when they were delivered to the Buenos Aires Physics Institute by mistake.

[49] There were no gamma rays produced by the fusions. There were only alpha particles (heliums) generated, and an alpha particle in air has a range of about one centimeter, preventing it from reaching any kind of remote radiation detector. Richter was counting on *bremstralung*, “braking radiation,” caused when the alphas slammed into the air, to register on his gamma-sensitive Geiger counters.



Richter's diagram of his large fusion reactor. The reactor pressure vessel was 18 meters high, with an outer diameter of 4 meters and a wall thickness of 60 centimeters. A magnet coil was wound around the bottom end of the vertical reactor, with two high-voltage "cross-pole" electrodes in the center of the magnetic field. Gases to be fused were injected at the bottom. How he planned to extract the energy and make use of it is unknown.

He interpreted this as a sudden increase in the speeds of the light-scattering plasma particles in the arc, throwing off the spectral line by the Doppler effect, and indicating a temperature which the arc was incapable of producing without excess fusions.[50]

[50] The "halo" effect did not indicate high temperature. It indicated that the spectroscope was shaken so hard by the arc explosion, it caused the beam of light to orbit around until the floor stopped vibrating. The fact that Richter and Jaffke interpreted this as spectral broadening indicates a high level of delusion. They were seeing what they desperately wanted to see.

Perón was advised of the success, and he scheduled a press conference for March 24, 1951, to make a triumphant announcement to the world.[51]

They witnessed a demonstration of the fusion reaction, the photo darkroom, and Richter's desk.[52]

He and everyone examining his methods missed the fact that when he shot a strong electric field across the electrode gap, he was establishing a powerful magnetic field around it, collapsing the plasma into a thin line and causing hot-fusion for a very short time.[53]

[51] At this same time, Perón was taking care of a problem that Richter had produced. The new garrison commander, Colonel Fox, decided to make an inspection tour of Huemul Island, apparently unaware of Richter's banning of any visitors. Richter met him as the boat docked, held a pistol on him, and backed him off the end of the pier and into the cold Lake Nahuel Huapi. The only way *El Presidente* could keep the army from executing Richter was to assign him presidential powers, which was probably unconstitutional.

[52] At the first BANG of the reactor, the 20 congressmen dived for cover. Seeing precious lithium poured out on the floor under the electrode gap, a technician, Bertolo, hastened to suck it up with a vacuum cleaner. The highly corrosive lithium compound quickly dissolved the insides of the vacuum, the motor shorted out, and it exploded. This time, the team of five investigators jumped for shelter.

[53] I cannot back this up with any written material, but in the mid-seventies I absorbed rumors from Savannah River that the AEC was working on a pulsed neutron generator for nuclear weapon triggers that would replace the deuteron-triton accelerators in use at that time. The nagging problem of the D-T reaction was that the T, the tritium, had a 12-year half-life, and that affected the shelf-life of the bombs. They were working on a small, hollow globe made of gold with a two-electrode spark gap at the center. It was filled with deuterium, and when set off with a "Richter-pulse," it would make a shower of neutrons by fusing a small percentage of the resulting deuterium plasma. Perhaps it was true.

Chapter 2
AFP-67 in the Dawson Forest

The result was a quick, decisive lunge by the president, ultimately resulting in a painful percentage of the national budget being drained away with nothing to show for it.[54]

Teller's first meeting with President Reagan was 2:00 PM on Friday, January 8, 1982, in the Roosevelt Room, with the High Frontier group sitting around a large mahogany conference table.[55]

Still a ball of fire, he limped with his prosthetic foot, spoke with a distinct Hungarian drawl, and flashed his untamed gray eyebrows.[56]

This makes an extraordinarily thin column of energy, and to make it mean enough to destroy a missile, hundreds or even thousands of the tiny, delicate rods are bundled together.[57]

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[54] Richter was also a nut-case. In support of this assertion, I submit his written statement to the U S Air Force in 1956, in which he claimed that in his hydrogen fusion experiments in Argentina he encountered an inexplicable energy pulse. He attributed this measurement to an exciting encounter with "zero-point energy." The quantum vacuum zero-point energy, as predicted by Albert Einstein and Otto Stern in 1913, is the reason why helium-3 doesn't freeze at absolute zero temperature and is the lowest possible energy that anything can have. The concept has, so far, been a good plot device for science fiction writings and a dreaming point for theorists, but only Richter has been crazy enough to claim in writing to have seen it in an unrelated experiment.

[55] This meeting was classified SECRET, and was not recorded on the President's official schedule. Some participants do not remember Teller being in the meeting, but Karl R. Bendetsen, captain of the anti-missile group, assures that he was. Bendetsen, who was very successful in private life and a member of the Bohemian Club of San Francisco, was the Army colonel who directed the internment of 110,000 people of Japanese origin during World War II.

[56] In 1928 Teller was enrolled at the University of Munich, Germany, to study physics under Arnold Sommerfeld, and on July 14 he was on summer break and was heading to the mountains to go hiking with some friends. On a three-car tram heading for the train station, he was loaded down with a heavy pack, and he was daydreaming. He realized as the tram was pulling out that he hadn't noticed that it had stopped at the station, and he lunged for the door. Falling on his face on the pavement as the tram gathered speed, he rolled over to look back, seeing a loose hiking boot lying by the steel track. His foot was in it.

[57] A feature of the x-ray laser that is rarely mentioned is that it shoots out two destructive x-ray beams, one out the front of the rod-bundle and one out the back. The front beam takes out the enemy bomb-vehicle, but the back beam wipes out the gimbal aiming-mount that has pointed it in the right direction. This is of no concern, as you will find out presently.

This difficult task is accomplished by mixing the selenium in a high-tech foam made from, believe it or not, sea weed, making the weapon bio-degradable.[58]

Hagelstein, a reclusive, shy young man, worked himself to exhaustion developing the idea, doing a lot of computer simulation on the laboratory's super-computer cluster.[59]

There would not be a second chance. Each EXCALIBUR vehicle would aim as many as 10 rods at different missiles before the H-bomb went off.[60]

The Soviet government had to throw money at its own x-ray laser project, without a lot of Teller-driven enthusiasm, but mainly they decided to upgrade their largest and most effective military asset, the Soviet ground army, with a dazzling array of new, expensive, high-tech tools and weapons.[61]

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[58] The foam is SEAgel (Safe Emulsion Agar gel) made of agar derived from kelp and red algae. After mixing with the selenium powder, the gel is freeze dried to remove the water content, and the result is a foam that is technically lighter than air. (This is true only in the vacuum of space or a test chamber, in which the air has been removed from the micro-voids in the gel.) This material is perfect for spacing the selenium particles, because it almost isn't there. It poses a minimum impediment to develop an intense x-ray signal in the laser rod.

[59] In 1986, seeing that the x-ray laser program had descended to crisis mode, Hagelstein resigned from the O Group, left the Lawrence-Livermore Laboratory, and joined the faculty at MIT in the Electrical Engineering and Computer Science Department. Teller was not pleased. He was, in fact, enraged. Falling back on his previous experiences with traitors, he accused Hagelstein of letting Hitler and the Nazis get the upper hand, and finished by leveling the most cutting damnation he could think of: He accused Hagelstein of being a pharmacist.

[60] As questions concerning the effectiveness of the EXCALIBUR weapon and its deployment strategies grew, Teller inflated the number of laser rods per vehicle, first to 100, then 1,000, and as high as 100,000 independently aimable devices surrounding one H-bomb x-ray source. The geometry of such a cluster of gimbal-mounted lasers, each getting a full x-ray broadside, boggles the mind.

[61] In the 1990s, I was a member of a team that analyzed, evaluated, and tested many of these foreign devices and systems. This work was classified SECRET and TOP SECRET. It's a pity, but I have not obtained permission to reveal what we were working on. I will go as far as to say that I was made cautious to learn that all but one member of the team that had developed one of these devices had died working on it. Yikes. What had killed them? An uncontrolled pulse of radioactivity? An explosion? The remaining scientist was interrogated, and the answer was startling. In celebration of a successful test, they drank the coolant and died of liver failure. The extremely poisonous liquid (ethylene phosphate) unfortunately smelled exactly like vodka with a hint of berry-flavor. The survivor was a recovering alcoholic who did not join the toast, and he lived to tell the tale.

After a brief test schedule to prove the now obsolete circulating-fuel concept, the molten-salt Aircraft Reactor Experiment back at Oak Ridge was cancelled and buried in secret classification.[62]

Nobody was killed, but the experiment raised more questions than it answered about flying a reactor in an airplane. A lot more systems and materials testing would be needed.[63]

Its mission would be to cruise outside the Soviet Union at subsonic speed and then dash inland in a supersonic rush to make craters at predetermined spots.[64]

[62] The Aircraft Reactor Experiment (ARE), with its lavish instrumentation displayed on an entire wall full of pen-chart recorders, cost millions of dollars to build, but it only ran for nine days. First criticality was achieved at low power at 4:45 in the afternoon of November 3, 1954. It ran perfectly at full power (2.5 megawatts), demonstrating that the molten salt idea was golden. Colonel Clyde P. Gassen, Chief of the Nuclear Powered Aircraft branch of the Wright Air Development Center in Dayton, Ohio, ceremoniously palmed the red SCRAM button at 7:04 PM on November 12, shutting down the reactor and the project. The molten salt fuel concept has resurfaced as a possible design for the advanced Generation IV commercial power reactors.

[63] Meanwhile, the Navy impaled itself on its own, independent nuclear airplane development program, code-named the “Princess Project.” They already had the airframe picked out. It was a four-stories-tall behemoth of a seaplane, the Saunders-Roe SR.45 Princess, built in East Cowes, Isle of Wight, UK. It was over 55 feet high and weighed 190,000 pounds before the nuclear reactors were installed. The engines were to be Pratt & Whitney closed-loop, liquid-metal cooled reactors, a design dropped by the Air Force for weight and complexity issues. The Navy was spared by the Department of Defense, which shut the project down before an SR.45 had been purchased. There was no apparent purpose for such an aircraft other than to show the Air Force how it is done.

[64] At this point in 1954, the Aircraft Nuclear Propulsion effort was technically dead. The X-39 engine was two GE J-47 jets using a common nuclear reactor core as the heat-source. It weighed a lot more than two conventional, jet-fuel-burning J-47s, but the lack of thousands of pounds of gasoline to run them made up for it. An X-39 was almost as powerful as a pair of normal J-47s, but it took four J-47s plus six P&W “Major Wasp” R-4360-53 engines (2.83 megawatts each) just to get a B-36 off the ground and eventually accelerate it to 230 miles per hour. The goal of a supersonic nuclear bomber was outside reality, but bear in mind the hidden agendum of spoofing the Soviets, and it begins to make sense.

In the late 1930s, Roscoe Tucker of Dawson County had begun buying up small farms in the Dawson Forest, and by 1950 he had a rectangular tract consisting of some cleared fields, woodlots, the confluence of two rivers and a creek, and a dozen carelessly concealed, taxation-avoiding cottage industries producing ethanol.[65]

Native Cherokees were persuaded by bayonet point and bribes of pure Georgia gold to relocate to a reservation laid out in Oklahoma, and it was a hard, tragic walk to get there.[66]

Up until about 1903, pits, mines, and ditches were dug and hills were dissolved using high-pressure water, altering the landscape and keeping the deer away.[67]

Families gathered to pray, and churches enjoyed unusual attendance with people anticipating and fearing the End Times.[68]

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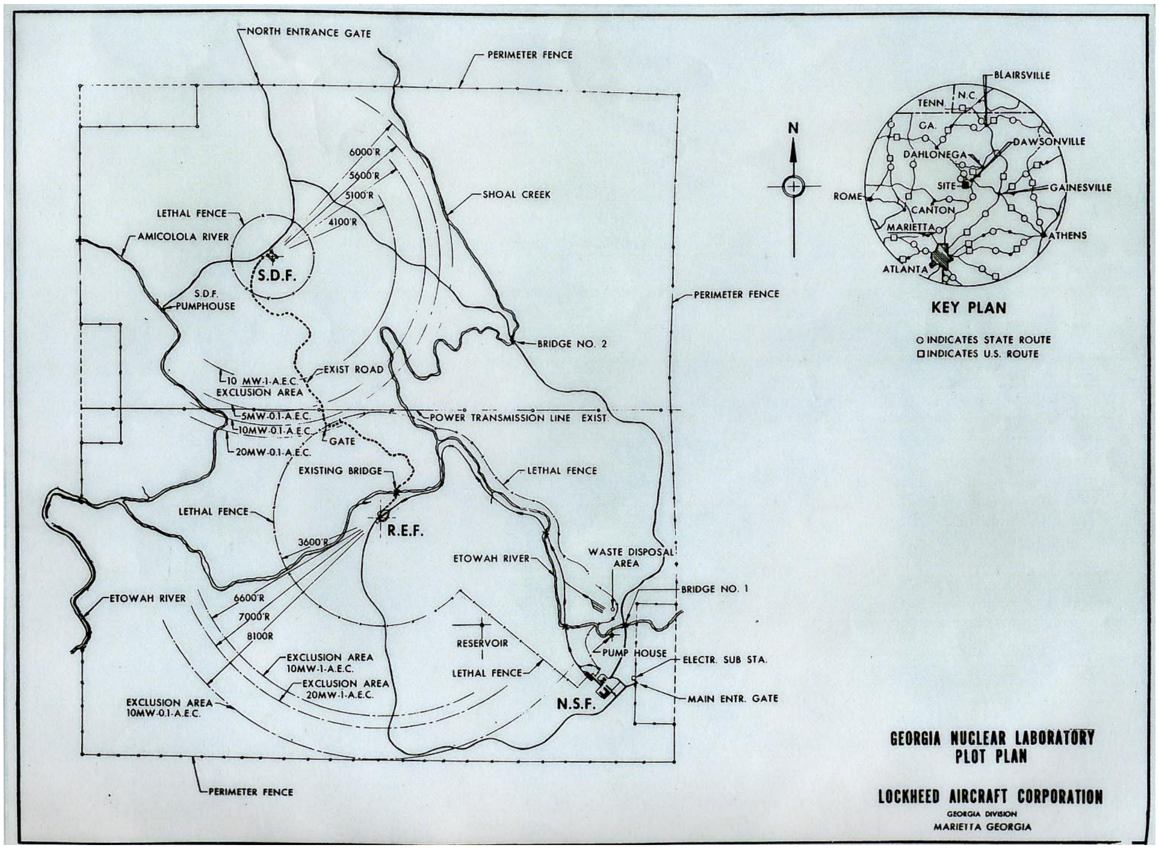
[65] In 2008 I participated in an attempt by Georgia Public Broadcasting to film a documentary about the Georgia Nuclear Aircraft Laboratory. We tromped all over the 10,000-acre site, filming me standing in front of ruins and explaining what they had once been. The producer had done her homework, and had found a former moonshiner who knew a lot of unwritten history of the place. I was surprised to learn from him that illegal micro-distilleries had been active on the property as late as 1977! I had been assured by old timers who had worked at the laboratory that all the moonshiners had been cleared out by the Corps of Engineers as they bulldozed everything to the ground and cleared the land for construction. They had not. The morning after we finished filming, the producer was fired in a budget crisis after nearly 30 years working for GPB, and her film project was never completed.

[66] There were no heavily wooded mountains and no gold to be mined in Oklahoma. Cherokees from Georgia who had become skilled in the gold-mongering art left the reservation and trekked to California with the rest of Dahlonega after gold was discovered in the Sierra Nevada Mountains in 1849. The gold-mining town of Cherokee, California, was named for them. Their skills would drive many mining operations, and the Cherokees moved on to Colorado and eventually to the Klondike, chasing the yellow metal and impressing the amateurs.

[67] When we were working on the GNAL documentary in Dawson Forest, we stumbled across an old gold mine. At first, all I could see was a heap of dirt, heavily invested in pine trees and brambles. We were a few hundred feet off the road, and the woods were dense and undisturbed. Behind the heap, which turned out to be a pile of mine tailings, was a neatly cut entrance into a tunnel, completely hidden unless you were right on top of it. Unfortunately, we had left the lights back in the truck, and all we had was a flashlight. Venturing into the tunnel, it looked almost as if it had been dug yesterday. You could still see tool marks on the walls and veins of sparkly quartz. The only inhabitant was a mouse, who gave us a "and who are you?" look. Our local guide piped up and said that it was an exploratory tunnel dug by the Kin Mori Mining Company back in the day. We could stand up in it, and it had a hard-packed, flat floor.

[68] Some people knew just enough about what was going on to speculate that an enormous nuclear reactor was in the middle of the property, and it had gone out of control and would kill everyone soon with radiation. Reality is much tamer. Many acres of pine and oak trees had been bulldozed down and gathered into a mountainous pile on a hill at the center of the lot. It was set afire and allowed to burn down for several days, sending up a column of smoke that would be illumined by the fire from below at night. It looked as if the entire sky was aflame. To just burn it was easier and faster than trying to get security clearances for an army of loggers and pulp-wood truck drivers.

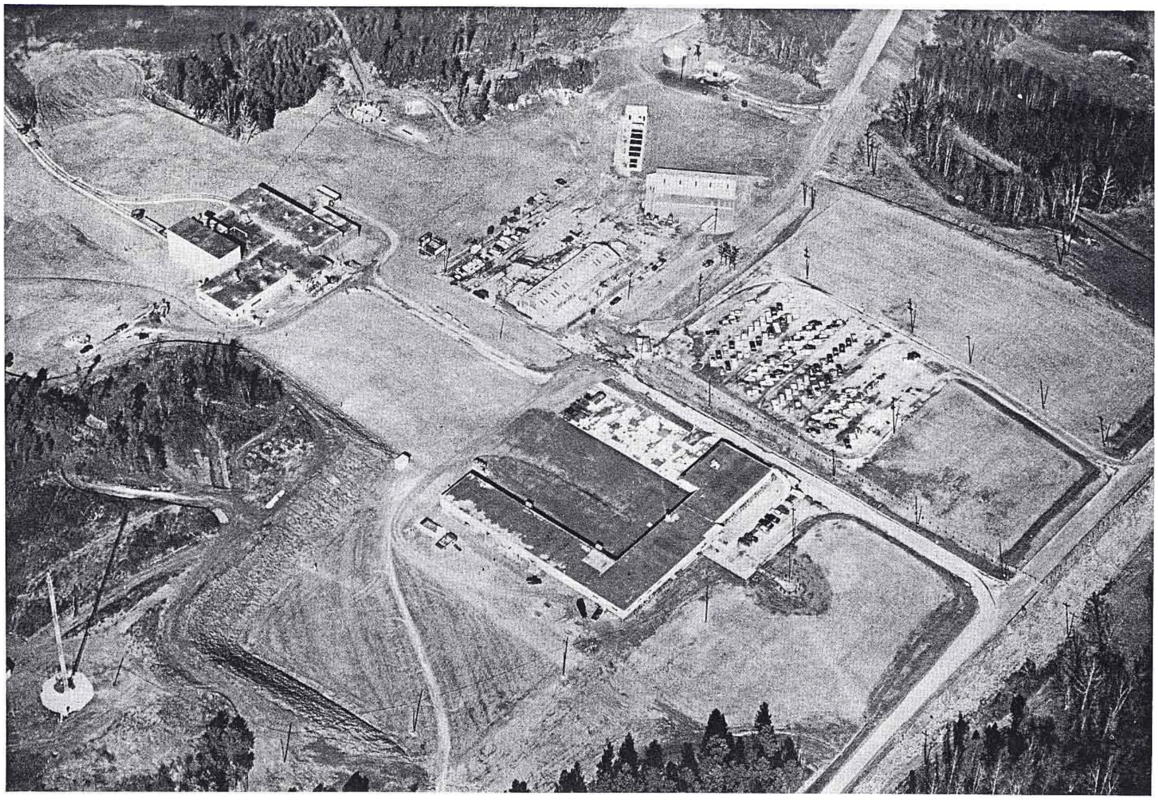
A similar barrier, the “Lethal Fence,” was built surrounding the materials test reactor in a circle 3,600 feet in radius.[69]



A map of the Georgia Nuclear Aircraft laboratory. N.S.F. (Nuclear Support Facility) is the administration and laboratories building, R.E.F (Radiation Effects Facility) is the main, 10-megawatt test reactor, and S.D.F. (Shield Development Facility) is the reactor hung in the air. It was purchased but was never installed.

[69] Using Google Earth, go to lat-long coordinates 34°21’56.64”N, 84°10’05.64” with an eye altitude of 10,698 feet. Look closely, and you can see a perfect circle etched into the heavy forest cover. That is the right-of-way for the Lethal Fence, still there. At the center of the circle there is a bare spot on the ground. Zoom in and look east. You can see a rectangular bright spot. That is the above-ground portal to the buried reactor control room. It’s a concrete cube, with the doorway blocked off to keep curious people from falling down the elevator shaft to the basement floor, 30 feet down. Just beyond it, to the east, is the foundation for the REF reactor building, completely overgrown with trees. A borated-concrete emergency shadow-shield, to be used if a worker were caught in the open when the reactor started up, has been appropriated by graffiti artists.

They reduced the building budget from $28.7 million to $13.6 million, and an entire wing and the second floor were left off, although the slab had already been poured.[70]



An aerial view of the GNAL. The administration building is in the foreground, and in the lower-left corner is the meteorological tower. In the top-left quadrant is the Radiation Effects Laboratory, consisting of the hot cells and the machine shops. At the top is the water works.

A stone's toss north of the warehouse loading platform was the water works, having seven rectangular purifying basins in a heavy concrete structure[71]

[70] The slab under the administration building, or "Nuclear Support Laboratory," is still there, and it is used as a parking lot for visitors with large horse trailers. See it on Google Earth at 34°21'00.34"N, 84°08'32.43"W, and eye-altitude 1,479 feet.

[71] The concrete warehouse floor and loading dock are still there, visible on Google Earth at 34°21'04.61"N, 84°08'31.06"W, at eye-altitude 1,086 feet. The water works are still there, but are hidden by foliage. At the north-east limits of the cleared area was an odd structure. It looked like Stonehenge, with a central spot and monoliths in a circle around it. I've never found the site remains or mention of it in the collected documents.

The tracks approached from the reactor area from the north and split at a switch, heading into the block-house doors or into the huge machine shop connected to the west side of the building.[72]

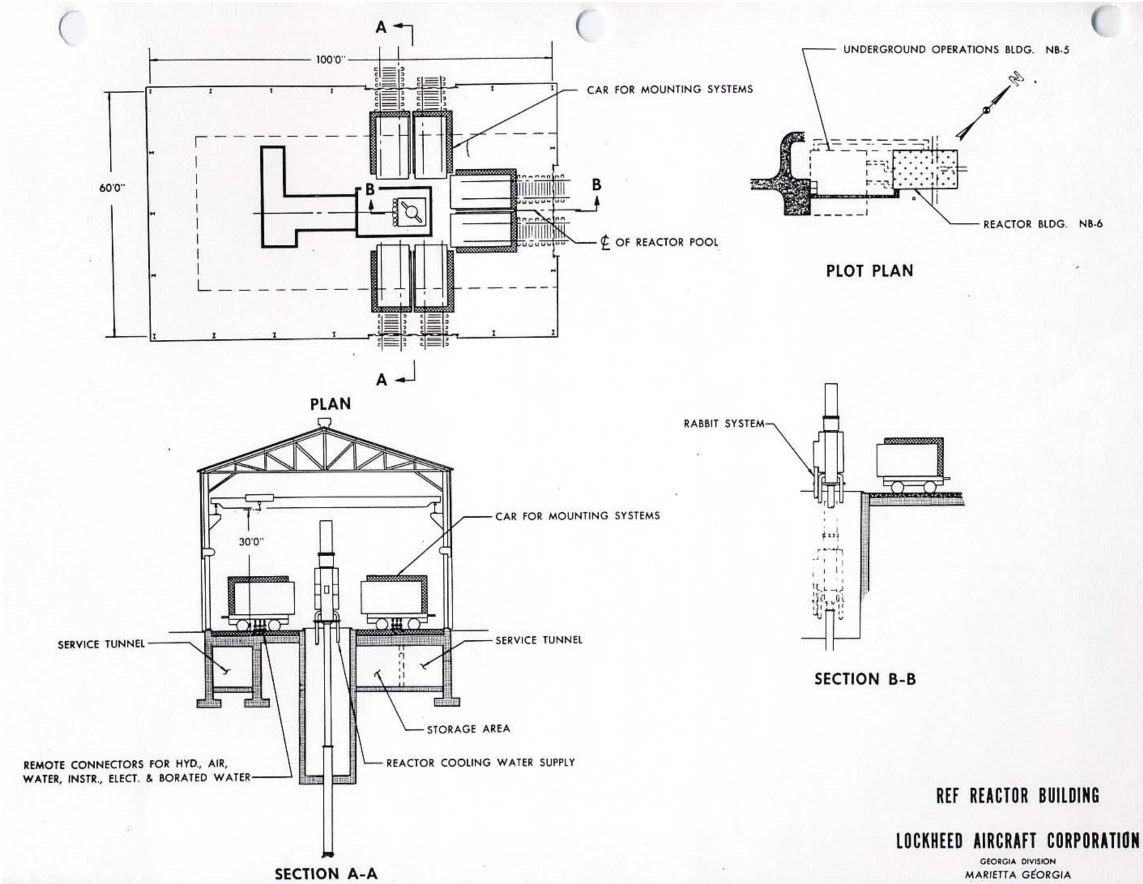
Each manipulator was a mechanical hand, wrist, and swinging arm that would precisely mimic an operator's every motion as he or she held the external control-sticks. Test objects, activated to high radiation levels by reactor exposure, could be examined, dismantled, measured, photographed, and evaluated still sitting on a flat-car rolled into the "hot work area." [73]

It was blocked by a concrete shadow-shield on the east side, facing the reactor building.[74]

[72] The rectangular blockhouse of the Radiation Effects Laboratory (REL) is visible from the satellite on Google Earth. 34°21'03.11"N, 84°08'37.79'W. Zoom in to eye altitude 1,298 feet. You can see a hole punched in the roof by "grave robbers," reminiscent of the Arabic adventurers who first penetrated the Great Pyramid at Gaza. The very large blower room is still attached on the south side, and the loading dock is almost intact. You can walk on the floor of the machine shop, but it is hidden from view by foliage. Penetrations on the east face of the buildings have been blocked off with steel plugs. These were for the viewing ports and the remote manipulators.

[73] The windows were not four-feet-thick blocks of solid glass, but were two thick panes of lead-glass with a manganese salt solution between them. Everything through the glass had a yellow tinge. Working on an object in the hot cell, behind the glass, was like taking apart a cuckoo clock with five-feet-long tools looking through a very large aquarium.

[74] The holding-tank shadow-shield, the cooling tower foundation, the make-up and main water tank foundations, and the control-room air conditioning condenser base are all still there on the grounds, but none are visible from the air. It's best to find them on foot in the winter, when the foliage is thin and the snakes are sleeping. Radioactively contaminated water in the holding-tank was drained into a rock-lined "seepage pond" and just allowed to evaporate and soak into the ground. That was an accepted way to get rid of contaminated water back in the day, but you certainly could not do that now.



Plan and elevation views of the 10-megawatt Radiation Effects Facility reactor.

The radiation pattern could be aimed using electrically controlled water tanks surrounding the core, and it was usually pointed north-east, away from the control-room parking lot but directly into rail cars on the far end of the building.[75]

Experiments in fuel and moderator configurations could be conducted using the staging reactor at the bottom of a pool of water without the danger of radiation from accumulated fission products or neutron activation of surrounding structures, because this reactor ran at near zero power.[76]

Buried thirty feet south-west of the reactor building was the operations building. Being outside in the vicinity of the reactor while it was running would be fatal, but all was safe in the concrete building with the top-floor roof buried under five feet of earth. To enter the building, you had to park in a small lot off the road to the left and down the hill. Inside the arched concrete entrance you would select a scooter, then drive down the 660-foot, lighted tunnel.[77]

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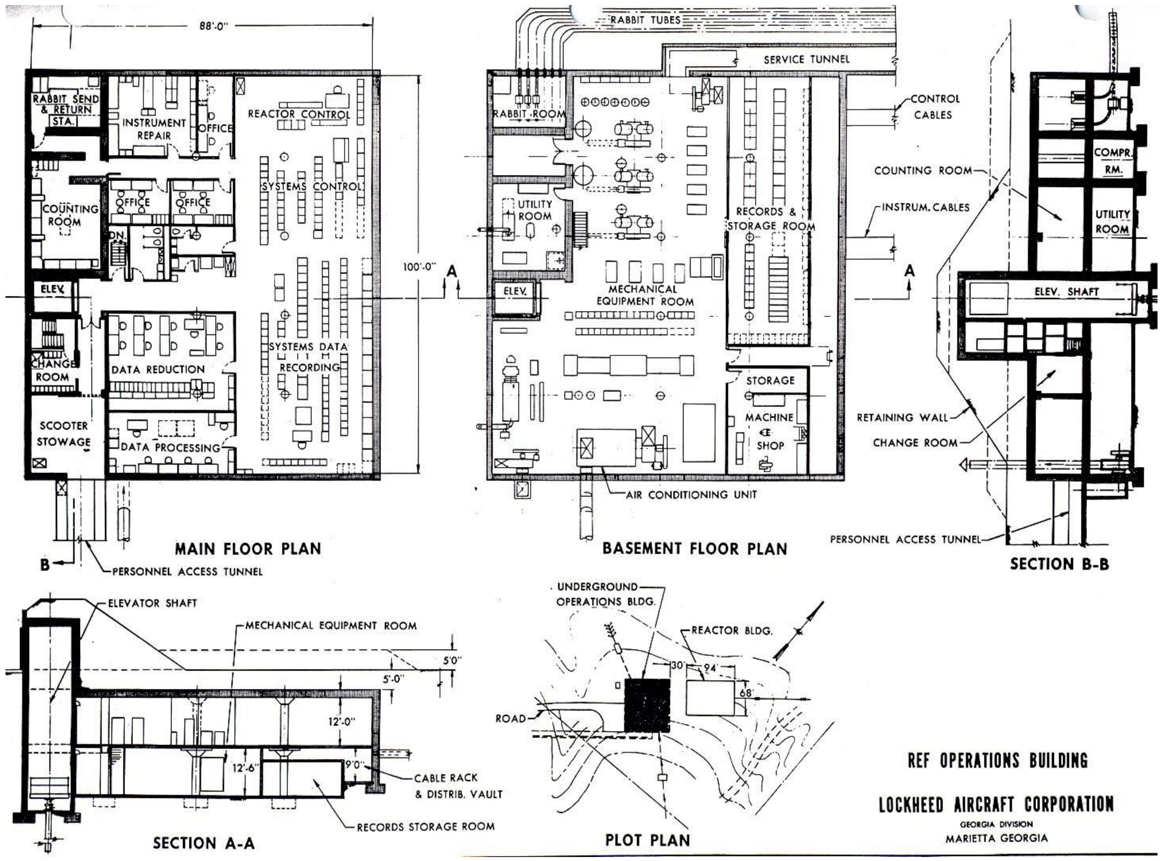
[75] At one point an unusual radiation pattern was required, and the only way to configure the reactor was to have someone work on it directly and up close. Unfortunately, the reactor had already been run at full power for days at a time, and the fuel was blazing hot with fission-product radiation. No human being would be able to stand near it, raised out of the shaft, ever again. This eventuality had not been considered in the facility design. The man who was most familiar with the aiming mechanism and who knew how to reconfigure it was Mel Dewar, and he volunteered to go in on a flat car behind a pile of lead bricks and quickly apply a screw driver to the mechanism. I have not run across his dosimeter record, but I would guess that he absorbed his allowed dose for multiple years in the minutes he spent working on the aiming problem.

[76] The CEF building foundation is still there, complete with its 15-feet deep reactor pool. From satellite-view it looks like a patch of plant growth in a bare spot, just off the main road that passes by what was the front gate of the GNAL and winds down to the REF reactor site, at 34°20’50.30”N, 84°08’50.34”W, with an eye altitude of 1,116 feet. The pool is filled in with debris and dirt, and acts as a water-retaining planter in which a lot of plant-life is thriving.

[77] Entering the reactor control complex, which was a most secret place, you did not have to open or close any doors. There was no code to be entered into a locking mechanism or even a door to keep in the air conditioning or the heat. It was an open, unrestricted tunnel. This was a standard way to build an underground control room, and I’ve been in the similar facility in Idaho. The tunnel was so long, there was no weather passing though the portal, and the security check was up the road at the gate through the Lethal Fence. The Park Service now tries to keep the entrance blocked with a covering of dirt, but many adventurers have been able to dig through it and make their ways to the buried control building. You have to use an inflatable raft to see the upper floor, as it is always under water. Just about everything is stripped out, but there are still equipment racks and electrical parts bolted to walls.



Plans and elevations of the buried control room for the REF reactor.

The first aircraft system to be tested was an AN/ARC-34 ultra-high frequency radio transceiver to be used for plane-to-plane communications in the nuclear bombers.[78]

Imagine, if you will, a dead, thoroughly irradiated mule that will not degrade normally over time.[79]

[78] The ARC-34, "Little Eva," had been around since 1952, and it was not exactly state-of-the-art equipment, as had been promised for everything in the advanced aircraft. It did, however, use vacuum tubes, which did not seem affected by high radiation. Semiconductor transistors and diodes suffered miserable deaths when subjected to the kind of radiation that would be present in the nuclear bomber. The Soviets were aware of such findings when they orbited the first Earth satellite, Sputnik, in 1957, into the unknown radiation-environment of outer space. The radio transmitter in Sputnik ran on dry-cell batteries and vacuum tubes.

[79] References mentioning any accident at the GNAL have not been discovered. There is a tale once told by a retired nurse who worked at a clinic in a nearby town. A sick young man was brought to the clinic by some very concerned personnel from the GNAL. He had symptoms suggesting acute radiation poisoning, and he died at the clinic in a few days. The implication is that a curious civilian defeated the Lethal Fence and approached the reactor building during a high-power run, which would have produced the observed symptoms and death. The clinic and its records are long gone.

Either option is a financial sink-hole.[80]

In 1963, Dr. Werner von Braun from the George C. Marshall Space Flight Center at the Redstone Arsenal in Alabama visited the laboratory site, personally examining the setup for nuclear rocket component testing.[81]

By September 1965, GNL was processing 6,000 board-feet of Lockwood per month, and it was being used in products from cigarette-burn-proof table tops to bows and arrows.[82] The 10-megawatt reactor, still operating under AEC license R-86, may have been used to activate inert cobalt-59 into cobalt-60.[83]

A big cobalt-60 encapsulation project for Westinghouse Astronuclear Laboratory was killed and transferred to the Georgia Tech Research Reactor in Atlanta, along with 2,000,000 curies of cobalt-60.[84]

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[80] There were more than two reactors. The GNAL was designed to have a Shielding Development Reactor (SDR) on the extreme north side of the lot. It was to be suspended in the air by four steel towers, simulating a nuclear bomber flying over the ground shortly after take-off, and it would bathe anything underneath it with a simulated blast from the nuclear jet engines. When the GAO got wind of this plan, which was sucking money out of the budget, the construction was halted immediately. There was a duplicate SDR already built at Oak Ridge, and there was certainly no need for another one. Lockheed had bought the reactor and had it delivered. A road and a bridge to the remote location were in the works. The reactor and its fuel-load, which cost $952,000, was stored in the CEF pool and used for spare parts. Another reactor, a remotely controlled Godiva II plutonium sphere mounted on a flat-car, was to be used to simulate the radiation spectrum of an atomic bomb explosion for aircraft systems testing. It was not delivered. The $400,000 spent on the road and bridge were a write-off.

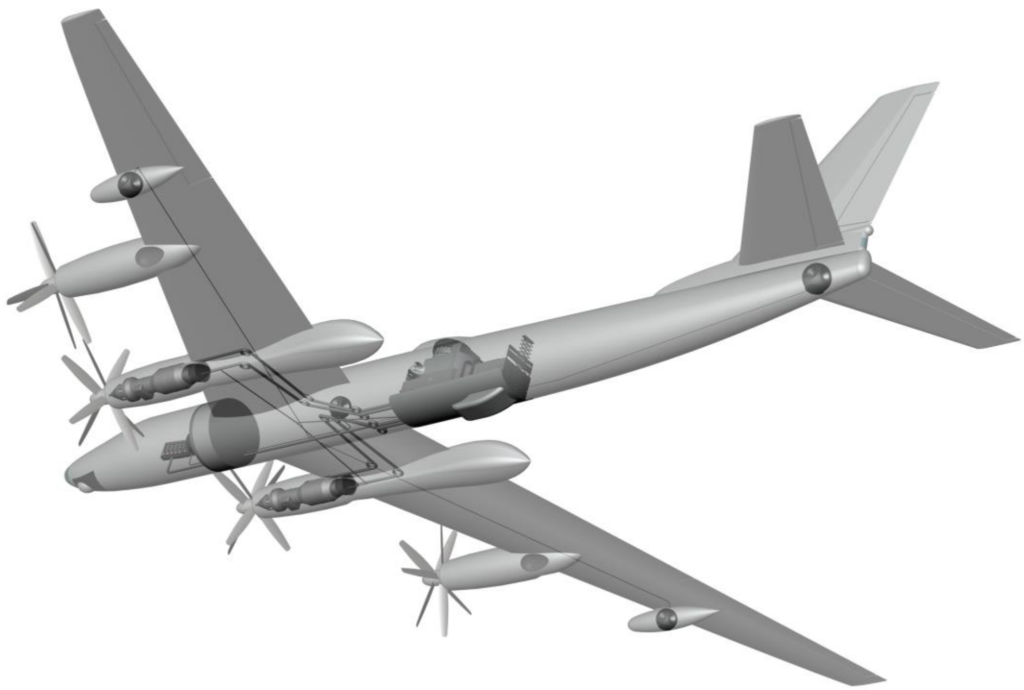
[81] Bob Boyd, meteorologist, health physicist, and reactor operator at GNAL, was assigned to show Dr. von Braun the facilities. Boyd took him straight to the REF, and led him to the center of the floor, pointing to the 10-megawatt reactor resting submerged in the water. Von Braun took a glance down into the deep pit and commented, “Seventeen thousand gallons.” He hit it right on the nose.

[82] A furniture salesman was impressed by the properties of this incredible product until he learned how it was made. “Does it grow hair?” he asked.

[83] Another GNL employee, Henry Cotten, mentions that he may have prevented a serious dilemma by noticing that the deployment cable on the cobalt rack was damaged and on the verge of letting go. If the thing had jammed in the up position, there would have been no way to send in a person to fix it.

[84] There are stories, only stories, of a fire in the hot-cells at GNL with cobalt-60 in use. The vaporized cobalt-60 was sucked into the air-blower system and piped to the machine-shop, covering everything with the highly radioactive dust. It may have been cheaper to default on the big NASA contract with Westinghouse and blow the site down than to try to clean it up. Air ducting was through concrete tunnels underground, and when the demolishable parts of the building were brought down, the cobalt-60 dust was ground into the dirt. This could explain why cobalt-60 radiation was still measurable in and around the hot-cell blockhouse 40 years later. Lead bricks scrounged at the blockhouse demolition site in 1971 were brought to Georgia Tech for use in the reactor building, but they set off criticality alarms at the back door with 250 rads/hour gamma and beta radiation. It raised questions. The Lockheed-Georgia Corporation strongly insists that there was no fire.

They mounted a test reactor in an existing bomber airframe, just as we did with the NH-36H Crusader.[85]



A diagram showing the reactor installed in the belly of a Tupolev bomber to test the way radiation spreads in the airframe. A thick radiation shield is shown in back of the crew cabin, and pipes lead to the two inboard engines. These enhancements were on the drawing board, but not necessarily in the airplane.

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[85] The only available picture showing the reactor that was mounted in the Tu-95LAL shows it underneath the airplane fuselage, sitting on the tarmac at an odd angle. It looks as if it broke free of the lifting apparatus and was dropped accidentally. It appears very large, implying that the "breakthrough' shielding of beryllium oxide and paraffin are around the reactor and not around the crew.

Chapter 3
Inside Cold Fusion

I was a Senior Research Scientist in the Georgia Tech Research Institute (GTRI), with an office in the basement of the Electronics Research Building on Ferst Street.[86]

Anyone could sign onto a specific sub-group, such as "alt.fusion," and post a message or read postings left by other interested parties.[87]

It's not spark fusion.[88]

Bluish objects were far away, and reddish things looked very close.[89]

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[86] GTRI at that time was divided into six or seven laboratories housed in five buildings on campus, a clump of buildings and a long-field testing range at Lockheed Georgia, north of town, and satellite offices in strategic places, such as the Redstone Arsenal in Huntsville, Alabama. Our laboratory, the Electronics and Computer Systems Lab (ECSL), had about 100 people inhabiting the three-story Electronics Research Building. The budget for GTRI was about $100 million in 1989.

[87] There were hundreds or perhaps hundreds of thousands of sub-groups. There was no directory, nobody took the time to count them, and more sub-groups were being added as the seconds ticked by. That morning on the "profs" campus mail system I found and deleted a memo from a project director reminding us of special security requirements at Warner Robbins Air Force Base, a press release announcing the results of someone's project over in the electromagnetics lab, and a copy of the last progress meeting of project A-8265.

[88] The day before, I had regaled Rick and Darrell with a brief lecture concerning compact Z-pinch fusion reactors used as neutron generators, and the same day I had received an unsolicited catalog from the Sigma Chemical Company, which sells deuterium oxide (heavy water), lithium deuteride, and several other deuterated chemicals. Darrell would later interpret these happenings as prophetic.

[89] For a complete explanation, see U.S. Patent number US4597634A, "Stereoscopic process and apparatus," at www.goggle.com/patents. Richard A. Steenblik holds 39 U.S. patents and uncounted foreign patents. His "Unison" product is protected by 12 unusually voluminous patents, containing more than 1,200 claims, or about 100 claims per patent. On average, a U.S. patent contains 18 claims. In comparison, the author's name is on a measly two patents.

His first invention was a spiral solar-power sunlight collector.[90]

The casual viewer may have missed the joke.[91]

In 1934, Dr. Enrico Fermi, co-inventor of the nuclear fission reactor, had measured the fission probability of neutrons hitting uranium-235, and had found that when the incoming neutrons were slowed to room-temperature speed, the probability of fission increased dramatically.[92]

Cooling the palladium, they expected the additional compression given by the shrinking of the crystal lattice of the metal to ensure fusion of the hydrogen absorbed under heated conditions.[93]

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[90] The sunlight focusing collector reminded me of a Fresnel mirror, but it wasn't. It was ingeniously unique. It was a spiral cut from mirrored Plexiglass, tensioned to make the outer edges of the spiraling plastic lean in and cause incoming sunlight to reflect and concentrate at a point in front. He carefully laid his newly completed working model on the back seat of his car so as not to disturb the focusing, and he went to perform some other task. When he returned, he found the car filled with opaque smoke. The sunlight through the window glass, focused neatly on the headliner, had significantly reduced the car's resale value. The windows were up, limiting the available oxygen inside and occluding the sunlight with the smoke, or the car would have burned to the ground. He and Georgia Tech benefitted greatly from his stereo-vision patent, named "ChromaDepth."

[91] We had started the tape 13 seconds into the news segment, and we had missed the opening sentence, putting us right there at the detonation of the Trinity test of the atomic bomb in 1945. See the first seven minutes of the interview on YouTube at https://www.youtube.com/watch?v=00IFpIBpa9Y. The video quality of Steenblik's VHS tape was much better than this YouTube rendition. We watched it twice that morning.

[92] Fermi had discovered nuclear fission, but he did not realize it. He thought that neutron bombardment had activated uranium into two new radioactive elements, which he named ausonium and hesperium. The importance of his discovery was that when neutrons were slowed down by colliding with the hydrogen nuclei in a wooden table top, they are much more likely to interact with uranium. He only misunderstood the nature of the interaction. This phenomenon was noticed when one of his activation experiments was transferred to a wooden bench from a marble-topped bench. The heavy marble top did not slow the neutrons down, but the wooden top, made of hydrocarbon compounds, did. The fission action was finally sorted out in January 1939 by Lise Meitner and her nephew, Otto Frisch, and Fermi's discovery of the fission resonance in uranium-235 finally made sense. Otto Hahn of Germany was given credit for the discovery, and he was awarded the Nobel Prize in chemistry for it. The fission cross-section of U-235 actually increases on a gradual slope as the speed of incoming neutrons increases, but at the lowest level of energy there is a narrow blip of enormous fission cross-section, called the "fission resonance."

[93] This was Paneth's and Peters' fourth attempt to synthesize helium. They had also tried submitting hydrogen to an electrical discharge in an ozone-making apparatus, putting hydrogen in a Geissler tube with aluminum electrodes, and bombarding certain salts with cathode rays. The heated palladium tube gave positive results, but a better controlled experiment followed, in which "paladinised" asbestos was heated.

It was the right thing to do.[94]

He died on November 3, 1968 in Lund, Sweden.[95]

In 1956, Louis Alvarez at Berkeley California, unaware of the previous theories, found evidence of muonic fusion in a bubble chamber photograph.[96]

When the excitement calms down, there are always two problems with cold fusion using muons: A muon has a mean lifetime of 2.2 millionths of a second, and it takes more energy to artificially generate muons than can be recovered from muonic fusion.[97]

The deuterium-deuterium fusion (D-D) results in one helium-3, one neutron, and 3.2 MeV of energy.[98]

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[94] Friedrich "Fritz" Paneth fled Germany in 1933 when Adolf Hitler assumed full control of the country, and he became a professor of chemistry at the University of Durham in England. In 1943, he was appointed head of the chemistry division of the joint British-Canadian atomic bomb project in Montreal. He returned to Germany after his retirement from UD in 1953, and became director of the Max Planck Institute for Chemistry until he died in 1958. The mineral Panethite and a crater on the Moon are named for him. Kurt Peters remained in Germany during the war and worked at IG Farben, working on catalysts. After the war, the American military government appointed him as trustee for what was left standing of IG Farben. After that, he returned to academia in Vienna, Austria. He died in 1978.

[95] I once gave a lecture on cold fusion at a Mensa convention in Atlanta. My lecture was canned by that time, and I always would mention that Dr. Tandberg had written a book describing his cold fusion experiments. It was only rumored to exist, and nobody had reported finding a copy, so I jokingly said that anyone having a copy of the book should see me after the lecture. As I turned off the projector and unclipped my microphone, a woman from the back of the audience came up and plopped a copy of Tandberg's book in my palm. I was stunned. Unfortunately, it was written in Swedish.

[96] A bubble chamber is a container full of a transparent fluid, heated to just below the boiling point. A high-speed particle zipping though it will leave a trail of tiny bubbles, and a magnetic field running vertically through the chamber helps to determine the electrical charge on a particle. Negatively charged things curve right, and positive things curve left, and. given the speed of the detected particle, the radius of the curve indicates the mass. Electrons and muons both curve left, but the muon moves with a much longer radius of curvature. Watching as the long-curve particles disintegrate in the midst of a bubble track, the half-life is determined. The first fluid tried in a bubble chamber was beer, soon replaced by liquid hydrogen.

[97] The mean or *average* lifespan of a muon is 1.44 times its half-life. Muons are like every other decay-prone object in the nuclear world, in that they decay exponentially, and the relative decay speeds are usually expressed as half-lives. After one half-life, half of the original crop of particles has decayed. In this case, the average time that a muon has to work on hydrogen fusion is more important than its half-life.

[98] As it turns out, there are natural sources of helium-3 that have nothing to do with fusion. It is in constant production by high-speed cosmic rays hitting nitrogen-14 nuclei in the atmosphere, the decay of tritium, and lithium spallation. Interplanetary dust collecting on the ocean floors, having sifted down through the atmosphere, is estimated to contain 1,200 metric tons of helium-3, and as much as seven percent of the primordal helium-3 is still in the Earth despite the length of time it has had to diffuse away. As much as seven percent of the natural gas you may burn in your home furnace and water heater is helium, and a few parts per million of that is primordal helium-3.

In 1986, Jones started trying to make fusion by loading up palladium, which is a more enthusiastic hydriding metal than nickel, using electrolysis.[99]

This seemed a lot more reasonable than the P&F claim of tremendous heat, but the fortune potential in Jones' findings was a lot smaller.[100]

Back during President Carter's alternative energy push, he studied hydrides as a hydrogen storage method."[101]

He says it's a much better hydriding agent than palladium, and he has a sample we can use."[102]

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[99] The element with the highest affinity for hydrogen isotopes is uranium. The second greatest affinity is shown by palladium. Unfortunately, alpha-phase uranium immediately collapses into a white powder upon hydriding. The reader is challenged with finding the hydriding characteristics of beta-phase uranium. In the early days of hydrogen-bomb development, when the fission and fusion components were thought best colocated, a beta-phase uranium deuteride/tritide was considered for the active ingredient of the device code-named "alarm clock." This research remains classified SECRET.

[100] To put Steve Jones the scientist in perspective, note that in 2005 Jones presented research indicating that the collapse of the World Trade Center buildings in New York on September 11, 2001, was not caused by airliners crashing purposefully into the sides. These disasters were, according to his findings, caused by previously installed thermite bombs placed with engineering precision against the vertical support structures in the buildings. They were set off by the United States government, with the destruction sequence perfectly synchronized with the sacrificial airliner crashes. This absurd and inflammatory accusation, presented as science, put him under review at BYU, but he resigned before the investigation was completed. His further work involves the study of archeological evidence of Jesus Christ having visited ancient Mayans in Central America and radiocarbon evidence of pre-Columbian horses in the Western Hemisphere, both in support of the Book of Mormon.

[101] If you are wondering about the accuracy of this dialog after a quarter century for it to become hazy, I made detailed notes at the time, kept an hour-by-hour timeline, and by the end of April I had begun writing a book about the experience. It was still fresh, and the word exchange memories had not had time to drift and improve with age. I've condensed it down a bit so that the chapter won't drag, but this dialog is about as authentic as remembered dialog can be.

[102] We did not realize it until March 29, Wednesday afternoon, but Steve Jones had already tried lanthanum-nickel in 1988, along with titanium, aluminum, and iron as hydrides. He used both electrolysis and pressurized gas to load these hydrides, and found "tantalizingly positive" results using electrolysis on titanium.

Obviously, to them, the palladium had suddenly reached a temperature far above the boiling point of palladium metal. I took it as a possible theft of their cathode.[103]

[103] Accounts differ, but it is agreed that young Joey Pons, Stan's son, was in charge of that fusion cell. He had lowered the electrical voltage and gone home for the night. Upon returning the next morning, he checked in on the cell, saw that the setup was modified, and asked his father to take a look. Later work found that if subjected to electrolysis for many months, the surface of the palladium electrode collects silicate corroded off the inner walls of the glass enclosure, and this greatly increases the resistance of the electrolysis cell. Using a voltage-controlled power supply, the current will rise accordingly, the resistive heating in the cell increases, and the water can start to boil. This effect is not caused by any nuclear reaction.

Chapter 4
Good news and Bad News

Rick wanted to talk about piezofusion, having by this time read about it in Steve Jones's paper.[104]

The fusion neutrons, moderated down to low speed by bouncing around in the heavy water in the fusion cell, would be scavenged like junebugs in a duck-pen.[105]

They detected neutrons at four to six times background using three US-made helium-3 detectors.[106]

He, for example, knew for a fact that a reactor could not be controlled using mechanisms outside the core, even with the diagrams of the SNAP-10A reactor laid out in front of him.[107]

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[104] Jones and Paul Palmer had begun their version of cold fusion research assuming that the anomalous helium-3 found in volcanic vents was due to deuterium traces in water trapped between rocks under extreme geologic pressure. They were considering an experiment in which they could simulate continental plates pressing against one another using a diamond synthesis press. Palmer wrote it up in a paper from March 28, 1986, *Experiments in Cold Fusion.*

[105] No, I did not steal the duck-on-junebug metaphor from *Gone with the Wind.* I stole it from the same place Margaret Mitchell got it, from Augustus Baldwin Longstreet's *Georgia Scenes*. Published in 1835, it is a birthplace of some basic southern writing characteristics.

[106] The use of three helium-3 detectors was a good way to detect neutrons. The detector is a hollow stainless steel cylinder, an inch or less in diameter, built like a Geiger counter tube with a thin stainless steel wire running down the center. A high voltage, about 1,200 volts, is established across the cylinder and the center wire, and any ionizing event in the helium gas that is pressurized within will cause an electrically detectable disturbance in the voltage. In this case the event occurs when a neutron wanders into the helium-3 and is immediately captured. The disturbed helium-3 nucleus blasts apart into a tritium nucleus and a flying proton. The proton ionizes a track in the helium, causing a momentary short across the wire and the inner wall of the tube.

[107] SNAP-10A (Space-borne Nuclear Auxiliary Power) was the first and only nuclear reactor that the United States ever put into orbit. It was controlled by four neutron reflector drums, turned by electric motors to face or look away from the core, located outside the core and the cooling jacket. SNAP-10A suffered an irreversible scram incident, but it is still up there, kicked into a high orbit after the electromechanical failure shut it down. You can make a ball of subcritical plutonium, a minimum nuclear reactor, go supercritical just by walking past it. You are reflecting thermalized neutrons back into the core.

"Yes, well, I got a call from Savanah River."[108]

BF threes to go with them, plus high voltage cables, a DC power supply with long clip leads, a thermocouple and readout, a rack for it all, a Ludlum survey meter, a portable BF three, about 50 lead bricks, paraffin slabs, a pallet of boron blocks, an H-P frequency counter, and a milli-ammeter."[109]

Well, we've got the graphite reflector blocks out of the old 104.[110]

While not utterly impossible on a quantum mechanical level, it begged the question of what was forcing these unlikely pairings to occur.[111]

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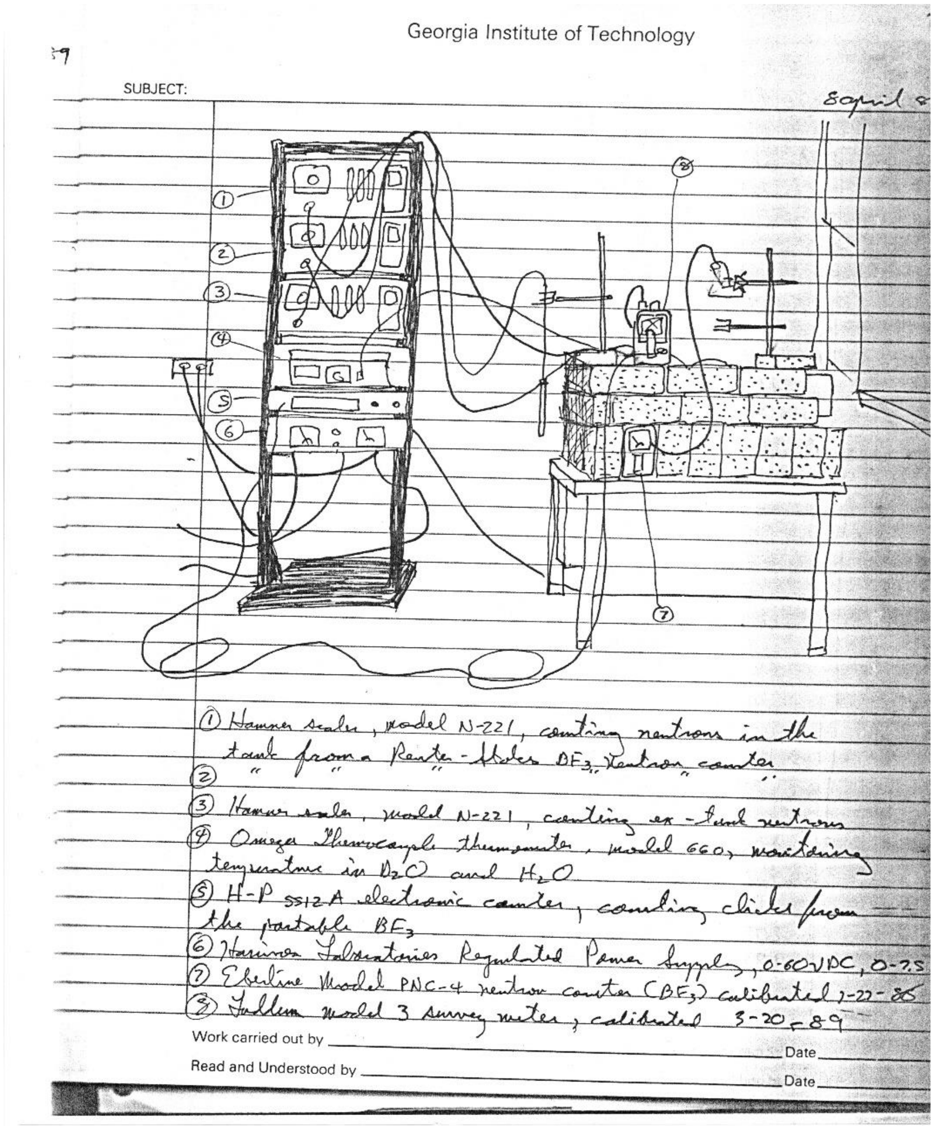
[108] The Savannah River Site was built in Aiken, South Carolina, beginning in 1950, as a mirror of the Hanford Site plutonium production complex built during World War II in Washington State. While the Hanford Site was populated with eight water-cooled graphite reactors for plutonium conversion, the Savannah Site had five heavy-water moderated reactors built for the same purpose. By 1989, only one reactor, K Reactor, was still in operation, and it was shut down in 1992. In 1956, the neutrino was discovered by Fred Reines and Clyde Cowan using the P Reactor as a neutrino source. The new Tritium Extraction Facility was not completed until 2005. The tritium for nuclear explosion initiators is now made off-site using Tennessee Valley Authority commercial reactors. Savannah River's stockpile of neptunium-237 was quietly shipped to Idaho beginning in 2005.

[109] The "BF three" is another species of neutron detector tube. A reliable workhorse for detecting neutrons, these devices have been popular since 1942, when they were used to monitor the uranium fissions in the world's first nuclear reactor at the University of Chicago. A BF three is configured similar to other ionizing-event detectors. It is a seamless, gas-tight brass tube with a thin wire running down the center. It is filled with isotope-purified boron-10 tri-fluoride gas, and the boron is extremely likely to capture a slow neutron that happens to wander in through the brass walls. Upon neutron capture, the boron nucleus immediately destructs into an alpha particle and a lithium-7 nucleus. The 2.78 MeV event causes a momentary ionization in the tube that is both energetic and unique, making it possible to discriminate it from other events, such as gamma rays, cosmic rays, or electrical noise. The resulting pulse caused indirectly by a neutron is amplified and evaluated for its pulse-height. If it looks like a neutron event, then a digital counter is bumped forward by one.

[110] The "old 104" was an AGN Model 201 nuclear reactor, serial number 104, made by Aerojet General Nucleonics in San Ramon, California, in the late 1950s. It was a small research reactor, designed to be used, believe it or not, to teach nuclear technology topics in high schools. The expected demand did not materialize, and only a few were built. This one had been operated in the high-bay of the biology building for several years, but it had been decommissioned and was now sitting on the tarmac in back of the Nuclear Research Center. Its cylindrical core, made of 20-percent enriched uranium mixed into polyethylene discs, had been removed and was in the fuel-storage vault, separated into four subcritical pieces.

[111] Paneth and Peters had correctly anticipated this problem back in 1925, and their solution had been to heat the palladium block, expanding the sizes of its cubic lattice locations so that more than one hydrogen atom could fit in one location. To squeeze them together and cause fusion, they then cooled the palladium block. It was not a bad idea. We should have thought of it.

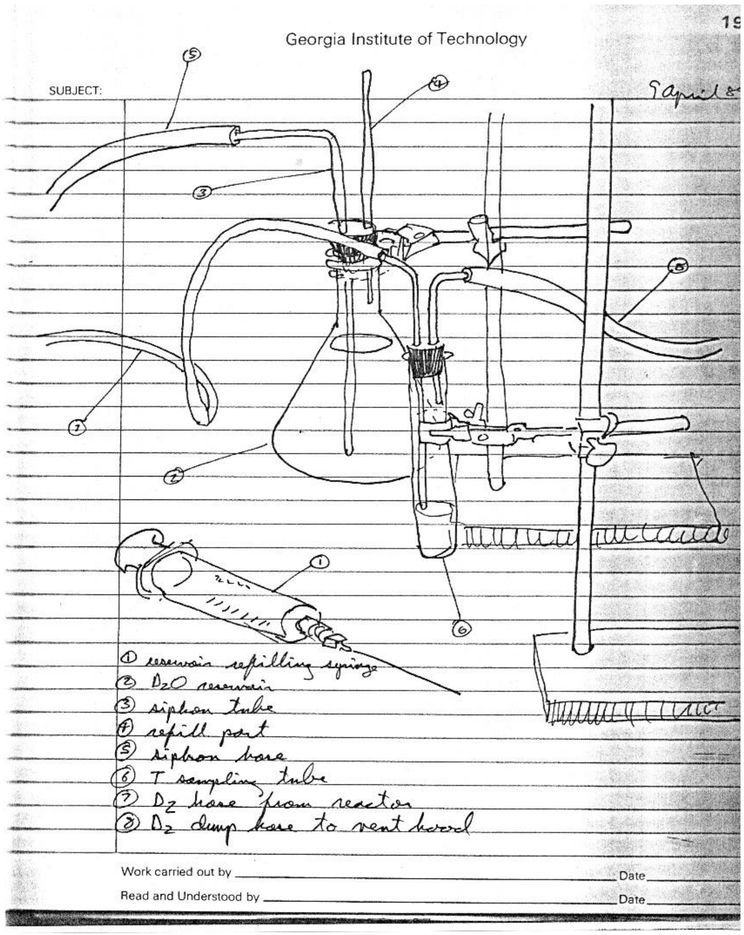
There was, of course, a massive run on lithium deuteride occurring, and soon the phone line to Sigma Chemicals would jam. Normally, there is not much of a market in lithium deuteride.[112]



A page from my lab notebook, showing the experiment setup.

112 Lithium deuteride is the active ingredient in a thermonuclear warhead. It comes in a very small, 3-gram bottle. Mix it with heavy water, and you have lithium deuteroxide. We used 0.1 mole lithium deuteroxide, or 0.324 grams of lithium deuteride dissolved in 360 milliliters of deuterium oxide (heavy water). I have an unopened bottle of lithium deuteride on my bookshelf, just to remind myself never to do this again.

We had four detector tubes, designated A through D. A, B, and C were Reuter-Stokes RS-P1-0809-101 BF3s, and D, which was our least antique and most sensitive detector, was a top-of-the-line Nancy Wood G-10-5 BF3.[113]



A page from my lab notebook, showing the tritium sampling tube and the deuterium replenishing flask.

[113] Nancy Wood was a grad student at the University of Chicago the day that the first nuclear reactor achieved criticality there, and she had participated in designing and building the boron tri-fluoride detectors used to measure neutrons in the ground-breaking experiment. She began manufacturing neutron detectors for the Manhattan Project, and in 1949 she started the N. Wood Counter Laboratory on East 53rd Street in Chicago, building special detectors for nuclear research around the world. In 1989, her daughter, Marjory Wood Crawford, was General Manager. The label on our detector said it was a G-10-2, but it was an error. I am positive it was a G-10-5.

The problems seemed to be at the interface between the SHV connectors and the cable.[114]

When deuterium fused with deuterium, half of the reactions would result in neutrons and half would result in tritium.[115]

Pons and Fleischman were elated at the news.[116]

I was not sure how to counter that without causing physical harm.[117]

There were now a hundred cameras pointed at me.[118]

I discovered in the morning edition that a reporter will always take the worst thing you say instead of your best phrasing and make a headline out of it.[119]

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[114] SHV means "Safe High Voltage."

[115] The products were evenly distributed between tritium plus ordinary hydrogen and helium-3 plus a neutron. The tritium and the neutron were both detectable in small quantities and were clear signatures, while hydrogen and helium-3 were harder to pin down as having come from fusion.

[116] The same day, almost at the same minute, Texas A&M University in College Station, Texas, announced that they confirmed that their Pons & Fleischman apparatus produced net energy using calorimetry, but they had not tried to detect neutrons. Their experiment looked a bit strange on the news, as electrical arcs and flashes were shown coming from the setup. Shortly after having made this announcement, TAMU went quiet, and it was hard to get confirmation of their confirmation. At Georgia Tech, we knew Texas A&M by its alternate name, the Sam Houston Institute of Technology, or its acronym.

[117] The Oak Ridge researchers had improved the Pons & Fleischman experiment by using a very large palladium cathode. It was spherical, hollow, and the size of a basketball. It exploded and destroyed the lab one night, right after the researcher tending it had left the room, and this they interpreted as confirmation that cold fusion was extremely energetic. It was more likely the result of deuterium compressing into the air-space at the center of the sphere by hydriding action and suddenly igniting, exploding the sphere like a grenade.

[118] I do not really know how many cameras were pointed at us, but it seemed like about 1,000, so I trimmed that number down to 100 as a more realistic estimate.

[119] Take this as a lesson learned: The reporter who interviews you will be extremely sympathetic and understanding, and your interaction will be cordial and relaxed. You will have made a friend, but the reporter, although he or she must be treated as such, is not your friend. The reporter is looking to make a sensation, and has no particular regard for your welfare. The worst case of this was a crew from the BBC. They came to film me for a *Horizon* show on British television. It would be repackaged as *Nova* on American Public Television. I made one slip, talking about the conspiracy theorists who thought we had been paid to suppress our cold fusion findings and joking that we might have considered doing that but we were never offered. That was the part of the film they showed, and they reported on *Dr.* Gai at Yale and *Mr.* Mahaffey at Georgia Tech. It was subtle, but effective in making their twisted point.

Chapter 5
The Lost Expedition to Mars

Meanwhile, under a strict information lock-down, scientists at the Los Alamos Laboratory, such as Stan Ulam and Frederick de Hoffman, drifted off-task and discussed nuclear rocket engines as early as 1944.[120]

He would become an Atomic Energy Commission Chairman in March 1955, but when he read Bussard he was a highly influential proponent of the ICBM strategy. He pushed the nuclear rocket engine as the perfect H-bomb hauler.[121]

In October 1954, two national labs began work on nuclear rocket engines for an enhanced Atlas missile, even though the design for the Atlas XSN-16A had just been frozen and production was supposed to start in January 1955.[122]

Herbert York, director of the Lawrence Livermore Lab in California formed the "Rover Boys" committee to study nuclear rockets, while Darol Froman, deputy director of the

[120] Stanislaw Marcin Ulan was a Jewish mathematical genius from Poland who escaped his native country on the eve of World War II, taught math at the University of Wisconsin-Madison, and was invited to join the Theoretical Division at the Los Alamos Laboratory to work on the atomic bomb project. After the war he and Edward Teller invented the thermonuclear nuclear weapon, or hydrogen bomb, but his most prized idea was for a unique nuclear spacecraft propulsion system, code-named Orion. Frederick de Hoffmann was a Harvard-educated nuclear physicist from Austria who met Ulam at Los Alamos in 1944. He was assigned to work for Teller, which was something of a baptism by fire, and in 1948 he received his Ph.D. In 1955 he founded the General Atomic Corporation in San Diego, California, and was its first president. The first defense project at General Atomic was to develop Ulam's idea for interplanetary flight, Project Orion.

[121] There is a touch of irony here. The expatriate Hungarians in the Manhattan Project, von Neumann, Leó Szilárd, Edward Teller, Theodore von Kármán, and Eugene Wigner among others, were collectively known as "the Martians," because their native language was incomprehensible and did not trace to any other language, modern or ancient. These individuals were therefore obviously not from this planet, or so it was conjectured, and most likely had come from Mars. They formed a core of unusual intellectual power without which the atomic bomb would have been delivered later and with greater confusion. There must have been something in the water in pre-World-War-I Budapest.

[122] The Atlas was a complicated beast, and production of test rockets produced 12 units, named the X-11s, by June 1957. Two out of three of the first test launches resulted in spectacular explosions on the launch pad, but eventually the Atlas was refined to the point where it was cleared for manned spaceflight, and ten of them were used to launch Project Mercury space capsules. John H. Glenn became the first American to orbit the Earth, launched by an SM-65 Atlas missile, and variants of the Atlas were used by NASA to launch scientific probes to Mars, Venus, and Mercury. The last SM-65E/F Atlas missile was launched on March 24, 1995. The Interstate Highway System, being planned when the Atlas was in development, did not use the clearance height of tractor trailer trucks as a specification for the height of overpasses. The overpasses were all built to allow an Atlas missile carrier to pass underneath.

Los Alamos Lab in New Mexico, put together the “Condor Committee” to do the same thing.[123]

Five reactor core designs with power ratings ranging from 600 to 2,000 megawatts (2 billion watts) using graphite as a neutron moderator came out of the Condor Project. Their aggressively odd code-names were Uncle Tom, Uncle Tung, Bloodhound, Shish, and Old Black Joe.[124]

At this point in 1956 no nuclear rocket engine had ever been built, and the technology consisted of designs on paper and some computer simulations.[125]

No such pump existed.[126]

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[123] *The Rover Boys* was a very popular series of juvenile books written by Edward Stratemeyer between 1899 and 1927. The Rover boys, Tom, Sam, and Dick, were involved in 30 stirring adventures, always getting into trouble with various authority figures as well as criminals and running into Germans, Italians, Irish, Chinese, and African Americans, all of whom were portrayed as having degrading speech patterns. A typical title was *The Rover Boys Under Canvas, or, The Mystery of the Wrecked Submarine* (1919, second series, populated by the sons of the original boys). Herbert York probably read these books as a young man and so named his gallery of young, eager engineers, ready to take on a very daunting mission. Froman named his project for the largest bird in the Western Hemisphere that can fly, the California condor.

[124] The use of African American characters in two of the names, Uncle Tom and Old Black Joe, may have been due to the use of black-as-you-can-get graphite for the high-temperature fuel assembly structures. In the early 1950s, racial sensitivity was not an agendum. The Uncle Tung design was a combination of Uncle Tom and Dumbo, which was based on tungsten core structures. The reasons for Bloodhound and Shish are not obvious. Shish did not use fuel assemblies that looked like shish kebobs. They were hollow tubes. “Soda Straw” might have been appropriate. The Bloodhound did not have fuel channels resembling the turbination in a bloodhound’s nasal passages, but it did have a big can of heavy water dominating the center of the core.

[125] In 1956, more than 90 percent of all electronic computer calculations in the United States were devoted to simulations of nuclear processes. For all the expense of running large computer jobs, over and over to correct and improve, it was still a lot less expensive than building and running a reactor or bomb design on speculation. Most electronic computers of the era, which were vacuum-tube-based money pits and often one-of-a-kind units, were owned by national laboratories and the Atomic Energy Commission. The Monte Carlo method and neutron diffusion theory calculations used in reactor design were of such extreme complexity, there was no way to do the arithmetic other than using high-speed electronic computation. Without a burgeoning need for computers in nuclear science and engineering in the 1950s, there would not have been enough demand for commercial development, and life would be different now.

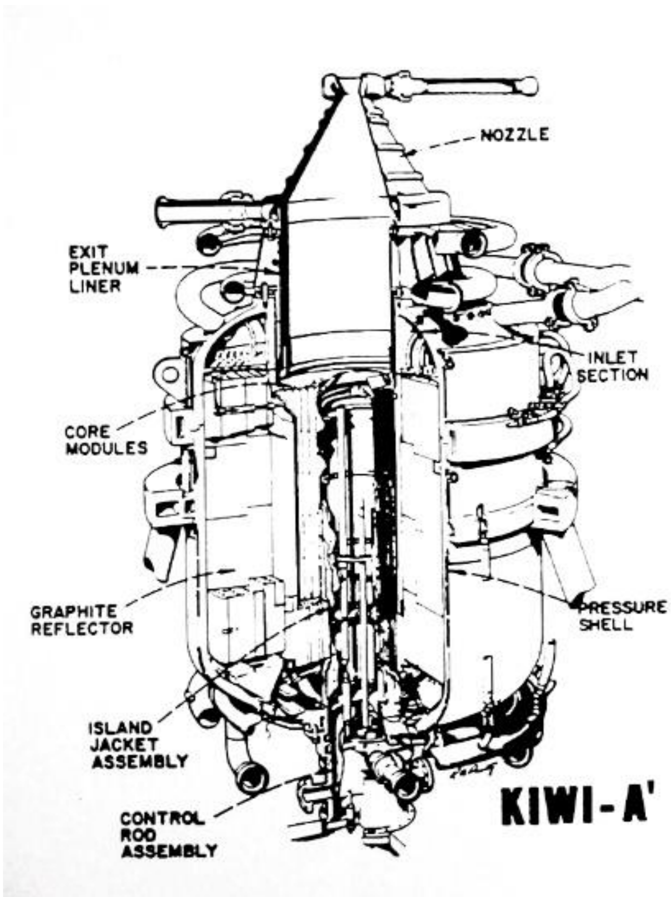
[126] Rocketdyne was awarded the contract to come up with this exotic turbo-pump because they were the only one with any experience. In 1956 they worked on a parallel program for Lockheed to develop a fuel pump for the top secret CL-400 edge-of-the-atmosphere reconnaissance airplane, code named “Suntan.” Its turbojet engine, operating at Mach 2.5, 98,000 feet above the ground, had to use the most efficient burnable fuel in existence in the rarified oxygen environment of the edge of space. That fuel was liquid hydrogen slush, pumped into the jet engine at five pounds per second. The KIWI pump would have to be 15 times bigger and operate in a lubricant-destroying radiation field.

Although the scenario was more realistic than AEC would care to admit, the fear of biosphere damage was definitely over-stated.[127]

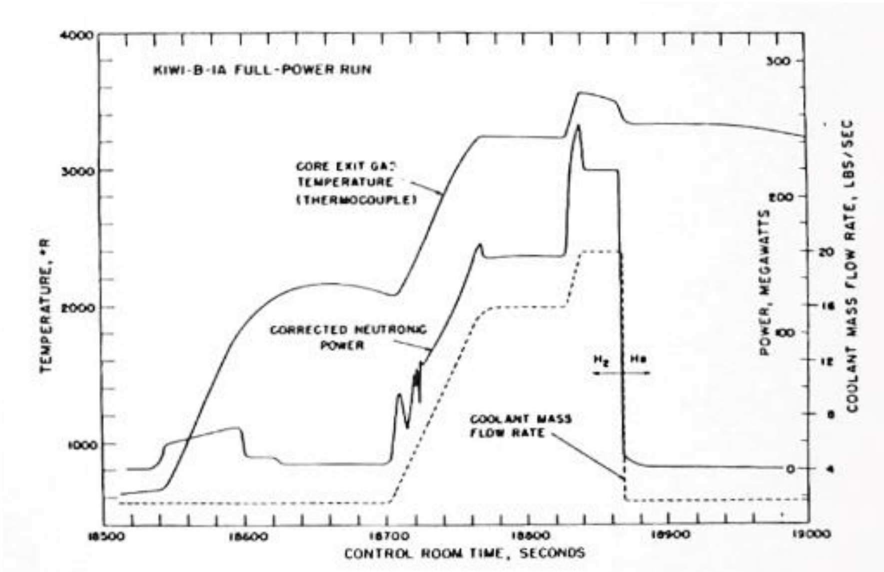
The corrosive hydrogen from the ammonia fuel, very high temperature, and heavy vibration made design work for the uranium fuel assemblies challenging.[128]

[127] This concern about nuclear fallout from nuclear propulsion originating at ground level came up several times as nuclear propulsion enthusiasm waxed and waned. The nuclear technologists had no choice but to acknowledge the fear, and accommodating mission adjustments were always made. However, those who understood the technology were aware that any debris from a rocket engine, whether it is in the atmosphere or in a low Earth orbit, eventually comes down and lands on the ground. Starting a nuclear rocket at 100,000 feet or assembling a Mars mission in orbit and then leaving by starting the nuclear engines will result in almost the same radioactive imprint on the ground as would blasting off from ground zero with nuclear rockets ablaze. In conversations with lawmakers and congressional hearings it was hard to keep a straight face when fear of nuclear rocket radiation killing spacemen was mentioned. The hazards of high-energy particles zipping through outer space and solar flares make fission radiation dangers seem trivial, and the daily radioactive fallout from cosmic rays hitting the Earth's atmosphere will exceed the danger of nuclear rocket exhaust.

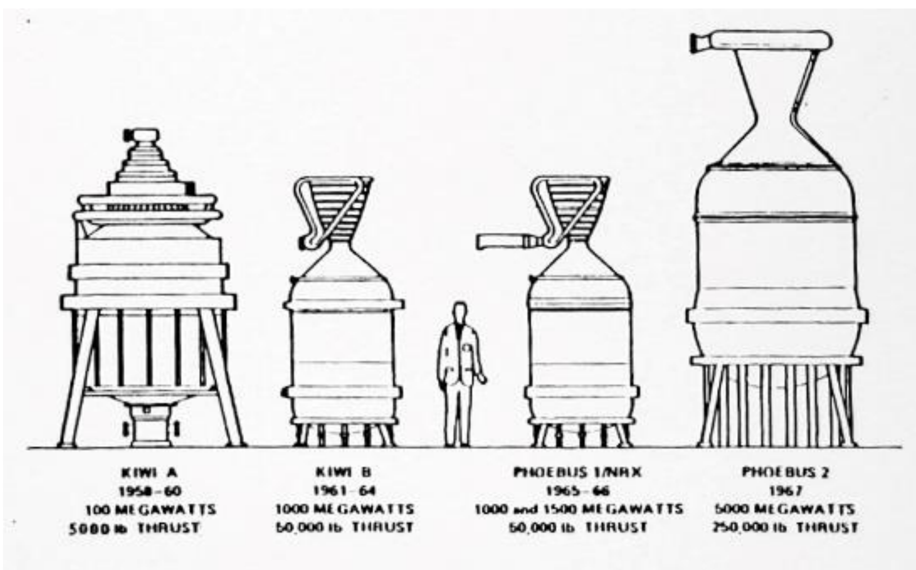
[128] A component of the nuclear engine vibration problem is that super-hot hydrogen gas coming out the exhaust nozzle immediately mixes with oxygen in the air and explodes. This phenomenon also adds to the lifting capability of the nuclear rocket, similar to the afterburner on a high-performance jet engine. In outer space, there is no air to mix with, and to get an idea of how the engine would work with no back-reflection of neutrons from air, a huge vacuum chamber was built to fit around an engine under test. Split down the middle and sealable using rubber gaskets, it was pushed into place on the test stand using a locomotive and came together like a clam shell around the engine.



A cutaway diagram of the KIWI-A Prime nuclear rocket engine. The output nozzle points up, but at this early stage of development it was not a true rocket nozzle, and it was using ammonia as a substitute for liquid hydrogen rocket fuel. Conventional control rods are inserted through the bottom of the reactor core.



The data-chart from the KIWI-B-1A test. Notice how the power-curve ("corrected neutronic power") seems to follow the coolant rate curve. A major finding of Project Rover was that the reactor in a rocket engine can be controlled by throttling the liquid hydrogen flow rate.



The sizes of Project Rover nuclear rocket engines shown in relation to the height of an adult human being. The Phoebus 2 is the largest, and it is rated at 5 billion watts.

The solar flare activity, for which crew radiation shielding would be difficult, was predicted to peak in 1980 and be over by 1982, when an Earth-Mars opposition flight would be ideal.[129]

Nuclear engines can be clustered.[130]

The complexity and the extra weight of the cadmium-beryllium control drums was not necessary at all, and when there was no more liquid hydrogen, the fission stopped for lack of neutron moderation.[131]

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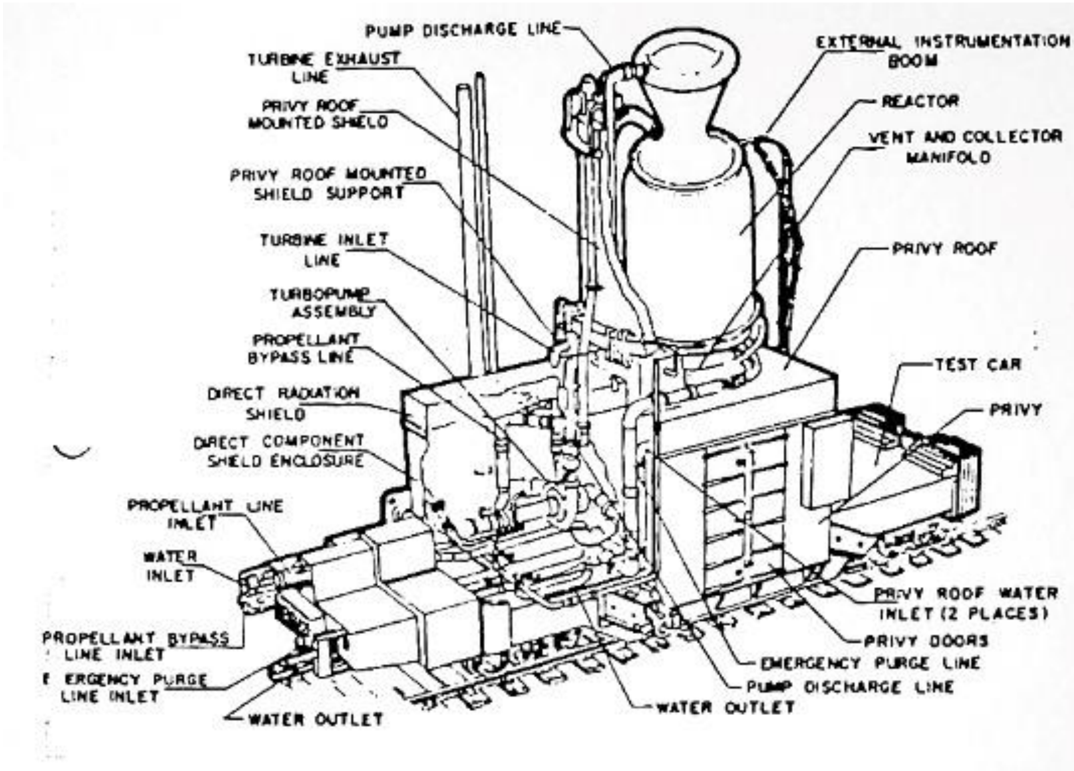
[129] Both Earth and Mars are in slightly tilted, elliptical orbits, and the distance between them and the resulting trip-time varies greatly, from 33.9 million miles to 249 million miles. About every two years Mars is in opposition mode, meaning that when viewed from the Earth it is on the opposite side of the sky from the Sun. At the time of opposition, if at midnight Mars appears in the exact center of the ecliptic in Atlanta, then it is high noon in Kansk, Siberia. Near this time, within a couple of days, Mars happens also to be the nearest to Earth it has been in the last two years. Scheduling a trip to Mars is complicated, as it involves both the variable distance to be travelled and the radiation level due to possible solar flare events, which are not easy to predict. A massive solar flare on October 25, 2003 would have baked a Mars flight if it had taken advantage of the unusually close opposition that year. On August 23, 2003, Mars was as close to Earth as it had been since 1924. It will be almost that close in August 2050.

[130] Excess reactivity in a nuclear reactor is measured in dollars and cents. (An atomic bomb has an initial excess reactivity of about $3.00.) One dollar of excess reactivity means that the reactor is prompt critical, or critical just using the neutrons that are immediately available and not waiting for the delayed fission neutrons to affect the reactivity. A prompt critical reactor is very supercritical, and prompt criticality is a factor in some severe criticality accidents, such as the SL-1 incident in Idaho in 1961. At a separation of 16 feet, each of the two rocket engine reactors had an excess reactivity of $0.03 (three cents) due to neutron sharing, and this degree of excess reactivity was easily erased by a slight rotation of the control drums. At nine feet, it was $0.12, and at six feet it was $0.24, and all of these excess reactivities were easily extinguished with no modifications to the controls.

[131] Controlling a reactor with moderator flow was called "mapping." It was not an entirely new idea. It had been considered as early as 1944 in reactor designs at Chalk River, Canada. The Canadian reactor ZEEP controlled the reactivity with actively pumped heavy water coolant/moderator, but it ran at essentially zero power, and the pump-rate of the heavy water was nothing compared to the aggressive turbo-action used to force hydrogen slush down the throat of the NRX reactors at Jackass Flats.



The NRX nuclear rocket engine test setup. If the reactor should go wild and melt, it would fall into the heavily shielded box on which the engine sits. It is named "the privy," bringing to mind an antique sanitation facility, the outhouse.

This problem was new, but much analysis was spent and it was finally concluded that the surging power was due to the "Heisenberg Curse."[132]

[132] In 1929, Werner Heisenberg, German physicist and noted quantum theorist, studied the strange properties of liquid hydrogen, particularly the spin isomers of H2, the hydrogen molecule. In its normal gaseous state, the molecule is orthohydrogen, in which both atoms are spinning in the same direction. In the parahydrogen state, the two atoms spin in opposite directions. Orthohydrgen when liquified is unstable, it evaporates quickly, and it absorbs neutrons, shutting down a reactor. Liquefied parahydrogen is stable, does not absorb neutrons, and is an excellent moderator. Parahydrogen is made by blowing the gas through a catalyst, such as iron oxide, while it is being liquefied, and apparently that step was missed when the Phoebus 2A liquid hydrogen was processed.

Chapter 6
The Chic-4 Revolution

Chaundhry was more than qualified to start this effort, having worked at the Cavendish Lab at Cambridge University under Lord Ernest Rutherford, but the relatively new Islamic Republic was underdeveloped in most technical areas, starting with the manufacture of soap.[133]

A year later, Chaundhry's colleague, Dr. Nazir Amed, led the Pakistan delegation to the Peaceful Uses of Atomic Energy International Conference in Geneva, Switzerland, and shortly after he was named chairman of the Pakistan Atomic Energy Commission (PAEC).[134]

Initial installations were a 14 MeV neutron generator, a subcritical assembly using British magnox fuel, and a sparkling new IBM 1620 computer, named "CADET."[135]

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133 For what started out in 1947 as a "third-world" country with many technical disadvantages, Pakistan has turned into a manufacturing economy of notable accomplishment. The first Unilever factory for making vegetable oil was built in Rhim Yar Khan in 1958, and Unilever moved on to make everything from Lifebuoy soap to Lux dishwashing detergent in Pakistan. The Pakistan Soap Manufacturer's Association reported in 2014 that Pakistan now makes 120,000 metric tons of toilet soap per year. That is 60 percent of the domestic consumer demand. Eleven percent is made up for by smuggling of the product by the Afghan Transit Trade, and the rest is imported.

134 In April that same year, 1955, representatives from Pakistan and China met at the Afro-Sino Summit, held at Banburg, Indonesia, and the two countries mutually recognized their importance to each other. China wanted Pakistan to counterbalance the west side of India as a nagging threat, and Pakistan wanted technical assistance from China for certain projects. India was a growing problem for China, with Himalayan boundary disputes and an unease in Tibet, thought to be encouraged by India. Dr. Ahmed, feeling bold at the Atomic Energy Conference, asked the United States to sell Pakistan a CP-5 research reactor for peaceful purposes, of course. "Not for all the tea in China," replied the U.S., aware of the meeting in Banburg. The CP-5 used metallic uranium-aluminum fuel, fully enriched to 94% U-235, and with a full fuel core-load plus a couple of spares, Pakistan could have its revenge on New Delhi with a 16-kiloton atomic bomb built using the fuel. (The Georgia Tech Research Reactor was a CP-5.)

135 The 1620 was a very small computer at the time, about the size of a large desk, but it was designed for the type of calculations appropriate for nuclear research and development. CADET was an acronym, meaning "Can't Add, Doesn't Even Try," referring to its use of a lookup table instead of a logical adder for additions, a method of processor design that would reappear 30 years later in the Intel Pentium. The 1620 ran FORTRAN II (assuming that PAEC had bought the necessary extra memory option) and a simplified interpreter version called GOTRAN. Programs were composed on paper tape or punched cards, and the cycle time was an unusually sedate 20 milliseconds. For many decades, various versions of FORTRAN were used in the United States and around the world as the language of choice for most nuclear calculations and large-scale simulations.

At 7:00 Universal Time on October 16, 1964, China set off a 22-kiloton nuclear explosion atop a steel tower at the Lop Nur weapons test range.[136]

Pakistan had only to promise that they would never use it to do what it could be used for, to make weapons-grade plutonium.[137]

Needing a new type of nuclear warhead that could be delivered with the modestly powered Dongfeng (East Wind) DF-2 medium range ballistic missile, China developed the "548," or the CHIC-4 as we named it.[138]

The CHIC-4 was small and light weight, burned highly enriched U-235, could stand to be roughed up in the launch of a Chinese missile, and gave an explosive yield of 12 kilotons.[139]

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[136] If the United States had been ready for this event, we would have named it CHIC-1. We didn't name Chinese weapons tests until CHIC-2 (CHInese Communist). The Chinese named the weapon "596," meaning June 1959, the time when the Soviet Union refused to provide China with a prototype nuclear device. It was a solid-core implosion weapon, very similar to the Fat Man of World War II, only made with highly enriched U-235 instead of plutonium. It weighed a hefty 3,420 pounds, and the Chinese had no vehicle that could fly this bomb anywhere.

[137]The term "weapons-grade plutonium" is thrown around a lot, but a weapon can be (and has been) made using "reactor grade" plutonium taken from spent commercial light-water reactor fuel. Weapons grade is defined as 93.6% Pu-239, 5.8% Pu-240, and 0.6% Pu-242, and it is made by low-burnup reactor operations, in which natural uranium fuel in a low-absorption moderator, such as heavy water or graphite, is not used to full efficiency. By pulling the fuel before it is spent, the Pu-239 converted by neutron activation from inert U-238 in the fuel has less likelihood of being further neutron-activated into Pu-240. The Pu-240 is an undesirable contaminant, in that it fissions spontaneously, trying to set off the bomb before it is time and causing the plutonium to at least undergo sub-critical fission and generate heat. For this reason, making electrical power with a nuclear reactor and making weapons-grade plutonium using a nuclear reactor are crossed purposes. Reactor grade plutonium is 2.0% Pu-238, 61.0% Pu-239, 23.0% Pu-240, 10.0% Pu-241, and 3.0% Pu-242. An A-bomb built with reactor-grade plutonium would be about 50% heavier and larger than one built with weapons-grade material, and weight is everything for weapons shot using guided missiles. The Canadian CANDU design uses natural uranium fuel, heavy water for the moderator, and is refueled while it is running. This makes it a perfect plutonium converter reactor, if it is run on a weapons-grade plutonium refueling schedule instead of a power-production refueling schedule, which would keep the fuel burning as long as possible and start to turn Pu-239 into Pu-240.

[138] The Chinese DF-2 (NATO name CSS-1, Chinese Surface-to-Surface) is interesting because it shows a transfer of secret defense technology from the Soviet Union to China in the early 1960s. The DF-2 is a copy of the Soviet R-5 Pobeda ("Victory," or the SS-3 Shyster), which was introduced in 1956 and was considered obsolete by the time the Chinese were building them in 1966. It ran on alcohol and liquid oxygen, with a range of 1,250 kilometers. The first Chinese version, launched in 1962, blew up on the pad.

[139] The Chinese name, 548, means August 1954, but I'm not sure what this date means. The Constitution of the People's Republic of China, or "The Organic Law of the Central People's Government of the People's Republic of China," was written in August of 1954 and enacted on September 20. It was the first document to stipulate that China is a communist country.

He was asked to translate reports from Germany concerning their new G-1 and G-2 centrifuges, the latest and greatest hardware used to turn mined uranium into bomb-grade U-235.[140]

As Munir Ahmed Khan famously asked his team, "If the Americans could do without CNC machines in the 1940s, why can't we do the same now?"[141]

With long-distance encouragement and written plans from A. Q. Khan, Bhutto approved a $350 million budget for Project 706 to build a production-level cascade of 3,000 centrifuges, capable of making bomb-grade U-235, in Kahuta.[142]

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[140] Mined uranium is only 0.72% U-235, and the rest is unusable U-238. To make a bomb, the U-235 isotope must be extracted from the uranium, making "highly enriched uranium." There are several ways to do this, none of which is easy. An early development was the ultracentrifuge, invented by Dr. Jesse Beams at the University of Virginia in 1936. He used it to separate neon-22 from neon-20. It was and still is the most efficient way to separate gaseous isotopes, but it is also the most complicated, and a great deal of further development stood between the separation of neon and the separation of uranium turned into a gas. During World War II, the United States atomic bomb project required as much highly enriched uranium as could be produced, and the ultracentrifuge was tried, but it would clearly take years to perfect the machinery to spin uranium hexafluoride gas at 90,000 RPM, so the ultracentrifuge separation method was dropped in 1944 and much simpler thermo-column, magnetic mass-spectrometer, and gaseous diffusion methods were all employed instead. During the war, Professors William Groth and Paul Hartek tried to separate uranium isotopes using ultracentrifuges for the German atomic bomb project without any practical result. After the war, practical versions of the ultracentrifuge were developed by the German scientist Max Steenbeck in the Soviet Union. In 1956 an Austrian mechanical engineer named Gernot Zippe, who had worked on the Soviet centrifuge, was allowed to leave and go back to Austria. His dispersal of information is responsible for the ultracentrifuge design that is now in use all over the world. The ultracentrifuges familiar to A. Q. Khan were "Zippe-type" centrifuges.

[141] The question was incorrectly phrased. The Americans at Los Alamos in 1945 used their AA1 priority to commandeer a Kellermatic CNC milling machine at the Chrysler plant in Detroit, Michigan, to make four aluminum masters for the Fat Man explosive lenses, shutting down the B-29 bomber engine assembly line for three days. From the masters, molds were built in the Los Alamos machine shop using Cero-Tru non-shrink bismuth alloy. The Kellermatic, named for K. T. Keller, president of the Chrysler Corporation, was a state-of-the-art machine, using a paper-tape program and capable of making weird, very precise shapes that were impossible by any other means. The Americans did not do without CNC machines, and it was unlikely that the Pakistani effort could succeed without this technology plus some others in short supply.

[142] Highly enriched uranium (HEU) is defined as uranium with a 20% or higher content of fissile U-235, with the rest being mostly U-238. In theory, a bomb could be made with any concentration of highly enriched uranium, but a bomb of reasonable size and weight requires an enrichment of about 80%. The higher, the better. The practical limit for enrichment is 93.5%, and as the degree of desired enrichment goes up, the amount of effort, time, and the number of enrichment machine stages grows rapidly. The number of cascaded stages of enrichment grows into the thousands, as the total enrichment per stage becomes smaller and smaller with rising enrichment percentage. A critical mass (the amount of fissile material necessary to support a self-sustained fission reaction) of 93.5% enriched uranium, with an enclosing beryllium neutron reflector, is only 14.1 kilograms. A critical mass of reflected 80.0% uranium is higher, at 19.3 kilograms. The same thing in 20.0% uranium is a hefty 245 kilograms. The size and weight of a simple uranium bomb depends greatly on the ability of the enrichment facility.

Caught in the rapidly spinning cylinder, the very slightly heavier gas containing U-238 would tend to hug the wall, while the very slightly lighter gas containing U-235 would be pushed to the center, where it was sucked out of the centrifuge through a tube at the top and sent to the next stage in the cascade.[143]

It could not do anything but explode.[144]

In this state, the mass releases energy at a steady rate.[145]

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[143] This is a simplified explanation of the Zippe-type centrifuge (known in Mother Russia as the Kemenev centrifuge). This design also uses the thermal-column principle, as used in the steam-driven S-60 process at Oak Ridge in World War II, in tandem with centrifugal force to separate the isotopes. The bottom of the rotating maraging steel cylinder is induction heated, causing the lighter U-235-fluoride to float to the top and the heavier U-238-fluoride to sink to the bottom. There is one input pipe, an output pipe for lighter gas at the top, and an output pipe for heavier gas at the bottom. The cylinder spins in a vacuum to reduce the aerodynamic friction, and the aluminum cover acts as both a shrapnel catcher and a vacuum chamber. Each P-1 or P-2 ultracentrifuge has 96 component parts.

[144] It was so easy to make a uranium assembly-weapon explode, it remains one of the most dangerous bombs ever deployed. It has just one detonation point, and a spark, a fire, or electrical glitch could activate it. (B-29 bombers catching fire was not a rare occurrence.) The implosion bombs, on the other hand, have as many as 90 detonation points, and if one fails to go off at exactly the right time, the bomb is a dud. An assembly weapon can go off without any detonation at all, just from being dropped on the nose. And, keep it dry. If water were to seep inside, it would enter the cannon through air-pressure relief slits at the front of the barrel and act as a neutron moderator, causing the touchy projectile to go critical. Safeguards for the Little Boy assembly-weapon included not installing the detonation components until it was on the way to Japan, installing three copper pins in the smooth-bore barrel of the assembly gun to keep the uranium projectile from sliding forward to a critical configuration, and including a timer to turn on the radar altimeter late in the drop, to keep it from interpreting the bottom of the airplane as the ground.

[145] To be precise, the coefficient is “k-effective.” It is a divisor, located under the eigenvalue multiplying the fission-source term in the neutron diffusion equation, and, as a solution to the equation, it is used to predict the degree of criticality of a nuclear assembly. The “equation” is actually a set of 23 (typically) partial differential equations to be solved simultaneously, expressing the addition of all sources and the subtraction of all losses of neutrons in the assembly, set to zero indicating perfect criticality and rendering the equations solvable. The k-effective term forces the collection of terms to add to zero by artificially lowering or raising the eigenvalue that multiplies the neutron source term representing nuclear fission. To solve this equation in three, two, or even one physical dimension is impossible without electronic digital computation, a capability that did not exist when the Little Boy was designed. The best that could be done was to solve the equation in zero dimensions, mathematically treating the bomb core as a single point and tolerating the inaccuracy thereof. The exact sub-critical masses of the projectile and target components were thus found experimentally and not mathematically.

If k is greater than or equal to 2.0, the power level rises explosively, and the mass is hyper-critical.[146]

With the 93.5-percent U-235 as used in the W-33, it takes only 14.1 kilograms to do the same thing.[147]

By 1965, they were using the RFYAC-VNIITF nuclear artillery shell and had mercifully shortened its designation to ZBV3.[148]

The Germans did not ask why they needed it.[149]

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[146] Under the hyper-critical condition, it takes 0.560 microseconds to go from zero power to the power of 20 kilotons of TNT going off all at once. That's what we mean by "power level rises explosively." In that fleeting length of time, a little more than half of a millionth of a second, there are 56 generations of neutrons, in which neutrons are "born" from fissioning uranium and are then lost as they crash into adjacent uranium nuclei and cause further fissions.

[147] Or, it could have been any of the other miniaturized, gun-assembly nuclear warheads developed in the United States, including the W7, W9, W19, or, the really tiny one, the W48. I have centered speculation on the W33 because it was the only nuclear artillery round that was made in 1,800 units and deployed widely in Europe. It was the warhead most likely to be found in the illicit novelty weapons market.

[148] There is a rumor, only a rumor, that the Soviets improved the W33 design by making it a "complex gun" assembly. In this design, the cylindrical neutron reflector is actually parked a couple of centimeters away from the impact point of the two uranium projectiles. This allows a further increase in the assembled k-effective (hyper-criticality) by adding the reflective reactivity only after (by microseconds) the core has been assembled. This trick is accomplished using a two-dimensional shaped explosion that does not require three-dimensional lens design or manufacture.

[149] They needed it to boost the CHIC-4. The original W33 artillery shell was rated at 10 kilotons yield unless the fission was boosted by a vial of a few grams of tritium in the center. Tritium, under the stress of being compressed and heated by a collocated nuclear explosion, fuses, releasing a large burst of neutrons, which hasten the fission in the U-235 and amplify the explosion. With the tritium booster, the W33 was rated at 12 kilotons. The Chinese insisted that the CHIC-4 and the Pakistani CHIC-4 derivative bombs were not boosted.

Substituting depleted uranium (mostly inert U-238) for the 93.5-percent U-235, these devices could be proof-tested by detecting a neutron burst upon detonation, caused by crushing the bomb's explosion initiator between the two correctly fired projectiles.[150]

They had developed a light-weight, slim-profile fission weapon using implosion assembly.[151]

For that he got a truckload of Rodong-1 ballistic missiles and the plans for making them with a North-Korean-level economy.[152]

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[150] The initiator, or "modulated neutron source," used in nuclear weapons is technically unnecessary in a gun-assembly weapon. At least one free neutron is necessary to start a chain-reaction in U-235. A neutron is always available from U-238 and U-234 impurities, which fission spontaneously and release neutrons at random. In the Little Boy device with 80% U-235, there were 12.8 kilograms of U-238/234 in the 64 kilograms of uranium, producing a background count of one fission per 14 milliseconds. For a precise detonation time, such as is necessary for air-dropped bombs, waiting for a random neutron to start the reaction does not work, and a neutron source that can be turned on instantly is necessary. This is accomplished by smashing together and mixing a sample of polonium-210 (an alpha particle source) with a sample of beryllium-9, which blasts apart under alpha bombardment and releases neutrons. At least 3 curies of polonium-210 are needed, resulting in one neutron per 100 nanoseconds. Polonium-210 for this "po-be" neutron source is made by bombarding bismuth with neutrons in a nuclear reactor, such as KANUPP.

[151] What exactly was this device? It appears to have been a "linear implosion," which is a lot simpler than a 3-dimensional, spherical implosion, plus it makes a thin bomb that can fit under a fighter plane. The barely subcritical U-235 mass is shaped like a football with a hollow center. To become hyper-critical, it must be mashed into a sphere by being pushed simultaneously at both ends of the football, and the void in the center must be crushed down to nothing, improving the density and the surface-area ratio of the mass. This is accomplished by embedding the mass in a cylinder of high explosive, with a detonator on each end, set off precisely at the same time. (The twin-detonator technology had been worked out for the double-gun design of the original CHIC-4.) An inert wave-shaper is cast in on both ends, between the ignition points and the two ends of the oblong mass. It's not an efficient use of uranium, but it gives you the bragging rights of having developed an implosion weapon. This technology, the W54, was developed by Los Alamos National Lab in 1956, and was famously used in the Davy Crockett recoilless gun and the "back-pack" weapons designed to be carried by one person.

[152] The Rodong-1 is basically a copy of the old Soviet SS-1, and is usually called the "Scud missile." There are, by now, several variations, including the Pakistani Ghauri and the Iranian Shahab-3. North Korea probably got the design from Egypt (Scud-B) or from China (Scud-C) and re-packaged it as a longer distance bomb hauler. Its range is about 900 kilometers. As happened with the CHIC-4 bomb design, the SS-1 design got around.

Oddly, these three bombs were set off simultaneously in underground shafts, probably to shake the ground as much as possible.[153]

Two days later, Shakti 2-1 and Shakti 2-2 were fired, just to make sure that the point was made.[154]
The Earth shook noticeably as a small rock slide started on the Ros Koh Hills, and Chagai 1-1 through Chagai 1-5 disintegrated.[155]

[153] The problem with setting off three bombs at the same time is that they tend to influence one another, skewing test results with neutron cross-contamination. One kiloton of fission yields 3×10^{24} free neutrons. That is a neutron fluence of 1.5×10^{10} neutrons per square centimeter at a distance of 500 meters. Most arrive at a distance in a 3-millisecond pulse, with thermal (slowed down) neutrons arriving much later. Delayed neutrons continue for one minute. Delayed neutrons are only one percent of the total, but that is still 2.5×10^{6} neutrons per second per square centimeter for a one-kiloton explosion half a kilometer away. Solid rock does not stop neutrons. The fact that three weapons were exploded simultaneously indicates that there was more showmanship than science involved with this test. The neutron fluence from weapon detonation is especially important for battlefield use, in which a warhead blast a kilometer away can send an entire stack of safe W33s into super-criticality, instantly heating the barely sub-critical cores and “cooking off” the stockpile all at once.

[154] It is interesting to note that Shakti 2-2 was made using U-233, a derivation of the Indian thorium-cycle power reactor program. It yielded 200 tons, which was probably enough to prove the concept. India has 846,000 metric tons of thorium-232 reserve in the ground, and using it to make U-233 for energy production will make them independent of any other country for power resources.

[155] That, at least, is the Pakistani story. They claimed to have set off a total of 36 kilotons of nuclear explosive in five tritium-boosted fission devices. Western observations put it closer to one device yielding 6 to 12 kilotons.

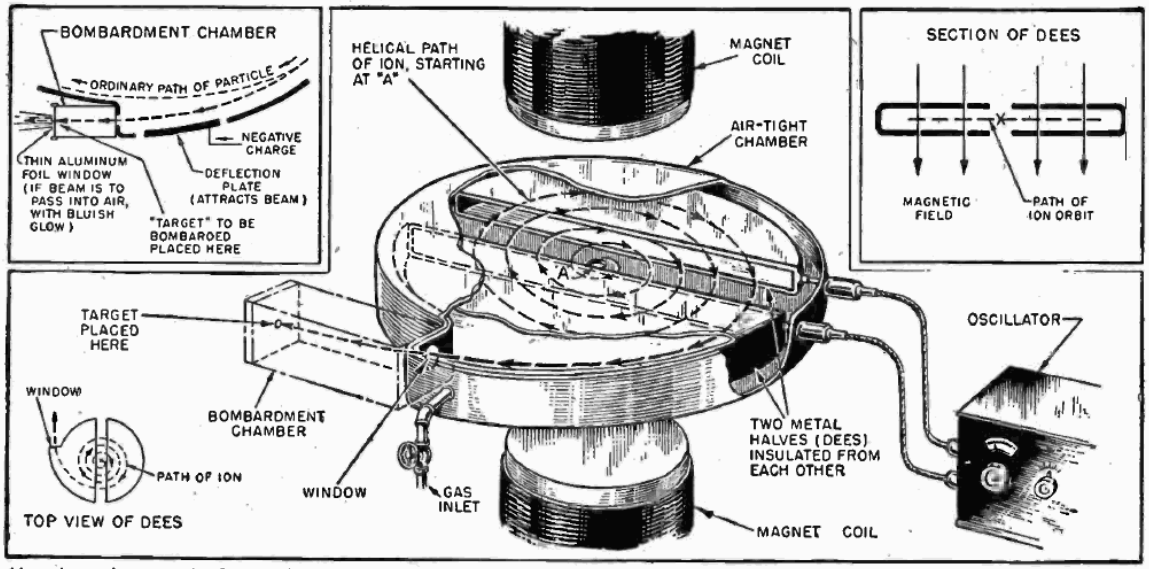
Chapter 7
Japan's Atomic Bomb Project

The navy was equipped with radar, fast and nimble fighter planes, and an unquestioned willingness to die for the Emperor.[156]

In a few years, he was generating 600 megawatts of electricity with the Chosin Reservoir.[157]

[156] When the Second World War started, Japan did have a frighteningly good navy, but the Americans were confident of their superiority to Japan and to the other Axis powers when it came to electronics and communications. After the war, detailed studies confirmed that the Japanese radio equipment was pathetically behind almost everything the Americans used in the Pacific Theater. The Japanese did not even have decent batteries to power their radios, components were not protected against humidity and fungus, and radio coils were wound on cores made of dried mud. There were, however, two stunning developments in Japanese electronics. In 1926 the very advanced Yagi radio antenna had been invented at the Tohoku Imperial University, and Japanese voice transmitters from World War II were equipped with a new type of microphone – the electret. Today, every telephone in the world, including your smartphone, uses an electret microphone, and if you have ever seen a television antenna on top of a house, then you have seen a Yagi. Mounted on the airframe of both the Little Boy and the Fat Man atomic bombs were four, three-element half-Yagi UHF antennae, used by an array of four AN/APS-13 "Archie" aircraft tail-warning radar units. The Archies were used as radar altimeters to ensure a precise detonation altitude, and they would not have worked without the Japanese-invented Yagis.

[157] During the war, estimates of the industrial capacity of Japan were used to dismiss any speculation that they were working on an atomic bomb. The extremely large uranium enrichment effort at Oak Ridge, Tennessee, using electromagnetic calutrons (Y-12), gaseous diffusion (K-25), and thermal diffusion (S-50) required 250 megawatts of electricity as supplied by a string of TVA hydro plants on the Tennessee River. The entire electrical power inventory in Japan was 3,000 megawatts. Adding a 250-megawatt load to the power grid that was already inadequate to keep the lights on in Japan was not an option, but these estimates did not take the Chosin Reservoir into account.



This diagram from Radio-Craft in 1947 shows very clearly how a cyclotron works. The vacuum chamber is set in the gap of a huge magnet, and the vertically running magnetic field in the gap constrains charged particles (deuterons) to run in a circle as they are pulled back and forth by the oscillating electrical field introduced on the right. As the particles gain speed, they spiral out and finally escape out the window.

Ernest O. Lawrence, the professor at the University of California at Berkeley who had built the first cyclotron in 1931, had two of them in operating condition, a 37-inch unit making 8 million electron-volt (MeV) deuterons, a 60-incher doing 16 MeV, and a 184-inch monster that was not completed until after the war.[158]

In Japan, they had five cyclotrons, and one was a replica of Lawrence's 37-incher that they bought from the University of California in 1939, right before things started getting ugly in the Pacific.[159]

[158] The inch-size of a cyclotron refers to the diameter of the flat, circular vacuum chamber in which the charged particles are accelerated. The bigger the chamber is, the more times a particle can go around the spiral before it exits, and therefore the faster it becomes. Also, the diameter of the vacuum chamber determines the size of the electro-magnet gap that must be maintained, and this determines the thickness of the concrete floor under the cyclotron plus the amount of electricity it requires to run. Lawrence's 184-inch cyclotron spun particles up beyond 100 MeV, and it was designed to simulate cosmic rays, confirming the existence of meson particles.

[159] At the end of the war, when the Japanese scientists were instructed to identify their five cyclotrons, they could not put their hands on the fifth unit. It was a 39-incher, built by the Eighth Army Technical Labs in the shops at the Ischikawajima Dockyards. It was probably never finished and was lost in the confusion at war's end. The week before the search for cyclotron number five was conducted, the U S Army had begun the systematic destruction of all cyclotrons in Japan.

Cyclotron-generated neutrons were used for everything from finding the number of neutrons emitted in fast fission to checking the efficiency of uranium enrichment by inducing fission.[160]

Japan was also equipped with excellent research and development facilities for advanced concepts, including the University of Tokyo, Tokyo Engineering College, Kyoto University, Nagoya University, Tohoku University, Chiba University, Osaka University, the Eighth Army Technical Lab, and the Navy Technical Research Lab at Yokosuka. Japan also had the Institute of Physical and Chemical Research, or "the RIKEN."[161]

Japan had been collecting military data from the United States for a long time, and with a new top secret project in place to exploit nuclear fission, the Japanese government was hungry for information about this new endeavor.[162]

Eight Spaniards were imported, each managing a group of operatives.[163]

Valesco drew pay from SIM, the Spanish intelligence service, and in the fall of 1940 he was dispatched to London to be a spy for the Nazis.[164]

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[160]Dr. Lawrence at Berkeley also used the cyclotron-generated fast neutron stream to convert uranium to plutonium, making the first measurable quantity of Pu-239, and he used the intense magnetic field at the cyclotron gap to demonstrate electromagnetic isotope separation. This exercise made a measureable quantity of pure U-235, and it led to the alpha and beta calutron clusters built at Oak Ridge at location Y-12. The Little Boy atomic bomb dropped on Hiroshima was made of uranium enriched using these cyclotron-inspired devices. There is no record of any Japanese use of cyclotrons for plutonium production or experimental electromagnetic separation during the war.

[161] RIKEN is an acronym, made from the first syllables of the two Japanese terms, Rikagaku Kenkyūsho, sounded out in English. RIKEN is still in business, with 3,000 scientists and an annual budget of about $760,000. It relocated to Wako, Saitama Prefecture, just outside Tokyo, in 1963. Scientists at RIKEN investigate everything from terahertz radiation to supercomputer research and development.

[162] Technically, the United States began a government investigation into the military use of uranium fission on October 21, 1939, with the first meeting of the Advisory Committee on Uranium, or the "Biggs Uranium Committee." A budget of $6,000 was grudgingly approved. The organizational meeting of the S-1 Project, which was fully dedicated to the development of nuclear weapons, was held on December 18, 1941, 11 days after Pearl Harbor was bombed. It was eventually named the Manhattan Project.

[163] There was at least one double agent working for the United States out of the American Embassy in Madrid. The FBI and the OSS (Office of Strategic Services) were acutely aware of the Spanish spy rings, and many of the participants were tailed for the entire war, making them nervous and ineffective as spies. OSS formally warned the Joint Intelligence Committee of Spanish espionage on March 10, 1942. There are thousands of pages of documentation in the FBI files and what is left of the OSS files. They are difficult to get to. The FBI code-name for TO was Span-Nip.

[164] Some sources call the Spanish intelligence agency SECED, but this is Valesco's story, and he called it SIM.

They often found his intelligence reports and his expense statements difficult to believe, but they sent them on to Tokyo anyway.[165]

Its purpose was to calibrate the instrumentation for the later atomic blast. The Spanish agents could not help but notice the warnings, and it may have been interpreted as the atomic weapon test.[166] [167]

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[165] Valesco was capable of some taller-than-life tales. He, for example, claimed to have taken Martin Bormann, Hitler's personal secretary, to Argentina, escaping Soviet-held Berlin on May 1, 1945. Artur Axmann, a Hitler Youth leader, remembered it differently, having escaped from Hitler's underground bunker with Bormann at 11:00 a.m. that day. Axmann was sure that Bormann died near the railroad bridge at Lehrter Station, just outside Berlin. Bormann or his remains were nowhere to be found, not even in Argentina, until December 7, 1972, when some construction workers accidentally dug him up near the tracks at Lehrter. Identification of the remains was eventually confirmed by dental records, facial reconstruction, and definitively by DNA matching with his living children.

[166] There is a problem with this account. Valesco did not mention this incident in any of his post-war books or articles, and it just came out when he was specifically questioned about atomic bomb espionage. If he was bounced out of North America on July 4, 1944, then he was not around to manage spy-craft in New Mexico when any large-scale explosions were happening. The data-collection method makes perfect sense, and it seems that this misreading of an explosion test is in agreement with Japan's initial response to the Hiroshima bombing on August 6, 1945. The military was so certain that the Americans did not have an atomic bomb, it was hard to come to grips with the fact that Hiroshima had just been destroyed by one. Valesco may have acquired the story by swapping war-stories with one of his fellow Spanish spies long after the war. The other guy was too reluctant to claim it in writing, but Valesco had no such qualms. No other Spanish intelligence accounts are as easy to get to as are Valesco's. Or, maybe it never happened.

[167] This test-shot on May 7, 1945 actually contained a radioactive sample. A spent fuel slug from the Hanford B-reactor was dissolved in acid and placed in a sealed glass container at the center of the explosive pile. It was 1,000 curies of beta activity and 400 curies of gamma activity from a mixed bag of fission products, uranium-238, and what remained of the small percentage of uranium-235. The purpose of this sample was to test radiation instruments in place at the Trinity Site, and, technically, it was the first "dirty bomb" ever exploded. The radiation sample was dangerous to handle in its concentrated condition, but when the explosive pile went up, it was spread evenly in an aerosol across square miles of desert. In this modified concentration, it was indistinguishable from background radiation, and it did not show up as harmful radiation contamination on the two test subjects.

Glued to each can was a brown paper label. On the labels was "U235", in Japanese script.[168]

On May 10, the surrender order from Dönitz was received by radio, and the course was changed, heading west towards the United States.[169]

From what the Alsos team could tell by translating truckloads of reports, memos, and material requisitions, the German research and development seemed inadequately organized and lacking certain expertise.[170]

The story was difficult to believe, but other stragglers were giving similar accounts of the off-shore A-bomb test.[171]

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[168] So says the account by Lt. (jg) Karl Pfaff, who had directed the loading of U-234 at the port of Kiel and was taken prisoner upon surrender. There is a conflicting report by Wolfgang Hirschfield, the radio operator, who claimed that the uranium oxide was contained in lead cubes. The "gold-lined" cans version is supported by the personnel who x-rayed the containers before opening them with an acetylene torch, but the gold lining story does not make sense. The Germans were technical show-offs, but not to that extent. The cans were probably treated inside with an iridite-chromate process to prevent the uranium oxide from reacting with the aluminum. The treatment looks just like dull gold plating. (The Islamic shrine, Dome of the Rock, in Jerusalem was roofed with iridite-chromate treated aluminum in 1963. It was replaced with 24K gold leaf in 1993, and both treatments look about the same.) The "U235" labels did not mean that the uranium was the pure, fissile isotope. It was natural uranium, with no U-235 enrichment. The x-rays revealed what looked like a stick of TNT in one of the cans, and a booby trap was feared, but Pfaff assured the Americans that it was only a wooden stick, used to tamp down the uranium oxide powder and was somehow left in the can.

[169] On May 8, 1945, another radio transmission was received reporting that the Togo government in Japan had severed all relations with Germany and was now arresting all German citizens. The boat was turned around and was prudently headed back to Bergen, Norway.

[170] The ultimate prize of the Alsos Mission was the German heavy-water reactor hidden from Allied bombing raids in a cave under the cathedral in Haigerloch, Schwabian Alb, Germany. A first impression of the reactor setup was that the Germans were lucky that the thing was incapable of working. It was inadequately instrumented and had no controls of any kind. If it had somehow gone critical, it would have quickly killed everything in the cave, down to the bacteria on the floor.

[171] There is an eerily similar story of a German A-bomb test, within days of the German surrender, near Rügen Island, off the coast of Pomerania in the Baltic Sea. Again, the Soviets were right there soon after, and everybody had to demolish the equipment and flee. One soldier escaped and lived to tell the tale. These stories seem fabrications by the vanquished, claiming that they had all the technical ability of the Americans as well as the determination, but they were morally superior to the Americans and therefore did not use these terrible weapons against human beings. This story is not backed up by any German accomplishment. During the war, they could not make a simple, self-sustained chain reaction, much less an explosive one.

Snell never revealed the real name of the Japanese officer who had given him the story.[172]

At almost exactly the same moment, on April 10, 1940, the first meeting of the MAUD Committee met in Great Britain, to plan how they were going to use nuclear fission for military purposes.[173]

This war was going to be one quick, massive takeover of the Pacific, and it would be over before they could make significant headway in nuclear power research.[174]

Finally, in July 1941, RIKEN was given a contract and a budget to develop nuclear weapons.[175]

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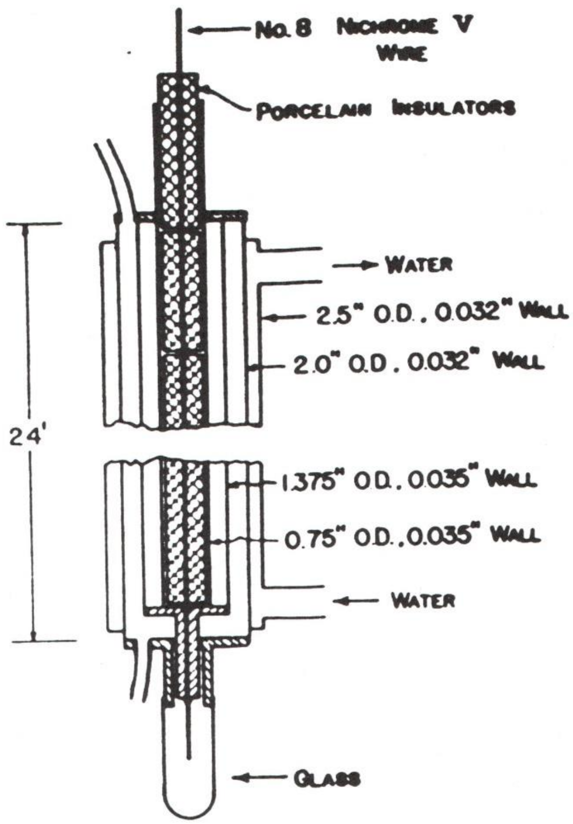
[172] Without naming a credible witness who could be further interviewed, Snell's sensational story could not be confirmed, and it was generally considered to be a hoax. The Army did not step forward with any information to support it. In January 2014, Dwight R. Rider, a Senior Intelligence Associate with Intelligence Decision Partners of Virginia, published his impressively researched paper, *Tsetusuo Wakabayashi Revealed*. In it he makes an excellent case for identifying Lieutenant Colonel Tatsusaburo Suzuki, physicist, Imperial Japanese Army, as Snell's source, working under the pseudonym of Tsetusuo Wakabayashi. Suzuki graduated from Tokyo Imperial University in physics. Although he was in the Imperial Japanese Army, he was attached to the RIKEN, a non-government institute, after graduation. There he worked with Yoshio Nishina, the most honored physicist in Japan, and he was tasked with writing a plan for the development of atomic power in April 1940. Tracing his whereabouts as the war ended, Rider makes a convincing argument that Suzuki was the man who told Snell about the A-bomb test. Suzuki's obvious participation in the beginning of the Japanese nuclear weapons effort will be detailed shortly.

[173] Although the committee met on April 10, 1940, the name MAUD was not adopted until June of 1940. It was not meant to mean anything, as is appropriate for the name of a top-secret operation, but it later came to mean "Military Application of Uranium Detonation."

[174] The Japanese bomb project was unlike the American effort but similar to the German work, in that it was scattered and divided, with different factions competing for the same limited resources and having divergent goals. In the United States, we had one military commander, Leslie Groves, in charge of everything, and the entire mammoth undertaking was focused on one outcome. A Japanese project did pursue a nuclear reactor design, but the only thing that was eventually built was a cardboard scale model, made by Professor Eizo Tajima, a neutron specialist. A problem was the availability of heavy water, thought to be necessary for the moderator material in a natural-uranium reactor. Heavy water was produced at the fertilizer factory in Konan, similar to the German source in Vemork, Norway, but the output was in 20-gram batches. For a reactor, they needed to start with 5 tons of it. The heavy water produced in Korea was used as a source of deuterium, the projectiles that were cyclotron-accelerated to make neutrons by striking a beryllium target. There is no record of criticality experiments in Japan using heavy water moderation.

[175] It is difficult to pin down the amount of money spent by the Japanese government on the atomic bomb project at RIKEN. The best estimate is ¥20 million, or $35 million in 1940s dollars. In war-time Japan, that was a lot of money, but in America the Manhattan Project spent $2 billion (1940s dollars) in the same length of time. To put that large number in perspective, $3 billion was spent to develop and test the B-29 strategic bomber that dropped the atomic bombs.

He was given ¥50,000 ($125,000), priority assistance from the 8th Army Technical Lab, and his choice of 10 young men from universities, each to be given a draft deferment.[176]



A 24-foot-tall thermal gas diffusion column, as described in Physical Review in 1940. The isotope separation device used in Project NI was based on this design.

Purified U-235 gas would be drawn off the top of the column.[177]

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[176] At that time, Enrico Fermi was spending $2.7 million to build CP-1, the world's first nuclear reactor, in Chicago. Nishina should have mentioned that he also needed a few tons of metallic uranium.

[177] Instead of picking one of the possible isotope separation methods, the American bomb project tried them all at once. The first method to work was the thermal diffusion column, but the American version used liquid diffusion instead of gas diffusion, and the innermost tube was heated by steam and not electricity. The thermal diffusion separation plant at Oak Ridge, S-50, was a 21-stage cascade, and when working perfectly could improve the concentration of U-235 in natural uranium (mostly U-238) from 0.720 percent to 2.0 percent. It was better than nothing, and it was used to feed the gaseous diffusion plant (K-25), which improved the separation product up to 20.0 percent U-235. The output from K-25 was then sent to the electromagnetic (calutron) separator plant (Y-12) where in two stages, alpha and beta, the separation was again improved up to 84.0 percent U-235.

They had no pure carbon on hand, so they decided to make some by burning sugar.[178]

The American team doing the same thing took 36 hours.[179]

He had too little experimental data to pin down a critical mass, but he predicted that a U-235 enrichment level of 10 to 20 percent would be necessary.[180]

After a lot of debate, the design team had decided to make it out of copper, so that the highly corrosive uranium hexafluoride gas would not corrode it, and the gap between the hot and cold walls, where the gas would separate into light and heavy molecules, was only 2.0 +/-0.1mm.[181]

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[178] Unfortunately, sugar was an expensive, strategic resource, and it had to be flown in from Formosa. As they perfected the carbon reduction, batches of sugar would disappear overnight from the lab. People were sneaking small quantities to take home. Kigoshi found that common starch could be used instead of sugar to derive carbon, and the supply problem was solved.

[179] While researching this incident, I noticed an important mistake in this procedure as described in Army interrogations of the researchers. The Japanese researchers had not, in fact, produced uranium hexafluoride gas. They had, instead, made uranium tetrafluoride, which is called "green salt" in the nuclear business. Green salt is a solid at room temperature, and it must be vaporized with heat to make a gas. Uranium hexafluoride (hex) is a gas at room temperature, and it is made by heating green salt to 320 degrees Celsius in fluorine gas. For the purposes of thermal diffusion separation of isotopes, there is a big difference between the two substances. The green salt vapor will condense on the cold pipe surface in the separation tower instead of exiting out the top port. This explains all the trouble that the project was in for trying to separate U-235. I don't think that this problem had been noticed before, at least in print.

[180] Was it possible to build an explosively assembled atomic bomb with only 20 percent U-235? The L-11 "Little Boy" bomb that destroyed Hiroshima was built using 80-percent enriched uranium metal, explosively assembled into a cylinder 6.5 inches in diameter weighing 64 kilograms, making nearly three critical masses. A single, fast-neutron critical mass of 80-percent enriched uranium, beryllium reflected, is 19.3 kilograms, and the bomb required 3.3 times as much material. A critical mass using 20-percent enriched uranium (beryllium reflected) is 245 kilograms, or an explosive, hypercritical mass weighs 809 kilograms. That is 1,784 pounds, just for the bomb core. Explosive assembly of the Little Boy required a 6.5-inch ack-ack gun barrel. Assembly of Tamaki's weapon would require a 15-inch naval gun weighing many tons. In World War II, there was not an airplane or torpedo boat in the world that could carry such a bomb.

[181] The design was almost a direct copy of a thermal diffusion column described in *Physical Review*, volume 57, from 1940, but that column was 24 feet high and the gap between the hot and cold walls was 16mm. The team in Japan reasoned that they could get better isotope separation in one stage by making the gap very narrow, and their building was not tall enough for a 24-foot column. The American version, using a liquid solution instead of gas, was made of pure nickel.

Back in 1938 he had been put in prison by the "thought police" for being a communist, but had been released to work for Sin-Itiro Tomonaga, a famous scientist.[182]

A window was added, so they could watch the gas swirling around in convection currents.[183]

Sagane had an international reputation, to the extent that American scientists later in the war had a B-29 drop a letter on him appealing for the surrender of Japan.[184]

A static magnetic field at the top was supposed to stabilize it and dampen vibrations.[185]

The theoretical work in F-go was performing well, with Hideki Yukawa, a future winner of the Nobel Prize in physics, in charge.[186]

[182] Sin-Itiro Tomonaga shared the Nobel Prize in physics with Richard Feynman and Julian Schwinger in 1965 for having developed quantum electrodynamics. He worked at the RIKEN with Nishina after graduate school, and during the war he worked on magnetron vacuum tubes (for radar transmitters), meson theory, and his "super-many-time" theory, which sounds like something Feynman would have done.

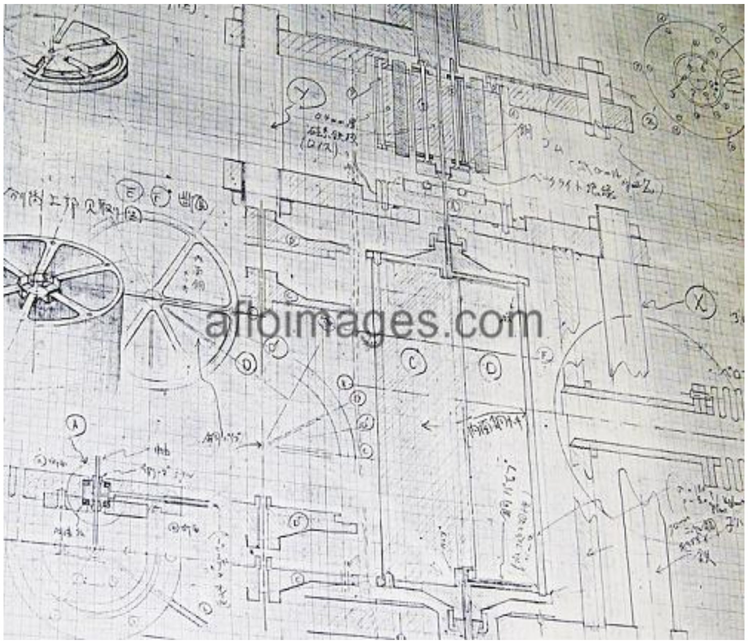
[183] Having a window to watch the gas was a bit odd. Gas is invisible. What they were watching was uranium tetrafluoride vapor in which molecules were bound together into visible droplets, like the "steam" from a teakettle. In this clumped state, molecules of different weights cannot be separated by diffusion. They had put the cold and hot walls so close together, the cold wall was above room temperature and the vapor did not condense in the column, so it appeared to be working.

[184] It was an interesting idea, to avoid massive destruction and loss of life by convincing a renowned scientist that resistance was futile, but despite Segane's world-wide fame in science circles, Japan was not his to surrender.

[185] This was an interesting design, different from what the Germans were working on during the war and what would become the standard ultra-centrifuge configuration of the 1990's, as is now used in certain Middle Eastern countries. The flattened, large-radius rotor would probably have self-destructed at the very high angular velocity. (Newfound documents indicate that the rotor was to be made of super duraluminum, a fairly exotic alloy at the time.) It has since been found that the only way to make this device is to use tall, thin rotors instead of short, fat ones. Instead of hoping for complete separation in one stage that breaks the sound barrier at the rotor rim, it is better to have a cascade of many rotors running at a less dangerous speed. Using air-bearings and a stabilizing magnetic field, however, were definitely a correct way to do it.

[186] Hideki Yukawa won the Nobel Prize in physics for having predicted the existence of the meson particle, explaining the relationship between the proton and the neutron. In 1943 the Japanese government, as the world was beginning to come down around it, awarded him the Decoration of Cultural Merit. In 1977, he was named the Grand Cordon of the Order of the Rising Sun. He died of pneumonia at his home in Kyoto in 1981 at the age of 74.

“Couldn’t we do something with thorium?”[187]



Plans for the centrifuge, discovered recently in the Kyoto University library.

The “2” meant “Visual effects greater than Trinity,” “6” was “Hiroshima primary target,” and “9” was “Conditions normal in airplane, proceeding to regular base.”[188]

There were no cyclotrons in Korea. Nobody noticed any nuclear physicists missing after the war, having been spirited off to Moscow for questioning.[189]

[187] There was a thorium factory in Niihama on the Japanese island of Shikoku, making lantern mantles. The one thorium isotope occurring in nature, Th-232, is not fissile. However, it can be neutron-activated into a uranium isotope, U-233, which is fissile and can be made into a bomb. No isotope separation would be necessary. If they had a decade to work on it with no American bombing missions, they could have done something with thorium.

[188] I have never found the hand-written cypher cooked up by Parsons and Ferrell, but one can imagine that the message “A0000” would mean something like “Unable to reach primary or secondary target; all four engines on fire.”

[189] The chances of a nuclear physicist of any nationality surviving the global conflict of World War II was about 100 percent. It was not until a few days after VJ Day that we started losing them to criticality accidents.

Chapter 8
The Criminal Use of Nuclear Disintegration

There is no available evidence that the concept of radioactively poisoned food went any farther.[190]

A live human being is made mostly of water, so it would seem that a good way to kill somebody at a distance is to hit him with a beam of microwaves and boil him inside out. Research proved inconclusive.[191]

A tungsten-rhenium filament, coated with a dried pyrotechnic paste, ignited the zirconium by connection to a piezoelectric crystal struck with a cocked hammer, similar to a butane lighter ignition.[192]

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[190] This document seems odd and out of place in the steady stream of important letters bouncing around the country during the hectic days of the Manhattan Project. It is vague and wordy, but there is obvious effort to mention several people, including theoretical physicist Edward Teller, Harvard president James Conant, General George C. Marshall, Nobel Prize winner Arthur Compton, medical physicist Joseph Hamilton, director of the Metallurgical Laboratory Samuel Allison, and director of the Chemistry Division of the Met Lab, James Franck. No documented response or follow-on to this letter seems available. It is almost as if it was a dummy proposal, meant as a test to find any security leakage. This was definitely a tactic used during the war, to drop a false letter-bomb into the stream of communications and listen for an immediate response from Japan or Germany in encrypted messages. In this case, it may well indicate a security leak. The Japanese military was never convinced that the United States had an atomic bomb, but they were braced for an attack using gravity bombs and artillery shells filled with radioactive poisons.

[191] The only useful thing related to these projects was the microwave oven. Although the formal military projects remained classified, Navy personnel could not help but notice that the way to clear birds off a radar antenna, which blasts out hundreds of watts of pulsed microwave power, is to turn it on, which makes them instantly flop over dead. The dead birds falling on the deck appeared cooked and ready to eat. The microwave oven was patented by Percy L. Spencer of Raytheon on October 8, 1945, when he noticed that a candy bar melted in his pocket when he got too close to a radar transmitter being tested on a bench. Microwave ovens were used to make food in cramped submarine galleys long before the Radarrange became a popular accessory in American kitchens.

[192] The effect is very similar to an old-fashioned flash bulb, once used as a light source for indoor photography, but flash bulbs used crumpled magnesium wire or, in the most powerful bulbs, magnesium foil. The zirconium foil gives a 3-fold increase in the specific light energy over magnesium, with a 5 to 10 millisecond burn at 5,000°C. Certain metal salts are added to the zirconium foil to skew the light spectrum toward the absorption resonance of the laser medium.

The project was abandoned, American astronauts were invited to stay at the Mir while their bigger space station was being constructed, and the military academy was renamed for Peter the Great.[193]

Uranium is much heavier than a like volume of lead, and its density makes it an excellent radiation shield.[194]

Two years later, in May 2001, a similar thing happened in the Kandalaksha Nature Preserve near Murmansk, Russia, when four scroungers stole the radio-thermal generator out of a lighthouse and tried to remove the three strontium-90 radiation sources, each producing 35,000 curies of radiation.[195]

There were two metal signs on the gate, painted yellow with the international symbol for radiation in purple and the warning, in Estonian: DANGER RADIATION.[196]

It was only three centimeters long. This was a 190 curie (7 TBq) cesium-137 radioactive source, producing a dose rate of 250,000 rem per hour at a distance of one centimeter from the cylindrical source.[197]

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[193] This was not the only laser side-arm in the works. There was also a smaller revolver version, having six flash-lamps in a cylinder that would rotate into position and activate a ruby-rod laser. The flash was ignited by a percussion cap instead of an electrical pulse from a piezoelectric crystal. There may have also been a single-shot derringer version that a cosmonaut could keep hidden in a pouch on his right boot. It was rough out there in space. These devices are now on display in the Peter the Great Military Academy museum in Moscow.

[194] Larpen of Texas actually had three radiography "cameras," used to expose x-ray film to find hidden flaws in steel. The radioactive sources were shielded so as to direct gamma rays out a small opening in the front of the device, and a shutter would close when it was not in use, protecting people from the directed rays. The third camera used iridium-192, but it was old, and its radiation source had decayed down to the point where it was no longer useful or even terribly dangerous.

[195] There were actually eight different types of radioisotope thermal generators used in lighthouses in the Soviet Union, ranging from the Beta-M, generating 10 watts of electricity and 230 watts of heat, up to the IEU-1M, making 120 watts of electricity and 2200 watts of heat. The Beta-M weighed only 560 kilograms, and it was the easiest one to steal. The IEU-1M weighed about 2,100 kilograms, and it was just too bulky to make off with. The electricity from a radioisotope thermal generator is made by heating up one side of a thermocouple array using a strontium-90 heat source, made into a hard, ceramic block, and cooling the other side with air moving by convection over a circle of fins. There are no moving parts. A shield made of depleted uranium is supposed to protect handlers from the strontium-90 radiation. The 10 watts provided by a Beta-M was almost enough to run a small fluorescent light, warning ships in the dark several meters away.

[196] Signs cautioning about the dangerous presence of radiation are officially available in most languages, including Klingon.

[197] "TBq" is short for terabecquerels, or trillions of Becquerels. One Becquerel is one nuclear disintegration per second.

Eight crimes were committed using cesium-137, five using cobalt-60, four with iridium-192, two with strontium-90, two with phosphorus-32, and one each with polonium-210 and californium-252, which wins the prize for the most exotic nuclide used as a weapon.[198]

Eight months after the second divorce, on November 18, 1971, the oil well logging and perforating service involving Crocker was granted a license to have one curie of cesium-137 for wireline well logging.[199]

The victim rode around for five months with gamma rays impinging on his left thigh, soaking it down with a cumulative dose of 6,500 rads. (A 1,000-rad exposure is considered fatal.)[200]

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[198] The case of californium-252 used for an attempted murder in Riga, Latvia, on August 18, 1988, is insufficiently documented for inclusion in this chapter, but the successful use of polonium-210 as a poison on November 1, 2006, the murder of Alexander Litvinenko, has been publicized to the point where there is nothing I can add. I recommend the book, *The Litvinenko File: The True Story of a Death Foretold,* by Martin Sixsmith. Macmillan, 2007. I agree with the author's analysis and his conclusions.

[199] For gas and oil well drilling, a nuclear wireline log is a record of the gamma-ray backscatter intensity from a fixed radiation source into a Geiger-Mueller counter probe, slowly lowered into a drilled well on a steel wire. The amount of backscatter indicates the level of porosity or the density of the rock in the hole along its depth, usually recorded on a strip-chart or stored as a digital recording on a portable computer. It is particularly useful for mapping the shale beds in a drill-hole. A layer of shale makes a tight cap over an underground oil or gas reservoir, and its presence indicates that you are drilling in the right place. The shale is unusually solid and impermeable to oil, and it gives an enhanced gamma backscatter over sand or broken rocks. A nuclear log has an advantage over other methods of shale-finding, in that the gamma-rays from cesium-137 can penetrate the steel pipe that lines a cased well and feel for the quality of the rocks on the other side of the tube-wall. Crocker was an independent consultant at the time, and he was employing Sidney Morrison's well logging company for oil drilling jobs. Without his knowledge, Crocker made a copy of Morrison's radioactive source license and used it to justify access to the controlled cesium-137 pellets on demand.

[200] A rad is one erg of energy from radiation deposited in one gram of matter. It is considered an obsolete measure of accumulated radioactive dose, but it was in use for so long, used in so many thousands of nuclear physics documents, it remains a familiar measure. The more current, SI measure is the gray, which is equivalent to 100 rads. The rad (or the gray) is used to express the amount of radiation absorbed by anything solid. To more accurately express the amount of radiation absorbed by a human, the rem (radiation equivalent man) can be used, or the current SI unit, the Sievert. To improve a rad or gray measurement into to a rem or a Sievert, it is multiplied by a fudge factor that takes into account the biological damage specific to the type of radiation involved. The "quality factor" for alpha particles, for example, is 20. Neutrons have a quality factor of 10, and gamma rays, x-rays, and beta rays have a quality factor of 1. When discussing radiation damage by gamma rays, one rad is the same as one rem. Further rem improvements can involve taking into account the sensitivities and vulnerabilities of individual human organs or the age or gender of the subject, but for post-exposure estimates of whole-body exposures to radiation, the quality factor based on radiation type is as good as can be expressed.

Chapter 9
The Threat of the Dirty Bomb

The total number of visible light photons released is proportional to the number of gamma rays it absorbed over the dosage period.[201]

Using these objects as opportunistic dosimeters, the Russians were able to map the radiation levels everywhere in the house, from the bathroom to the veranda.[202]

Victoreen kept building them, stacking them on shelves, developing better and more sophisticated instruments, and waiting for that special moment when everyone would need an R-Meter.[203]

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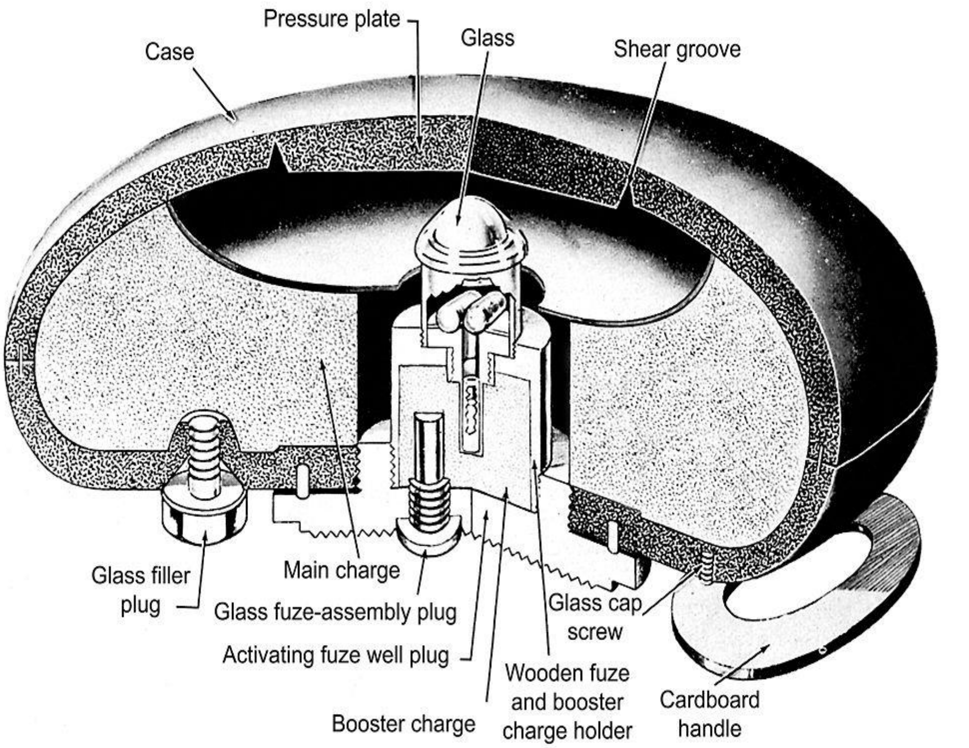
[201] Yellow calcite, a polymorph of calcium carbonate, is unusual in that for it, room temperature is the heated condition under which it will glow, releasing the light from gamma-ray exposure. To turn off the light, put the calcite in a refrigerator. It will go dark but retain the gamma-image indefinitely under this condition. Bring it back to room temperature, and it starts to glow until all the trapped quantum states have resolved. In complete darkness, you can read a newspaper with a calcite crystal that had been exposed to 200,000 curies of cobalt-60.

[202] The Russians also used electron paramagnetic resonance and chemiluminescense on samples of sugar in the kitchen, medicines in the bathroom cabinet, and mollusk shells on a decorative basket in the den as dosimeters. These methods are not as well developed as thermoluminescence, but using these exotic methods allowed the Russians to assert state-of-the-art expertise. The electron paramagnetic resonance phenomenon was first observed in the Soviet Union at the Kazan University in 1944, when it was the evacuation site for scientists fleeing Moscow during the German invasion of World War II.

[203] This type of instrument is now called a capacitive ion chamber. Victoreen was not the only manufacturer. The other was the National Bureau of Standards in Washington, D.C. They built hand-held instruments on a non-commercial basis. An excellent example with interchangeable radiation probes was the Lauriston Ion Chamber, developed by Lauriston Sale Taylor at the NBS. At least one Lauriston was supplied with the 29-inch cyclotron sold to Japan from Berkeley, California, right before World War II, and that instrument may have been their only hand-held radiation meter until after the war. They were supposed to use it to confirm radiation produced by the cyclotron, instead of peering into the deuteron exit port. Reports of Japanese scientists poking around in the Hiroshima debris with hand-held Geiger counters as the smoke cleared are mythological, but they probably used the Lauriston to confirm the presence of radioactive ground contamination. It was called the Lauriston instead of the Taylor because Lauriston was a much more interesting word. Taylor, who worked in radiation research all his life, died at the age of 102 in 2004.

It was a Geiger counter.[204]



The Topfmine. It is made of wood fiber, cardboard, glass, and wood, and it is therefore invisible to a metal detector. It was painted black, and the gritty inclusions in the paint were radioactive. It was not meant to contaminate the tank crew, but made it easy for the Germans to find their own mines.

[204] Information on the mine from intelligence sources probably referred to the *Topfmine A*, To.Mi.4531, also called the *Pappmine* (literally, cardboard mine). The hand-held mine detector, used by German troops walking slowly ahead in front of the tanks, was the Stuttgart 43 detector, which had both a metal-detecting head and a simple Geiger counter on a seven-foot pole, so that it could detect both German and Allied mines. The *Topfmine* had an additional advantage over steel or cast-iron mines. The Germans anticipated that after the war was won, all the hundreds of thousands of mines buried at 7-foot intervals on the Siegfried Line, which was 390 miles long, would have to be dug up and deactivated so that farming could resume. That would be an arduous, budget-killing task if the mines were the usual metal cans, but the *Topfmines* were biodegradable. They would last a couple of years in the field, which was the expected duration of World War II. Water would eventually seep in through a groove in the top of the case, eventually deactivating it, and the wood-pulp case would crumble into dirt, so it would not blow up a tractor tilling the soil. There was also a version fully waterproofed with tar for more permanent installations, the To.Mi.A4531. The radioactive tracer was incorporated into the black paint on the mine, called *Tarnsand.* The tank-mounted radiation detector that was assumed to exist by Allied analysts was not implemented.

A new program was organized to find the buried German mines, code-named Project Dinah.[205]

The idea of marking buried mines with radioactivity was good, and an Army program to do the same with the Allied mines was named Project Mamie.[206]

On television, every program, be it comedy or drama, had a Geiger counter in it, from the *Amos 'n Andy Show* to *I Love Lucy*.[207]

The author's gold-plated PRI Model 118 Royal Scintillator, tastefully presented in a leather-covered case, is one of two working examples known to exist.[208]

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[205] Rumor has it that the project director liked Dinah Shore, who was a very famous singer at the time. The British had a program with a similar goal, finding the hidden German anti-tank mines, but they used dogs trained to smell out the fumes from the TNT as it degraded in the leaky, cardboard mines.

[206] Possibly named for General Eisenhower's wife, Mamie? She did not resemble Dinah Shore. The U. S. Army did not actually deploy any non-metallic mines until 1955, when 1.5 million plastic anti-personnel "blast-type" mines, the MINE, APERS, MN, M14, were manufactured and stockpiled. It took ten years of experimentation to be convinced that we needed mines that could not be found with a metal detector. As a rule, all other U.S. mines were made of steel.

[207] The episode in which Lucy, Ricki, Fred, and Ethel join Fred McMurray to find uranium in Las Vegas, Nevada, "Lucy Hunts for Uranium," was actually on the *Lucy-Desi Comedy Hour* in 1958. The *Amos 'n Andy* episode, "The Uranium Mine," was one of the last filmed in 1955. Jack Benny had a Geiger counter in "Jack Hunts Uranium," in 1955, Phil Silvers held his on *The Phil Silvers Show*, "Big Uranium Strike," in 1956, and George Burns and Gracie Allen had their turn on the *Burns & Allen Show*, "The Uranium Caper," in 1955. Everybody, it seemed, had a Geiger counter.

[208] It certainly *looks* like it is gold plated, but it is not. The finish on the aluminum parts is irridite, the same surface process used on the aluminum cylinders filled with uranium oxide that were surrendered to the United States in 1945, from the German submarine U-234.

Their first release was PRI-3002, *David Pell Plays Harry James' Big Band Sounds.* For radiation instrument manufacturing, the big game was over.[209]
Hospitals will be overrun.[210]

Fortunately, polonium-210 is hard to get, and, so far, only a government has access to usable quantities.[211]

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[209] The popular market for radiation detection instruments in the 1950s was similar to the present combined demand for smart cellular telephones, iPads, Kindles, and laptop computers. It was a big market, and it was a shock to the system when it dried up in 1960. There was still a demand on a smaller scale for radiation detection equipment for nuclear power plants, hospitals, and laboratories. There was also a new market for mass-produced "Series CD V-700" Geiger counters, ionization chambers, and dosimeters for the Civil Defense Administration. Several manufacturers participated, including what was left of the Victoreen Instrument Company (it had been sold to General Electric), Universal Atomics in New York City, Bendix, Anton Electronics Labs, Chatham & International Pump and Machine Works, Electroneutronics Inc., Nuclear Measurements Corp., Nuclear Chicago Corp., Jordan Electronics, and Lionel, the maker of toy electric trains.

[210] The model demonstration of this psychological phenomenon is the Goiânia Incident in Brazil, beginning on September 13, 1987. Metal thieves Roberto dos Santos Alves and Wagner Mota Pereira broke into an abandoned radiotherapy clinic in downtown Goiânia and found a big cancer teletherapy machine just sitting there. They found the valuable-looking core of the machine, removed it, and moved it to Alves's house. It contained a 1,375-curie cesium-137 gamma-ray source. Later that day, both men exhibited symptoms of radiation poisoning, but trips to the hospital did not diagnose it as such. They eventually managed to puncture the nested stainless steel source capsules and release the powdered ceisum-137-choride. It glowed blue, and on September 18 they were able to sell the exotic substance to a scrap yard, owned by Devair Alves Ferreira. Thinking it supernatural, he brought it home to show his wife, Gabriela Maria, and all his friends were invited over to see the magical glow. His 6-year-old daughter, Leide das Neves, spread it over her body, causing her to glow like a fairy princess. On September 28, Gabriela Maria noticed that everyone around her was getting very sick, and it had something to do with that metal thing that her husband had brought home. She gathered up as much of the glowing powder as she could, put it in a plastic bag, and took it to the local hospital. The next morning a visiting physicist pointed his scintillator at it, and its rate meter slid off scale. By the end of the day, news of the stolen gamma-ray source was known internationally. The news media in Goiânia made certain that it was known locally, describing the symptoms of acute radiation poisoning. By that afternoon, 130,000 people were nauseated and dizzy, fearful that they had radiation exposure, and were jamming every hospital emergency room. The government had to use the Olympic stadium as a medical facility. Eventually, 249 people were found to be contaminated, 20 people were treated for radiation sickness, and five people died. The first death was the daughter, Leida das Neves Ferreira, on September 28. At her burial, 2,000 people rioted and tried to block the cemetery road using bricks and stones, fearing that her corpse would poison the water supply. Contamination was eventually found on two scrapyards, a hospital, 42 houses, 14 automobiles, three buses, five pigs, and 50,000 rolls of toilet paper.

[211] The principal industrial use of polonium-210 in the United States is the StaticMaster anti-static brush, manufactured by Amstat Industries, Inc. It is a soft brush with a 0.00025-curie polonium-210 alpha particle source at the base of the bristles. The heavy alpha flux from a recently purchased StaticMaster will vigorously neutralize the free electrons (static electricity) on a smooth surface. This device was very popular when photo enlargements were made from film negatives, as it was the only sure way to sweep the dust off the negatives. They are still used in high-tech industries in which any hint of dust must be eliminated. A replacement polonium cartridge sells for $134.

A CD V-700 Geiger counter, which is often available on eBay, is a good, usable low-level radiation detection device.[212]

[212] The CD V-700 is the only Civil Defense radiation instrument that is actually a Geiger counter. There are many other V-7XX units for sale, but they are all ionization chambers. The Geiger counter is 100 times more sensitive to gamma and beta rays than any ionization chamber, and it is appropriate for finding residual radiological contamination. Professional-grade Geiger counters, such as the Eberline E-120, are available as surplus, but they are usually sold without the probe assembly, which is what wears out when in constant use in a nuclear power facility. The probe is the expensive part, and installation of a new one will require calibration. The “Smart Geiger” sold for use on an iPhone or Android by FTLABS is interesting, but it is not a Geiger probe. It is a PIN diode. While it is sensitive to gamma radiation on a linear scale and it makes use of the telephone’s computer to integrate a dosage, its sensitivity is inferior to an ion chamber. Smart Geiger plugs into the earphone jack. If you get a phone call while using the FTLABS app, the ring will feed back through the microphone contact, and gamma counts will pile up rapidly, appearing that someone has just slipped a cobalt-60 source into your pocket.

Chapter 10
A Bridge to the Stars

We call them "insects," a class of life for which he could see no evolutionary reason for existing, so they must have come here from outer space.[213]

In just the last decade, improved optical telescope technology has taken us a step further, discovering planets orbiting far-away stars and indicating that they are not a local fluke.[214]

Bright objects in the Universe, as it turns out, emit radiation over the entire electromagnetic spectrum, from gamma rays to radio waves, and we had only been seeing them using a tiny slice of this spectrum, the visible light.[215]

Please hang on.[216]

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[213] Fred Hoyle died in 2001 at the age of 86. He was also a science fiction writer, and his book *The Black Cloud*, released in 1957, was critically acclaimed. One of his better quotes is, "It's better to be interesting and wrong than boring and right." Enrico Fermi was 53 years old when he died in 1954, a year before his patent for the nuclear reactor was declassified. A street in Rome, Italy, is named for him.

[214] The first discovery of an exoplanet was actually made using a radio telescope. In 1992 Alexander Wolszczan and Dale Frail discovered something large orbiting pulsar PSR 1257+12 and periodically getting in the way of the radio signal coming from the pulsar. A pulsar is actually a ruined star that has blown up in a supernova and left an energetic remnant. The radio-occluding object must be what is left of a giant, rocky planet that was sterilized in the supernova event. Since then, Earth-type planetary searches are carried out by the Kepler Space Observatory telescope, launched into solar orbit by NASA in 2009.

[215] Electromagnetic energy is released into the nuclear-powered Universe in a very wide spectrum of frequencies and energies, from infrared light to extremely high-powered gamma rays. This spectrum of available photons from the sky has a peak right in the middle of the visible light spectrum, right at the color yellow-green, and falls off to lesser intensities as the frequency trends higher and lower on either side of the peak. Yellow-green happens to be the most sensitive part of the narrow visible light spectrum for our eyes. Human vision seems to have evolved for us to see as much of the Universe as possible without the use of electronic instrumentation. Just look up on a dark night and see structures that are thousands of light-years away, without the use of a 305-meter radio telescope antenna.

[216] I shall scrupulously avoid the use of "Schrödinger's Cat" as a method of dipping the laymen into the quantum world. Dr. Erwin Schrödinger, a revered quantum theorist who invented wave mechanics, concocted the cat example as a *gedanken* experiment to illustrate the superposition of quantum states, and it was a clever way to bring the phenomenon into the macroscopic world where it could be effectively touched and seen, but I and others have found that it has a semi-violent counter-effect on people who may not have majored in physics. They tend to zoom in on the poor, half-dead/half-alive cat and miss the abstract point. Just as I try desperately to explain that Schrödinger did not actually put a cat in danger I fear that the angry villagers are starting to come up the driveway carrying pitchforks and torches. The cat experiment is covered specifically in many books, but not here.

In the photon mode, the particle either hops up and down or slides to and fro as it races forward. As is the case of the photon-wave traveling mode, the polarization (the direction of vibration), is undetermined until someone who knows what he is looking at tries to determine the state of polarization.[217]

The light from the M55 globular cluster, which is 17,500 light years away, has an undetermined polarization state until someone holds up a Polaroid filter and gazes at the light through it.[218]

If the two photons are separated by 12 trillion miles, the length of a light-year, it does not matter. Both assert the same polarization angle simultaneously.[219]
Half of them are horizontally polarized, and half are vertically polarized.[220]

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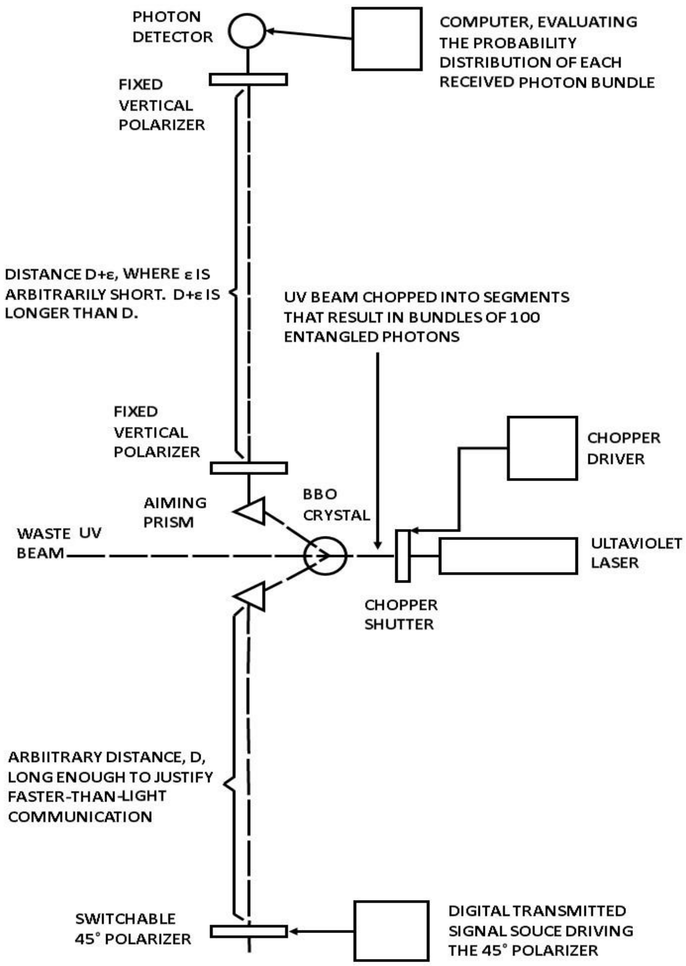
[217] How do we define horizontal and vertical? If, for example, the observer is floating in space, there is no up and down and no vertical and horizontal. In this case, hold a Polaroid filter in front of the eyes and observe a polarized light beam. (The light has already been through a polarizer and has been assigned a discrete polarization.) Turn the filter until the beam is blocked by the filter and the light is no longer observable. Name it "vertical." Turn the filter 90 degrees in either direction. Define that position as "horizontal," and observe as all the light comes through the filter. The polarization state of the incoming light is, by definition, horizontal. The only difference between horizontal and vertical polarization is that 90-degree angle.

[218] If you have ever worn a pair of polarizing sunglasses, then you have used polarizing filters. The filters that make up these glasses are set up to transmit vertically polarized photons. The usual sunlit scene as viewed through the glasses is shaded to one half the available photons. As they bounce off the scenery and into your eyes, the photons are randomly polarized, so exactly half of them turn out to be vertically polarized and make it through the filters into your eyes. However, the photons that reflect off the hood of your car are horizontally polarized, due to the fact that the hood is basically a flat, horizontal surface laid out in front of you. Those photons do not make it through the filters, so the Polaroid glasses do the neat trick of saving your eyes from the glare of the sun on the hood. Edwin H. Land invented this type of filter in 1929, using iodoquinine sulphate crystals bound in a transparent polymer film. This Polaroid filter, the J-sheet, was improved in 1938 by embedding pure iodine crystals in a polyvinyl alcohol. This formula was named the H-sheet. Land went on to develop the highly successful Polaroid instant camera in 1948. He made a fortune and then lost it all in 1981 after having developed the Polaroid instant movie camera. The home video cameras using VHS tape landed right on top of his instant movie camera introduction, and it was a solid wipe-out for Polaroid.

[219] As is the case of some simplifications used to make these explanations understandable, this is almost true. There are actually two modes of shared polarization between entangled photos: Type I and Type II. In Type I polarization correlation, the two separate photons have exactly the same direction of polarization, and they are deemed parallel. In Type II polarization, the two photons always become polarized in perpendicular directions. The angles are exactly 90 degrees out of phase. The polarization mode depends on what type of crystal is used to generate the entangled pairs.

[220] The fact that these photons are sorted into vertical and horizontal polarizations upon emerging from the crystal means that their polarization has been measured and they are locked into their polarization states. The situation in which the scientist notes the two red cones coming out of the crystal, illuminating dust particles floating in the air of his supposedly dust-free lab, is enough to make it so.



This schematic diagram shows basically how the faster-than-light communication system works using entangled photons. The problem of random polarizations from entanglement may be solved using quantum erasure. The signal is sent with the beam to the transmitter and the beam to the receiver both vertically polarized. To send a binary "1", the vertical polarization is erased by switching on a 45° polarization into the transmitter beam. The received beam responds instantly to the erasure, regardless of the distance.

The project was a deep industrial secret, code-named “TAXI.”[221]

The sender and the receiver in the spaceship communications system both have the exact same sequence of random numbers, available at both ends with zero speed-of-light delay, for what it is worth.[222]

Send a powerful stream of photon bundles across 12 light years of space, and before long you have downloaded the latest *Alvin and the Chipmunks* movie at a speed that defies relativity.[223]

This only means that the new and future generations of scientists and engineers are in for an exciting ride.[224]

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[221] In a recent light-speed communication with Rick Steenblik I finally found out where the code-word TAXI comes from. I quote him: “The TAXI name (not an acronym) arose as a code word. Shortly after I started doing serious research into the published methods of creating an entangled photon source I had to go on a business trip for Chromatek. I was reading published papers on the flight and then wanted to talk with Mark about what I had learned. I called him from the taxi, en route from the airport to my destination, and (in the interest of maintaining the security of the ideas) I explained the entangled photon sources in terms of the taxi engine, drive shaft, transmission, wheels, and so on. Mark immediately understood the analogy and we had an excellent brainstorming session about generating entangled photons without ever uttering a word about photons, entanglement, lasers, or non-linear crystals. Naturally, we had to code-name the project TAXI.”

[222] A good technologist can make a silk purse out of a sow’s ear, making use of the fact that one system’s fatal flaw is another’s feature. The simultaneous, continuous stream of digital random numbers at either end of the communication is being used for extremely high-speed banking solutions in which random numbers are needed for encryption. Using fiber optics and a centrally located source of entangled photons, two banks separated by hundreds of kilometers can have the same random encryption key appear at both ends, instantly. The numbers are completely random, and are not generated by a crackable algorithm. It is the first practical use of entangled photons. Einstein would find it irritating.

[223] I have described the first of four modes of superluminal communication claimed in Richard A. Steenblik’s U. S. patent number US 6,473,719 B1, *Method and Apparatus for Selectively Controlling the Quantum State Probability Distribution of Entangled Quantum Objects,* applied for on January 11, 1999, and awarded on October 22, 2002. Steenblik’s earlier patent of the same name, US 6,057,541, is referenced in Mark John Lofts’ U. S. patent application, US 2006/0226418 A1, filed on November 10, 2004. *Method and System for Binary Signaling via Quantum Non-Locality.* Lofts admits that Steenblik’s method will work, but he claims that his is less unwieldy. The abstract of this patent is difficult to comprehend. Be warned: because a scientific concept is granted a U. S. patent does not necessarily mean that it works. Remember, T. G. Hieronymus was granted U. S. Patent number 2,482, 773 for his crazy material analyzer (see Introduction). Having been granted a patent does, however, mean that the invention does not use or imply the use of cold fusion.

[224] Bear in mind, when I was an undergraduate, the terabyte hard drive was utterly impossible.

Chapter 11
Conclusions

"If it came from Mars, they have monkeys on Mars," was the last word.[225]

The Air Force had taken possession of a crashed flying disc on a remote ranch near Roswell, New Mexico.[226]

A tight lid was pulled over it, and no further information was available from the government authorities.[227]

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[225] This clumsy attempt at hoax was heard around the world, and the model for the flying saucer pilot became the small, green-colored biped that exists to this day in a jar of formaldehyde on a shelf in the Georgia Bureau of Investigation Laboratory. The signal from the first discovery of a pulsar was named LGM-1 from a first impression that it may have come from "little green men." The stereotype remained in place until the early 1980s, when it was replaced by "the grey," a thin, bald guy with large, black eyes and delicate hands.

[226] The term "flying saucer" was 12 days old when it was used in the *Roswell Daily Record* top story headline on July 8, 1947, "RAAF Captures Flying Saucer On Ranch in Roswell Region." It was first used on June 26, 1947, in the page-two headline, "Supersonic Flying Saucers Sighted by Idaho Pilot; Speed Estimated at 1,200 Miles an Hour When Seen 10,000 Feet Up Near Mt. Rainier," in the *Chicago Sun*. On June 24, 1947, Kenneth Arnold, a fire-extinguisher salesman from Idaho, was flying to Yakima, Washington, in a CallAir A-2 airplane, when he saw out the left window a string of nine shiny things flying around Mt. Rainier. They looked like "saucers skipping on water" glinting in the sunlight, and they seemed as if they were tied together on a string, moving like the tail on a Chinese kite. Seeing them go behind the mountain, he estimated the distance at 25 miles, and to see enough detail to say that they were "crescent-Moon-shaped," they had to be bigger than DC-4 airliners, or over 100 feet wide. Arnold thought they might be experimental military aircraft or possibly visitors from another world. Thus was born the flying saucer phenomenon.

[227] The weather balloon cover story was weak, but it was the last word on the Roswell flying saucer crash until 1980, when Charles Berlitz and William Moore rounded up 90 witnesses who had been there, interviewed them all, and wrote *The Roswell Incident.* In their research, the authors found that the debris field reported by the Air Force was only a touch-down point for the disabled spacecraft. It actually came to a stop miles from there, digging a trench and coming to rest against a hill. One of the crew was found hanging out of the opened hatch, and every one inside was dead on impact. This imaginative account was never mentioned in any story from 1947, but it bears a resemblance to another story from the Land of Enchantment in 1948 that was widely published. In March of that year, a large, disc-shaped spaceship, 99 feet in diameter, unsuccessfully attempted a controlled landing in Hart Canyon, New Mexico. The nearest town was Aztec. The Air Force quickly gained control of the crash site and transported the craft plus the 16 dead humanoids found inside to Hangar 18 at Wright-Patterson Air Force Base in Ohio for analysis. A strange detail was that the crew was dressed in Edwardian livery, as if they had expected to land in 1890 and did not want to stand out. Frank Scully wrote about the incident in his book, *Behind the Flying Saucers*, in 1950. A few years later, the incident was revealed as a hoax cooked up by Silas M. Newton and Leo A. Gebauer. The scheme was to sell a device that could detect oil, gas, and gold, based on technology found aboard the spacecraft that had crashed near Aztec. Both men began to serve time for fraud in 1953. The Air Force claimed to be unaware of a spacecraft crash, anywhere, ever.

It was a string of objects, 596 feet long, consisting of three radar corner reflectors, 23 polyethylene helium balloons (spaced at 20-foot intervals), four recovery parachutes, a radiosonde weather data transmitter operating at 74.5 megahertz, three automatic cutoff devices set to separate various balloons or ballast at set altitudes, eight aluminum tubes filled with sand ballast, the AN/CRT-1 sonobuoy with special microphone, and a couple of three-inch metal rings for holding the thing down before letting it go.[228]

On June 4, 1947, they released test flight no. 4 and quickly lost sight of it as it climbed away.[229]

Project Mogul dried up in 1949, having pioneered polyethylene balloons, altitude maintenance by aerostat, and the infrasound microphone. [230]

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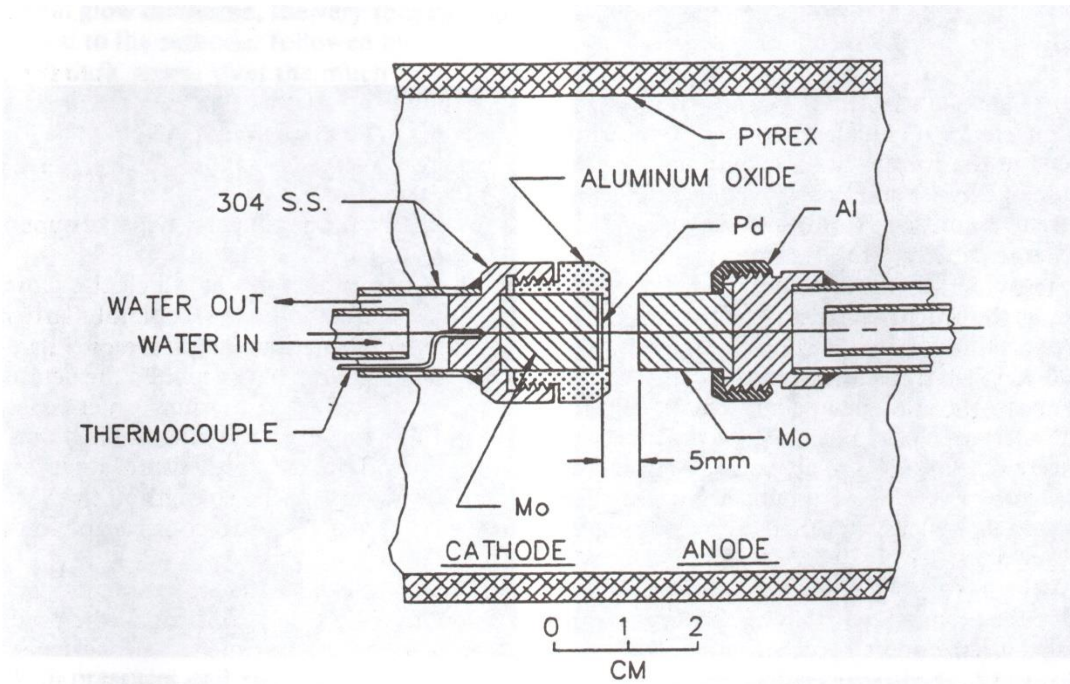
[228] Ellison's infrasound microphone looked like a snare drum, about two feet in diameter, and it was supported with its axis vertical by three cords, right above the AN/CRT-1, which was mounted upside down with its antenna pointed earthward. It was almost the last object in the 300-foot string. Below it was the sand ballast, supplied with a barometric cutoff that would drop it if the balloon string dropped to a specific altitude. Certain balloons in the string would be automatically cut away at 40,000, 42,500, and 45,000 feet, indicating that the optimum operating altitude to catch the sound channel was between 40,000 and 45,000 feet. The batteries supplying power to the AN/CRT-1, four size D flashlight cells plus two 67.5 volt batteries, would only last for four hours. If Mogul wanted to continuously monitor the Soviet A-bomb testing, then at least two balloons would have to be released every four hours for several years. As soon as they had figured out how to keep a balloon up for more than four hours, the next problem was going to be extended battery life.

[229] On May 29, 1947, flight no. 3 was released. It was a configuration duplicate of flight no. 4. The balloons apparently ran into high-speed wind at altitude and disappeared from radar heading north. Flight no. 3 was never recovered. Kenneth Arnold's sighting 26 days later, on June 24, 1947, of a string of nine shiny objects, flying as if they were tied together "like a Chinese kite tail," may be a description of the top segment of the Mogul balloon vehicle, blown all the way up to Mt. Rainier in the high-altitude jet-stream. The top segment was separated from the rest of the string by an electrically activated explosive squib as it reached 45,000 feet. That portion of the vehicle string would have been nine polyethylene balloons, looking highly reflective and metallic at a distance. The top two would have been big, one-kilogram balloons, separated by 36 feet of braided nylon rope ("lobster twine"). After another 79 feet of rope a series of seven smaller, 350-gram balloons would have followed, each spaced at 20-foot intervals. If so, then Arnold's description of the speed and distance of the objects would have been misjudged.

[230] A remainder of the Mogul infrasound microphones exists today in the ground-based Geophysical MASINT, Measurement And Signal INTelligence system, which is installed worldwide. On February 15, 2013, a meteor, coming in at a shallow angle above Chelyabinsk Oblast, Russia, exploded 97,400 feet over head. About 1,500 people were injured and 7,200 buildings in six cities around Chelyabinsk were damaged by the shock wave. It was the equivalent of setting off a 500-kiloton atomic bomb high above the city. The blast was picked up by MASINT microphones all over the world, and the data from these measurements were used to calculate the size of the energy spike, which was exactly what the Mogul balloons were supposed to do if the Soviets tested a nuclear device after World War II.

His description of the machine sounded like another version of the well-studied Cockcroft-Walton accelerator, except that the accelerating voltage seemed too low to induce fusion and thus neutrons.[231]

Efforts to find these instruments in Georgia Tech inventory were deeply disappointing.[232]



A cross-sectional view of our Kucherov glow discharge cold fusion reactor.

[231] When Ellison delivered an Activitron to a middle-man buyer in Austria, it was strictly forbidden to export an object containing radioactivity. The Activitron was completely inert except for the deuteron target, which was a one-inch disk of titanium saturated with tritium, a radioactive isotope of hydrogen with a 12-year half-life. When the Austrians asked advice on how and where they could get the 10-curie tritium source for use in the new Activitron, to their shock Ellison pulled it out of his shirt pocket and laid it on the table. Yes, it was an extremely active source of radiation, but the beta rays produced by the tritium are too weak to make it out of a paper envelope. The radiation from the tritium-infused titanium was not only perfectly safe to handle, it could only be detected by dissolving it in a scintillator fluid. He had walked through the airport terminals with no fear of being stopped and searched for radioactivity.

[232] I finally found evidence of an existing Activitron in Sydney, Australia, and I made a trip there to find it, giving cold fusion lectures at the University of New South Wales in Sydney and the University of Western Australia in Perth. The Activitron was not available for inspection. One Australian scientist got up and angrily claimed that an Activitron could not possibly work, and he had refused to sit through a demonstration of it. Another said it was being considered for use to irradiate luggage at the airport, detecting barium-based explosives by neutron activation.