ATOM BOMBS

The Top Secret Inside Story of Little Boy and Fat Man

John Coster-Mullen

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THE

Top Secret

INSIDE STORY
OF
LITTLE BOY
AND
FAT MAN

JOHN COSTER-MULLEN

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Y-1561 Implosion cross-section CAD drawing by Peter Johnson
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For Mary

"I was very much impressed." — **Paul W. Tibbets**, Brig. General, USAF, Retired

"What you have now written is the best, I am sure, of any discussion on the subject I have seen." — **Frederick L. Ashworth**, Vice Admiral, USN, Retired

"Your book contains the best description of the Nagasaki mission I have ever read." — **Dutch Van Kirk**, *Enola Gay* Navigator

"Your book is outstanding. Congratulations on an important historical record." — **Morris Jeppson**, *Enola Gay* Electronics Test Officer

"I think your story is excellent. I don't recall anything like it before." — **George Caron**, *Enola Gay* Tail Gunner

"I am very favorably impressed by the amount of information you have gathered together and presented in an interesting fashion." — **Norman F. Ramsey**, *Project Alberta*

"You have done a remarkable job." — **Philip Morrison**, *Manhattan Project* Physicist

"Your detailed and unique research is very impressive." — **Henry Linschitz**, *Manhattan Project* Chemist

"Most amazing document...In all first rate...There are drawings in there that are absolutely correct...He's got everything exactly: dimensions, materials, and things that have been really classified...He's an amazing guy. I don't know how he puts this all together...his cross-section drawings are the most incendiary portions of his book...If I still ran the shop, I'd have him back there in a heartbeat to tell everyone how he did this...It's mind boggling to me!" — **Harold Agnew**, *Project Alberta* and former Los Alamos Director 1970-1979

"You have done an incredible job as a nuclear archeologist... As you know, those of us who have clearances can't comment on the veracity of your findings...I have mixed emotions about your work - great archeology, but why not keep the details for those who have a need to know." — **Sig Hecker**, Los Alamos Director 1986-1997

"I can't comment on the accuracy of your work, but you are in direct violation of the NPT, whose signatories promised never to reveal nuclear weapons design information!" — **John C. Hopkins**, Los Alamos Associate Director 1960-1993

"I really appreciate your time and dedication to a key part of the lab, and the nation's, history." — **Eric Gerdes**, Los Alamos Classified Bomb School and Museum

"Your book about the two early nuclear weapons is extraordinary…I am much moved by your reverence and appreciation for the past…Keep up the work which you do with such integrity and attention to detail." — **Richard Garwin**, Author of the actual design used in the first hydrogen bomb, 2016 Presidential Medal of Freedom Recipient

"Every encyclopedia in the world, from the Britannica to the World Book, described how the Hiroshima bomb (Little Boy) was made, and included a diagram. News articles and school teachers referenced these diagrams. But here's the thing. Every single one got it wrong. John Coster-Mullen and his self-published memoir got it right." — **Howard Morland,** Author of *The Secret that Exploded*

"We have discussed the high quality of what you have discovered and written…it is great work…I respect what you do and applaud your tenacity, quality and courage." — **Robert Kelley**, IAEA Iraq Weapons Inspector Director 1992 and 2001

"All of us in the fast-disappearing Cold War generation, and many of the younger folks who will have to deal with nukes in less-friendly hands, owe you a deep debt of gratitude….(you are) one of the great detail-chasers of all time!" — **Thomas C. Reed**, former Secretary of the Air Force

"You are well known to the feds...I am flabbergasted...What is so marvelous is that not only have you collected the pieces in pictures and writing but you have truly put the puzzle together to rebuild it. That is an awesome accomplishment...Your perseverance is a marvel...The powers that be are scared of you and what you did because you were able to collect from unclassified sources." — **Anonymous,** National Nuclear Security Administration

"He came out of left field and really did something that I think is pretty dazzling." — **Richard Rhodes**, Pulitzer Prize winning author of *The Making of the Atomic Bomb*

"Coster-Mullen lets the reader look over the shoulder of those who assembled the bomb." — **Robert S. Norris,** Author of *Racing for the Bomb: General Leslie R. Groves, the Manhattan Project's Indispensable Man*

"To suggest that Coster-Mullen is a garden-variety classification freak, however, is like comparing a high-school trumpet player to Miles Davis…All the leading scientists at Los Alamos say he got it right." — **David Samuels**, The New Yorker author of *Atomic John*

"John Coster-Mullen has played a crucial role in establishing a public, permanent record of the creation of the bomb." — **Cindy Kelly,** Atomic Heritage Foundation

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Foreword

This book is the result of over a quarter century of meticulous research into the development of early nuclear weapons. The technical and design information presented in this book is based on both declassified documents and hundreds of interviews and much of this information is being revealed here for the first time. The author is the first person in history without any security clearances to uncover all the internal components of both WWII era bombs to an unprecedented level of detail. To his astonishment, the author found Los Alamos National Laboratory (LANL) mistakenly declassified an incredible amount of highly detailed nuclear weapon design information over the decades thus basically leaving all this hiding in plain sight. Nuclear weapons are THE most destructive weapons ever created and by revealing this classified information, Los Alamos has clearly endangered our country. In order to conduct his research, the author has never broken any laws, conducted espionage, paid for information, or had access to classified information. He has never had a security clearance, nor taken a security oath. He has never tricked or mislead anyone to obtain information. In fact, the author has scrupulously informed all his sources in advance of what he was doing. For the record, nobody has ever "leaked" anything to the author! All this information had been downgraded long ago to the classification level of *Confidential*, but after 9/11 it was upgraded back to *Secret* and *Top Secret*. Coster-Mullen has been acutely aware that his book contains many orders of magnitude more classified information than what earned Ethel and Julius Rosenberg their flaming rides to Valhalla aboard Sing Sing's "Old Sparky" electric chair back in 1953. It should also be noted that all the government documents and drawings (including the NKVD/KGB Fuchs drawing) reproduced here were first electronically scanned from the best available copy and then each was painstakingly retouched word-by-word, pixel-by-pixel by the author using state-of-the-art digital techniques in an effort to restore them to their original condition. This time-consuming process involved as much as ten hours or more of restoration time per page.

A 2005 internal LANL email, authored by one of the book buyers and circulated among the very top of LANL personnel, was handed directly to the author by someone at the top echelon of Los Alamos. As it was handed over, this person said, "No comment", smiled, winked, then turned and walked away. This email mentioned this book and stated alarmingly, "I thought all this stuff [LANL historical reports] had been withdrawn [after 9/11]. His book appears to be self-published and in limited circulation." This email author went on to state that if they want to stop it, the time to do it would be now! The implication here was that there was serious LANL internal discussion at that time to try and quash this book. In 2009, the author donated a signed copy to the LANL library. After quickly paging through it, the horrified staffer immediately took it into another room. When she returned, this clearly shaken librarian told the author, "Well, that won't go on the public stacks!" This book is currently in the Los Alamos Public Library. Back in 1995, initial copies sold out immediately at the National Atomic Museum (now renamed the National Museum of Nuclear Science & History) gift shop, but it was subsequently permanently banned a few days later under direct orders from a Sandia National Laboratory (SNL) manager even though it is currently used by the instructors (and recommended to the students) during the classes held at the Defense Nuclear Weapons School (DNWS) inside

Kirtland AFB located a short distance from SNL! This book is in the SNL, ORNL, and Fermilab Technical Libraries.

In a published 2005 UNLV interview, former Los Alamos Director Harold Agnew commented about this book. "Most amazing document...In all first rate…there are drawings in there that are absolutely correct...he's got everything exactly: dimensions, materials, and things that have been really classified…He's an amazing guy. I don't know how he puts this all together…It's mind boggling to me." After spending a week with the author on Tinian in 2005, Agnew also wrote to the author, "I suggested, maybe I told you, that the LASL [Los Alamos Scientific Laboratory-former LANL name under Agnew] security people should have you give a talk on how you put together what you did. So in the future if there really is something they want to keep close they might have a clearer idea as to how to do it. The senior person (John Immele) at the LASL to whom I made this suggestion was horrified, but won't do it. If I ran the store I would have done it." While on Tinian, Agnew told Coster-Mullen, "Your cross-section drawings are the most incendiary portions of your book!" and also mentioned that before leaving for Tinian, he scanned these drawings and emailed them to LANL. They called immediately and ordered him to purge his computer of classified information (these drawings). At the end of this 2005 symposium, the author asked Agnew if he thought the author was in any trouble whatsoever with the contents of this book. Agnew responded immediately, and very nonchalantly, "Nah. Your fine, don't worry about it!" Agnew died 9/29/13.

Several people at Sandia National Laboratory used this book as primary source material to generate classified reports regarding *Little Boy.* This book was used by NRDC author Robert Norris as the primary source for information on both bombs in his monumental "Racing for the Bomb" biography of General Groves published in 2002. Excerpts from the book pertaining to the *Little Boy* safing and arming plugs were used by the Defense (Exhibit K) in the famous case of the United States vs. Butterfields Auctioneers (Case No. 02-2776) and were instrumental in U.S. District Court Judge Susan Illston's 6/14/2002 decision to reject the government's claim to the plugs. The book was also used as the main source for Jim Sanborn's 2003 "Critical Assembly" exhibit at the Corcoran Gallery in DC. The book was used by Japanese author Kiyoshi Souwa for his 2003 book "Hiroshima Atomic Bombing, The Meaning To Drop It At 8:15 A.M.", by English author Stephen Walker for his 2005 book "Shockwave", and by Richard H. Campbell for his outstanding 2005 book "The Silverplate Bombers." The author contributed to the November 19, 2005 article in Physics, "The B61-based 'Robust Nuclear Earth Penetrator'" by Andre Gsponer. Manhattan Project scientist Lawrence Johnston used this book as source material for his August 9, 2006 lecture he presented at Los Alamos "Adventures at Wartime Los Alamos." This book was used as a source by Michael Gordin in his 2007 book "Five Days in August: How World War II Became a Nuclear War." The 2008 article "The rules of civilized warfare': Scientists, soldiers, civilians, and American nuclear targeting, 1940 – 1945" by Sean L. Malloy was published in the Journal of Strategic Studies and cites this book. The author's *Fat Man* cross-section drawing was used in the newly-released "Swords of Armageddon", Version 2 by Chuck Hansen. His *Little Boy* and *Fat Man* cross-section drawings are currently used as the primary drawings on Wikipedia in their articles on both weapons. The article "Highly enriched uranium and crude nuclear weapons" by Hanne Breivik of the Norwegian Defence Research Establishment (FFI) was also published in

July 2008 along with "No nukes: World leaders call for end to all nuclear weapons" published in Scientific American and both cited this book.

A major cover story about the author, "Atomic John", appeared in the December 15, 2008 issue of The New Yorker. He was the subject of the Lawrence S. Wittner article "The Bomb as Fetish" published in The Asia-Pacific Journal: Japan Focus, 1-2-09, December 29, 2008. Maury Shenk's article "Informationology: A New Framework for Understanding the Roles of Digital Information" was published in the November 2009 issue of Privacy & Data Security Law Journal and mentions this book. The 2009 book "Atomic Awakening" by James Mahaffey cites this book. The 2010 article "Reconstruction of local fallout composition and gamma-ray exposure in a village contaminated by the first USSR nuclear test in the Semipalatinsk nuclear test site in Kazakhstan" was published in Radiation and Environmental Biophysics and cites this book. In 2010, Boston University School of Public Health Chairman George J. Annas cited this book in "Worst Case Bioethics: Death, Disaster, and Public Health" and the author's *Little Boy* cross-section drawing was used in the book "The Twilight of the Bombs" by Richard Rhodes. On 3/30/11, the author was the subject of a story on the CNN webpage followed a few days later on 4/3/11 by one in the London Daily Mail and on 8/17/11, he was featured on the Rachel Maddow Blog. The 2011 article "Initial process of atomic bomb cloud formation and radioactivity distribution" by Tetsuji Imanaka published in Revisit the Hiroshima A-Bomb with a Database cited this book as did the 2011 article "Nuclear terrorism and the problem of burns" by Thomas E. Goffman, MD published in The American Journal of Emergency Medicine. Also in 2011 "The Physics of the Manhattan Project" by Cameron Reed was published and he cited this book some four dozen times. In his 2012 book "The Tehran Triangle," former Air Force Secretary Tom Reed credits Coster-Mullen with giving "the public an understanding of Little Boy" and the National Archives opened up the "John Coster-Mullen Papers" collection at the Harry S. Truman Presidential Library. On 6/12/12, the author was featured in an article in the BBC, on 8/9/12 in an article on the Popular Science website, and on 8/14/12 in the Huffington Post. In 2013, this book was used as a source in the Brazilian book "Bomba Atômica: Revelada" by Dinis Gomes Traghetta, by John F. McGowan in his article "Mathematics of the Manhattan Project" published on Math-Blog.com, an article on Slate, on the Smithsonian Air & Space Magazine website, by Eric Schlosser in his book "Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety," and in the book "The History of Nuclear War I: How Hiroshima and Nagasaki were devastated by nuclear weapons in August 1945" by John Richard Shanebrook.

In 2014, this book was cited in "Unmaking the Bomb: A Fissile Material Approach to Nuclear Disarmament and Nonproliferation" by Harold A. Feiveson, Alexander Glaser, Zia Mian, Frank N. von Hippel. On November 9, 2014, the New York Times ran an article "Dawn of Nuclear Arms, Declassified" that mentioned the author's research and book. Originally published in Nature News, a mention of his research appeared in the BBC online article "Become a nuclear superpower...in ten steps" that ran on November 18, 2014. This book was mentioned in the article "Iranian Vulnerability" by Lee Smith in the March 30, 2015, Vol. 20, No. 28 issue of the Weekly Standard. In the August 2015 issue of The Bulletin of the Atomic Scientists, the author was mentioned in their article "The harrowing story of the Nagasaki bombing mission." On May 23, 2016, his research was mentioned by Bill Broad in his New York Times article “The Hiroshima Mushroom Cloud That Wasn’t” about the Hiroshima mushroom cloud. It was also mentioned on May 27, 2016 in the article “Is Hiroshima 'Mushroom Cloud' Picture Real? True Facts About Iconic Photo” by Maria Vultaggio in the International Business Times. The author has served in an advisory capacity to the Atomic Heritage Foundation, Hiroshima Peace Memorial Museum, National Atomic Museum (NAM), National Geographic Television, Smithsonian Institution National Air and Space Museum (NASM), and The Children of the Manhattan Project Heritage Preservation Association (MPHPA).

This book has been purchased by people in all 50 states as well as by people at various DOE facilities such as Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Fermilab (FNAL), Hanford, Lawrence Livermore (LLNL), Los Alamos (LANL), Nevada Test Site, Oak Ridge (ORNL), Pantex, Sandia (SNL), and Savannah River National Laboratory (SRNL), along with Aldermaston (AWE-UK’s nuclear site) and the Korea Atomic Energy Research Institute (KAERI). Copies are in the libraries at FNAL, LANL, ORNL, SNL, Aldermaston, SIPRI, and the IAEA/SGIM in Vienna. In addition, copies have also been purchased by the CIA, Drexel University, the FBI Hazardous Devices Response Unit (HDRU) at Quantico, Georgetown University, Harvard, Hope College, Illinois Wesleyan University, Marquette University, Miami University, MIT, Naval Post Graduate School, NRDC, Princeton, Smithsonian Institution, Stanford University, UC Berkeley, University of South Carolina, USAF Museum at Wright-Patterson, Waseda University in Tokyo, and Washington and Lee University. The Deputy Chief of Mission at a prominent embassy in DC also bought a copy along with people both in and out of government from Australia, Austria, Belgium, Canada, Czech Republic, Cyprus, Denmark, Dubai, England, Finland, Germany, Italy, Japan, Mexico, Norway, Saipan, South Korea, South Africa, Spain, Switzerland, The Netherlands, Tinian, and Uruguay.

Coster-Mullen has been interviewed by ABC News, Design News, Landline Magazine on Sirius, Metro International, National Public Radio in Vienna, Austria, Hiroshima TV, Hiroshima Chugoku Shimbun newspaper, radio stations TBS eFM in Seoul, Korea and Newstalk106-108fm in Dublin, Ireland, Trucker News, WUWM’s “Lake Effect” radio program, and The Bulletin of the Atomic Scientists.

In 2013, one of the author’s book buyers contacted him and together they conducted a week-long “Nuclear Archeology” expedition at a still-secret site *formerly* on government land, but now most definitely on public property. Los Alamos has completely lost track of this site after they constructed and test dropped about 100 *Little Boy* and *Fat Man* weapons all over the West in 1945, including this particular area. This book buyer and the author located with a metal detector, dug up, measured, and retrieved tons of both weapons (including the still-secret *Little Boy* “dummy case” containing the still-classified 6.5” gun bore), which provided the author with an exclusive and unprecedented amount of highly accurate internal dimensional information thus allowing him to greatly increase the accuracy of the information and drawings presented in this book. In 2015, at his University of Chicago Enrico Fermi Institute, his Los Alamos Fuller Lodge presentation, and in 2017 at his presentation at the American Physical Society (APS) conference in DC, the author showed both nuclear weapon fragments and photos from this expedition. Clearly shaken at this discovery, at the 2015 Los Alamos talk he was asked directly by former LANL Director Sig Hecker and former LANL Weapon's Division Director John Hopkins the exact location of this site. Coster-Mullen responded jokingly to both men, "At my age, my memory has been in decline. This site is somewhere between my house and Japan and I don't quite recall what direction I took to get there." In fact, Hopkins accused the author to his face that he was in violation of the NPT. After checking with his contacts at the IAEA, the author was assured he is definitely <u>not</u> in violation. In the opinion of Coster-Mullen, to be blunt, Los Alamos bears most of the direct responsibility for this collection of incredibly colossal and dangerous National Security blunders that took place over many long decades! It was Los Alamos that placed weapon casings in public museums all over the world with classified material left inside for the author (with the complete cooperation and assistance of the museum staffs) to discover. It was Los Alamos that declassified documents in their entirety thus leaving highly classified revelatory information unredacted. Since 2006, this book has been used as a textbook at the FBI Quantico Training Academy Hazardous Device Response Unit (HDRU). Also, since 2009, this book had been the 2nd best-selling book (behind Richard Rhodes' *The Making of the Atomic Bomb*) at the now-closed Los Alamos Otowi Station Bookstore situated directly adjacent to the LANL Norris Bradbury Science Museum.

Coster-Mullen has poured over thousands of pages of declassified documents and photographs and traveled well in excess of 100,000 miles around the world to inspect, measure, photograph over a dozen different *Little Boy* and *Fat Man* weapon casings at nine different museums, attend 509th Composite Group (the Atomic Bombers) military reunions, and conduct hundreds of hours of interviews with Manhattan Project, 509th Composite Group, and Project Alberta veterans. Whenever possible, the author has tried to inspect the original places where all of this originally occurred. He has been to Los Alamos, Oak Ridge, Wendover, Tinian, Hiroshima, and has spent over an hour inside the *Enola Gay* on two occasions, including the bomb bay. In 2017 the author took an hour-long ride seated directly behind the Pilot and across from the Flight Engineer in one of two remaining flying B-29's and this gave him further insight into what occurred on both atomic missions to Japan. In 2001, the surviving members of the 509th Composite Group voted to make the author a Permanent Honorary Member of this prestigious group and he's attended almost every reunion of this organization since 1994. He was commissioned to create a full-scale exact steel replica of *Little Boy* for permanent display at the Historic Wendover Airfield Museum. Before final delivery to Wendover, it was signed by all the surviving members of the 509th at their 2004 reunion in Wichita. The author served as co-chairman for their 2007 reunion in Chicago.

On April 6, 2005, Coster-Mullen was invited to meet with the Hiroshima World Peace Mission delegation at Wendover, Utah. They inspected the areas where the original test bombs were assembled and uncovered the fragmentary remains of the grounded copper-covered floor used in the *Fat Man* final explosives assembly building. In August 2005, the author was honored to accept an invitation by the government of Tinian to deliver a series of presentations on the 60th anniversary of the dropping of the atomic bombs on Japan to an audience that included both US and Japanese veterans. During the visit to Tinian, he was able to prove conclusively for their government which pit was used to load both combat *Little Boy* and *Fat Man* weapons into their respective B-29's for use on Japan in

1945. The loading pits had been mislabeled by the government. Upon their return from attending this commemoration event, the members of the Hiroshima mission presented a copy of this book to the Mayor of Hiroshima and it now exhibited at the Research Library of the Hiroshima Peace Memorial Museum. In August 2010, the author personally presented this museum with an updated copy shortly after first delivering a presentation on Tinian as part of their "Manhattan Project and Tinian Educational Symposium." This museum now uses a 3D drawing animation of *Little Boy* showing the projectile movement and subsequent explosion that is credited as coming from his research and this book. While in Hiroshima, he also took this opportunity to donate a copy of his book to their Radiation Effects Research Foundation (RERF).

In addition to providing archival material, Coster-Mullen also appeared in the 2007 documentary about the 2005 60th anniversary Tinian event entitled "Echoes from the Apocalypse." He worked with PBS for their 2006 program "Dr. Teller's Very Large Bomb." The "Tech Effects" program "Hiroshima" runs on the History Channel and he is listed in the credits. The author worked with filmmaker Jon Else on his 2007 PBS documentary "Wonders are Many" about the making of the opera "Doctor Atomic" where his book was utilized as an important reference during the production of the opera. In addition, drawings and equations from this book appeared in this opera when it was presented in San Francisco, Amsterdam, Chicago Lyric Opera, New York Met, and London. The author appeared in the "Nagasaki" episode of the Weather Channel's "When Weather Changed History" program and on 3/9/09, he gave a presentation about his research at the University of Chicago's prestigious Enrico Fermi Institute. He appeared in the documentary "Atomic Trucker" shown on the Internet on Motherboard VBS TV. His *Fat Man* cross-section drawing was used in the 2009 documentary "Die Bombe" produced by Cinecentrum in Hamburg and subsequently shown on ZDF, German public TV. In 2010, his *Little Boy* cross-section drawing was used in the documentary "Countdown to Zero" (shown at Cannes and Sundance) and he contributed to the National Geographic Television Channel's documentary "24 Hours After Hiroshima." Also in 2010, this book was cited in the Nagasaki mission documentary "The Last Heroes." On 2/16/11, the author delivered a lecture about his book and research at Fermilab near Chicago. On 5/28/15, he delivered a Colloquium at the University of Chicago Physics Department and on 6/2-3/15 he attended the 2-day Manhattan Project 70th Anniversary Symposium at the Carnegie Institute in Washington, DC. While he was about to enter that building the first day, there was a person standing in front of the building taking pictures of it. "Excuse me, but if you show me how to use that camera, I will gladly take a photo of you standing in front of it." This person glanced over at the author and said, "Oh, that's ok John." Completely taken aback, the author replied, 'Excuse me, but how do you know who I am?" His simple response was "Oh, <u>everyone</u> knows who YOU are!" The author still does not know who this person was or how he knew the author. On 7/17/2015, the day after the 70th Anniversary of the Trinity Test, Coster-Mullen was honoured to deliver his Colloquium in the most historic building in Los Alamos, the Fuller Lodge. In 2016 he was interviewed extensively by a Japanese NHK crew for a TV program airing in Japan August 6, 2016. In January 2017, Coster-Mullen participated in the annual conference of the American Physical Society (APS) and was subsequently interviewed by Cindy Kelly for the Atomic

Heritage Foundation "Voices of the Manhattan Project" website. He also participated in a Colloquium at the University of Wisconsin-LaCrosse in November 2017.

The following month in December 2017, Coster-Mullen was invited to participate in the 75th Anniversary Events at the University of Chicago commemorating Enrico Fermi's first nuclear reactor (CP-1) going critical under the Stagg Field squash court stands in December of 1942. The following week, he delivered two talks at the University of Maryland (UMD). In between those talks, Coster-Mullen was also interviewed at length on tape for an upcoming Nagasaki mission documentary and by NPR Science Editor Geoff Brumfiel for a segment on NPR's "Morning Edition" that ran on 12/26/17. On 12/29/17, the article "How a truck driver figured out specs for the atomic bomb" appeared on Fox News. On 1/18/18, the author attended the premier in Oregon of the new documentary about Los Alamos scientist Raemer Schreiber entitled "The Half-life of Genius." The author is listed in the film's credits. Just before the premier, he was interviewed for a podcast by Linfield College Physicist Prof Michael Crosser. The author also attended the premier of this documentary in Los Alamos on 7/14/18. On 8/22/18, the author was featured in the Gizmodo article "Meet The Nuclear Weapons Nerds" by Paddy Johnson.

The adventure continues!

Chapter 1

Trinity

"No one who saw it could forget it,
a foul and awesome display
...now we are all sons of bitches!"
Kenneth Bainbridge – July 16, 1945

It was early morning on July 16, 1945, at the Army bombing range located near Alamogordo, New Mexico. The overnight desert thunderstorms had cleared and Sgt. William R. Stewart had just arrived in pre-dawn darkness at the S-10,000 firing and instrumentation bunker. He was attached to the United States Army Corps of Engineers Special Engineer Detachment (SED)[1] and was taking part in a test that had been code-named Trinity. As one of eight members of the arming party, Stewart had been released from duty shortly before 5:00 AM and was one of the last people to leave the 100-foot shot tower (a surplus Forest Service fire-watch tower) before the final countdown began. At the top of the tower, securely bolted in place, was the world's first atomic bomb. Stewart's job had been to rig a 5-lb. Comp B explosive charge at the base of the tower. This charge was to be fired just before 5:29 AM to calibrate the instruments that were to be used to gauge the velocity of sound measurements during the test.

Stewart remembered, "Professor Bainbridge had me install this as late as possible once the test was 'go.'" Upon returning to the tower, only Prof. Bainbridge and Lt. Bush were still there and I left while they finished the last of Bainbridge's check list."[2]

In about a half-hour, if everything went according to plan, primordial cosmic forces would be unleashed which would completely obliterate the area where they were standing. Although the scientists had a pretty good idea as to how large this explosion was expected to be, none of them actually really knew for sure. The arming party consisted of Trinity test director Kenneth Bainbridge, Joseph McKibben, George Kistiakowsky, Jack Hubbard, Sgt. Stewart, Sgt. J.C. Alderson, Trinity Base Camp Commanding Officer Lt. H.C. Bush, and Sgt. Lloyd. After the group made sure the numerous electrical connections were ok and all of the switches were set in their final positions, the group hurriedly piled into their vehicles for the 5.7-mile trip across the desert back to the safety of the control bunker. Bainbridge quipped later, "The drive out to S-10,000 was not made above 35 mph, contrary to rumors."[3]

To protect themselves from the expected UV radiation from the blast, some of the scientists applied suntan lotion to their exposed skin. Welder's glasses, from the Trinity Base Camp Fubar stockroom, were supposed to have been issued to all personnel in order to help protect their eyes from the intensity of the flash. Because Sgt. Stewart had been unable to obtain any of these glasses before the test, he was forced by circumstances to make do with what available materials were at hand. In what must have been a strange sight, he simply reached down, picked up an empty cardboard box, and placed it over his head. Stewart then turned and faced away from the tower. With only the simple cardboard for protection, he closed his eyes tightly and waited with all of the others for the monumental event that was about to occur.[4]

As the final countdown reached precisely 5:29:45 AM, years of hard work by countless thousands of people all came to an abrupt climax. The atomic device exploded in total and complete silence with a blinding intensity brighter than ten suns! "Suddenly and without any sound, the hills were bathed in brilliant light, as if somebody had turned the sun on with a switch," wrote physicist Otto Frisch.[5] The steel tower evaporated in the twinkling of an eye from a ferocious heat four times greater than the center of the sun. The tremendous explosion also created a pressure equal to 100 billion atmospheres. This immense shock wave slammed into the ground directly underneath the blast and hammered it down with such force that it created a crater 10-feet deep and some 1,200-feet across. The desert sand in this crater was then drawn up into the rapidly expanding fireball and finally redeposited back down on the desert floor as a sea of radioactive bubbling, molten green glass. This glass would come to be known as Trinitite.

Everyone present was instantly struck by the warm rush of thermal radiation, which stood in marked contrast to the cool air of the desert morning. It would be over half a minute before the enormous sound and shock wave created by the largest man-made explosion in history reached any of the over 425 stunned observers scattered throughout the valley and hills of the Jornado del Muerto, or Dead Man's Route.

Otto Frisch wrote that, "The report was quite respectable and was followed by a long rumbling, not quite like thunder but more regular, like huge noisy wagons running around in the hills."[6]

William Stewart later recalled his impression of the test:

> When the count reached zero, I had a momentary thought 'it didn't work,' but was immediately overwhelmed by intense light. A few miles away was a ridge, this was as visible as bright white against a black sky, the color separation was sharp even through the cardboard whose corrugations were faintly visible. There were also some thin red lines, which I realized were veins in my eyelids! As this light faded I removed the box and looked toward the test site. There was a large brilliant purple cloud, probably ionized gas, which slowly transformed through various colors to red and became the fireball. Slowly as used here is an impression, I do not really have any idea how fast this occurred. As for the blast wave and earth shock I have no recollection, I guess my senses were already overwhelmed.[7]

At almost the same time 1,200 miles to the north in San Francisco, the crew of the cruiser USS *Indianapolis* watched quietly in the same early morning darkness as large wooden crates and a heavy lead bucket were loaded onboard their newly refurbished ship. Over in Potsdam, President Truman was just about to take a sightseeing tour of war ravaged Berlin. Half a world away, almost 500 of General Curtis LeMay's B-29 bombers were busy hammering away at a severely battered Japan, a militaristic nation whose leaders stubbornly opposed even the mere thought of surrender.

Meanwhile, back in New Mexico, Sgt. Stewart would have precious little time to fully contemplate the enormity of what he had just witnessed. He was part of Capt. Wilbur Schaffer's implosion assembly team. They had three more of these complex devices to assemble in a period of less than two weeks and ship out to a secret base on a small island in the Pacific, called Tinian.

Chapter 2

Beginnings

"God and uranium were on our side.
The wrath of the atom fell like a commandment
and the very planet quivered with implications!"
Norman Corwin – August 14, 1945

In the late 1930's, important discoveries were being made regarding the atom. Several scientists were proposing that nuclear fission of uranium might indeed be possible. A tremendous release of energy would occur and these scientists foresaw the feasibility of a fission weapon and its subsequent potential for military use. Experiments were taking place in Europe, Japan, Russia, and the United States that were beginning to confirm this fact.

On September 17, 1942, Brigadier General Leslie Groves of the U.S. Army Corps of Engineers was placed in charge of all activities relating to the development and production of an atomic weapon. The new District formed to work on the Development of Substitute Materials (DSM) Project was called the Manhattan Engineer District (MED). Because the original office had been in New York, the project became known as the *Manhattan Project* (S-l). Groves was chosen because he had just performed the almost impossible task of building the Pentagon ahead of schedule and under budget!

The *Manhattan Project* was started because of well-founded fears that the Germans, and later the Japanese, had been working on developing an atomic bomb. As it later turned out, Germany had been behind the United States in both development and manufacture of an atomic bomb. The Nazis did not think it was worth pursuing. They considered it "Jewish Science." Both the Allied and Axis powers were using all of the weapons at their disposal to win the war. Had Germany or Japan been able to build atomic weapons, there is absolutely no doubt they would have used them against the Allies.

On December 2, 1942, a team of scientists working at the University of Chicago under the direction of Dr. Enrico Fermi succeeded in producing history's first self-sustaining nuclear chain reaction. Physicist Robert Christy was one of the people who was involved with machining the many hundreds of tons of graphite used in the reactor.

> I was assisting in some of the experiments leading up to that, and also in some of the calculations. Even for awhile, some of us were asked if we would volunteer to work in the wood shop machining graphite. A lot of us spent time doing that. Graphite dust is very, very dirty. It was quite an exciting time, but the most remarkable thing was the absolute confidence that Fermi had in everything that was done. He planned it all, thought it all out, and knew everything that was going to happen and it happened the way he knew

it should. When it was done the way he knew it should do, he shut it down and said, 'Ok, that's that!' He had it all figured out. I was very excited, because this was the beginning of nuclear energy. I was worried about it. I thought this was a very important step.[8]

Acting on a recommendation from Dr. Ernest Lawrence, Gen. Groves picked Dr. J. Robert Oppenheimer to head up the part of the project pertaining to bomb development. This was to happen at a small city in New Mexico called Los Alamos (Site Y).[9] Oppenheimer arranged to have some of the best and brightest scientific minds in the country come to work for him. The MED was to become the largest scientific project in the history of the world. There are several excellent books listed in the bibliography detailing the entire remarkable story of the *Manhattan Project.*

According to Los Alamos physicist Robert Serber, the object of the *Manhattan Project* was "to produce a practical military weapon in the form of a bomb in which the energy is released by a fast neutron chain reaction in one or more of the materials known to show nuclear fission."[10]

In late 1944, a special group of personnel was formed by Col. Paul W. Tibbets, a fearless, brash, and outspoken 29-year-old pilot, to handle bomb "delivery." This group of about 1,800 people became known as the 509th Composite Group. It consisted of the 393rd Bombardment Squadron, Headquarters and Base Service Squadron, 1st Ordnance Squadron (AVN), 390th Air Service Group, 320th Troop Carrier Squadron, 603rd Air Engineering Squadron, 1027th Air Material Squadron, and 1395th Military Police Company (AVN).[11]

Tibbets reported directly to Groves who had given him carte blanche to do anything necessary to carry out his mission. Lt. Col. Tom Classen commanded the 393rd Bomb Squadron. This squadron had been training in Fairmont, Nebraska, and was about to be given an overseas combat assignment. Tibbets selected this group as the core of his newly formed 509th. Classen eventually became 509th Deputy Commander and essentially took over running the day-to-day activities of the group in Tibbets' absence. According to Tibbets, "I was fortunate during this hectic period [spring 1945] to have an officer as capable as Colonel Classen as my deputy chief. He ran the final training operations in exactly the same manner that I would have done it if I had been on the scene full time."[12]

Although they started work at the beginning of September, the 509th was not officially activated until December 17, 1944, which also happened to be the 41st anniversary of the Wright Brothers first flight.

According to Tibbets:

At the start, my primary focus was on the 509th. Organization and Training, manning, and the airplanes. Taking into account devising the tactics and strategy for getting those bombs on the target, etc., I had my hands full. I had my liaison with the scientific side to give me the specifics I needed. In this connection my interest was limited to the bomb's weight, size and shape, fuzing and ballistics.[13]

Project Silverplate was started in the fall of 1943 to produce the specially modified B-29 bombers that would eventually be used by the 509th. The newly developed B-29 bomber could fly farther and carry more bombs than any plane in history. Around $3 Billion was spent to develop and test the B-29. The *Manhattan Project,* by comparison, cost a "mere" $2 Billion. The B-29 could fly above 30,000 feet, had a 3,800-mile range, and carry a 20,000-lb. payload. This was very important since both atomic bombs weighed almost half that much.

Silverplate carried the highest priority possible. The mere mention of the name meant instant compliance throughout the military with any request connected to the project. Modifications to the first prototype B-29 began November 29, 1943. The testing program continued until the fall of 1944. It was decided additional planes would have to be modified for testing. The first of these seventeen planes were delivered to Wendover Field, Utah, in September 1944. They had been modified at the Martin-Omaha plant under Project 9814S. As a result of the testing, an additional 26 planes were modified under Project 98228S. Fifteen of these planes were eventually delivered to the 509th in the spring of 1945.[14] By the end of 1946, a total of 65 *Silverplate* B-29's had been produced.

Along with modifications to the bomb bays, pneumatically operated Winker-type bomb bay doors, fuel injected Wright Cyclone R-3350-57 engines, new Curtis electric reversible-pitch propellers, and the installation of special wiring, the gun turrets were also removed in an effort to increase both the maximum speed and altitude.

Major Charles Sweeney headed up the group responsible for testing these planes. He had been involved with B-29 testing and would fly the instrument plane, *The Great Artiste*, on the Hiroshima mission. Tibbets then chose him to command the second atomic mission over Japan.[15]

Based out of the remote, desolate Wendover Field (W-47 or Kingman), Utah, the 509th crews spent six months learning how to drop the bombs accurately and perform the special 155° diving turn that would place them over eight miles from the bomb when it went off. This maneuver was very difficult. During the crew competition at Roswell AFB for the postwar Operation CROSSROADS it is believed one of the B-29's went into a spin following this procedure. It crashed in the desert killing all aboard.

The ballistics of the two different bombs were so bad, during one of the drop tests at Muroc (now Edwards AFB), a photographer (Berlyn Brixner) filming the drops placed his tripod near the center of the target because he figured nobody would ever hit it.[16] One of the difficulties was that the design of the bombs kept changing. This included the external shape and weight, both of which have a great effect on ballistics. The ballistics of the more conventionally shaped *Little Boy* were less problematic when compared with the *Fat Man* design. By working together as a team the Los Alamos designers, 1st Ordnance Squadron, and flight crews were eventually able to greatly improve their accuracy.

Referring to the 1st Ordnance personnel, Tibbets wrote:

> They [Manhattan people] could not have done anything without the 509th 1st Ordnance Squadron and their tool and die makers, machinists, welders, etc. of the highest skills. These skills fabricated the engineering drawings [and ideas] into reality. This squadron was commanded by an exceptional man, Major Charles Begg. This man was skilled at coordinating the efforts of the 'brain trust' and the 'dirty hands' guys...Before there was a 509th, Sweeney, Albury, and Kuharek had been working for me in the B-29 testing business. I knew them and their abilities. Kermit Beahan was in my B-17 Group in England and North Africa as was Ferebee. When I was given the assignment,

these were the first 'names' I requested for Wendover assignment. When the crews were formed at Wendover, I saw to it that Sweeney, Albury, Beahan, and Van Pelt would fly together as would myself, Lewis, Ferebee, Van Kirk, and Duzenbury. When Sweeney and I were not flying, Lewis and Albury took command.[17]

The atomic bomb delivery operation both in the States and in the Pacific was known as *Project Alberta* or *Project A*. Their main task, in today's terminology, was to "weaponize the physics package." Although formally organized in March 1945 as a Los Alamos project, personnel from their Ordnance Division had been working with the delivery group since June 1943.

Starting in May 1945, the 509th was sent to Destination or Destination "O," the code name for the North Field area on Tinian Island in the Pacific that would serve as their base of operations. Navy Commander Frederick "Dick" Ashworth had personally selected this site in February 1945 and construction of the base was started in April. Ashworth worked as the assistant to Navy Captain Wm. "Deak" Parsons and would later serve as weaponeer on the Nagasaki mission.[18]

Tinian was an island in the Marianas just south of Saipan. During 1944 and 1945, the 20th Air Force, headquartered south of Tinian on Guam and under the command of Army Air Force Gen. Curtis LeMay, used airfields on Guam, Saipan, and Tinian to launch mass air raids against the Japanese Empire. These raids, which at times utilized 500-600 B-29's, dropped combinations of mines, incendiaries, and high explosives. LeMay's timetable dictated that over 100,000 tons of bombs were to be dropped on Japan each month until the end of 1945.

On the night of March 9, 1945, Tokyo was firebombed by over 300 B-29's. At the time, it was the third largest city on Earth. The downtown business district was almost completely leveled. Estimates of the dead and missing ran from a conservative 80,000 to one Japanese document that reported a figure of almost 200,000.[19] It was the highest single day death toll of World War II.[20] Coincidentally, this was also the very same day Paul Tibbets first saw the *Enola Gay* during an inspection tour of the Martin assembly plant in Omaha.

The incendiary raids caused more death and destruction than anything else used in the war, *including the atomic bombs*. Almost 500,000 people were killed, 13 million were made homeless, and 178 square miles of 66 cities were razed. Indeed, photos show the destruction in these cities to be indistinguishable from that inflicted later on Hiroshima and Nagasaki. Typical Japanese highly flammable, paper-walled wood structures disappeared without a trace in the incredibly destructive firestorms created by these raids. In addition to the hundreds of thousands who were incinerated, many thousands lucky enough to escape the flames ultimately suffocated and perished simply because these massive fires also consumed all of the available oxygen. In the end, nothing remained standing except concrete and brick. These raids went on for almost six months. With callous disregard for the immense suffering they were causing, particularly to their very own countrymen, the Japanese military leaders' strict military Code of Bushido forced them to arrogantly mandate everyone to continue fighting on in the name of the Emperor. Surrender was not an option.

Even though the *Manhattan Project* had been moving forward around the clock at almost breakneck speed, the war in Europe ended before the bomb was ready. Had the bomb been finished in time, the plan had always been to use it first against Nazi Germany since the Allies visceral hatred of Hitler's evil fascist regime was certainly as strong as it was against Japan's.

Under orders from the President, the Japanese cities that had been selected as the target cities for the atomic bombs were to be left relatively untouched by the mass bombing raids. This was so that the damage done to these cities by the atomic bombs could be accurately assessed. The cities chosen as the target cities were all considered legitimate military targets. These were Kyoto, Hiroshima, Niigata, Nagasaki, and Kokura (now Kitakyushu). Kyoto was dropped at the insistence of Secretary of War Henry Stimson, because it had been Japan's imperial capital and cultural center for more than one thousand years. Stimson was convinced that its destruction would drive the Japanese into the hands of the Russians after the war.

These target cities all had major industries, arsenals, military bases, and/or ports. Along with many important wartime industries, Hiroshima was the home of Mitsubishi Heavy Industries, Hiroshima Shipyards, Second Army Headquarters, Hiroshima Army Ordnance Supply Depot, and a large embarkation port. Almost all of the Japanese troops that fought in the Pacific had departed from this harbor. Hiroshima was also the site of the headquarters to repel the upcoming much-anticipated invasion of southern Japan. Nagasaki, known as the "San Francisco of the Orient," contained the large Mitsubishi-Urakami Ordnance Works (Torpedo Works), Mitsubishi Steel and Arms Works, Nagasaki Shipyards, and the huge Nagasaki Port. It is important to note that had the atomic bombs *not been used*, these strategically important cities of Hiroshima and Nagasaki would also have been totally destroyed months earlier during LeMay's B-29 firebomb raids and no one alive today would even remember their names.

The atomic bomb assembly on Tinian was under control of the *Project Alberta* personnel. They were responsible for the training, test, and combat units. The bulbous training bombs, called "pumpkins," were filled with a conventional explosive and dropped on select targets in Japan. These missions were known as "pumpkin raids." It was hoped that one or two B-29's flying at 30,000 feet, and dropping only one bomb, would not provoke the Japanese into sending up fighters or using antiaircraft fire. This tactic proved enormously successful.

While the 509th crews were doing their final training with the pumpkins, the *Project Alberta* personnel were busy readying the numerous test units. Each of these test units was used to check final sub-assemblies for both the *Little Boy* and *Fat Man* bomb designs. Information received from ongoing test programs back in the States was utilized to make last-minute modifications to the test units being assembled on Tinian.

Although the Trinity test in July 1945 had proven the concept that a spherical nuclear implosion would work, the design of the atomic bomb that was to be used on Nagasaki was far more complex than the Hiroshima bomb design. In addition, dropping a weapon from 30,000 feet over enemy territory under combat conditions was vastly different from detonating an experimental test device bolted safely atop a tower in the New Mexico desert. There were no guarantees the bombs would explode successfully over targets in Japan. In fact, the day before the Hiroshima bomb mission, a drop test of one of the last *Fat Man* test bombs (F18) was unsuccessful. Both weapon designs utilized the same proximity fuzing system.

According to *Project Alberta* scientist Luis Alvarez:

> I watched, with field glasses, the bomb being dropped from the bomb bay of a B-29 flying over the ocean, north of Tinian Island, and we were simultaneously listening to radio signals from the bomb. At a certain height above the ocean, the "proximity fuzes" were to send out a signal, and also release some puffs of smoke. You can imagine our consternation when neither the signal was emitted nor were the puffs of smoke visible – the dummy bomb simply splashed into the ocean.[21]

Lt. Morris "Dick" Jeppson, who assisted Parsons in arming the *Little Boy* bomb, recalled, "There was a lot of concern at the last minute that the fuzing was not reliable."[22]

After the two atomic bombs were dropped and Japan surrendered, most of the *Project Alberta* personnel left Tinian over the next month. A few stayed behind for almost six months to help coordinate the removal of equipment and supplies. Anything that could not be shipped back was sent to the bottom of the Pacific. Back at Los Alamos, many of the personnel had left or were thinking of leaving. The great push to complete this project had burned out a lot of them and, after all, the war was over. The personnel that stayed formed the core group that kept Los Alamos going during the Cold War and on through to today.

Chapter 3

Little Boy

"It was equal to a trainfull of TNT five miles long!"
Philip Morrison – 5/18/95

The first two atomic bombs were referred to by their code names *Little Boy* and *Fat Man*. The names came about as a natural progression through the design program.[23] Two completely different weapon design programs were pursued. *Little Boy* used uranium (U-235) in a gun-bomb arrangement (see below), while *Fat Man* utilized an implosion-type design (see chapter 5). The attempt to use plutonium (Pu-239) in a gun-bomb turned out to be a device about 17' long. It was referred to as the *Long Boy, Long Man,* and *Thin Man,* but the design was subsequently dropped in August 1944 due to insurmountable technical reasons. The shorter configuration for the uranium gun led to the name *Little Boy.* When spherical implosion was devised, and the bomb shape turned out to be relatively short and fat, it seemed logical to call it *Fat Man.* Both devices were also referred to as "gadgets" or "gimmicks." The *Little Boy* gun-bomb design was far simpler.

A *Manhattan Project* engineer recalled, "The gun-bomb was kinda like old fashioned development, where a bunch of blacksmiths get together and hammer something together. It was really in the tradition of old-timers doing something. There was much more science in the other thing (implosion device)."[24] Though certainly true, there was still a remarkable amount of tough engineering problem solving and ingenuity manifested in the deceptively simple design of *Little Boy.*

An explosive nuclear chain reaction occurs when a sufficient quantity of nuclear fuel, such as plutonium or uranium, is brought together to form a critical mass. This is the minimum amount of fissionable material needed to start a chain reaction. The chain reaction starts when neutrons strike the heavy uranium or plutonium nucleus which splits releasing a tremendous amount of energy along with two or more neutrons which, in turn split more nuclei, and so on. The critical mass varies inversely with the square of the density of both the fissile material and the reflector (tamper) that surrounds it.[25] In the case of *Little Boy*, 64.15-kg [141.42-lb.] of U-235 (Oralloy or Oy) was separated into a 38.53-kg [84.94-lb.] subcritical projectile (60%) and a 25.62-kg [56.47-lb.] subcritical target (40%).[26] "The original design contemplated a nearly equal division of the active material between projectile and target insert."[27] When these two subcritical masses were brought together, they formed a supercritical mass and a nuclear chain reaction explosion occurred. In effect, *Little Boy* was simply a big gun consisting of both a U-235 bullet and target.

The code name "Oralloy" stood for Oak Ridge alloy. It was named after the secret manufacturing complex in Oak Ridge, Tennessee that had produced it. This material is presently referred to as highly enriched uranium-235 or HEU. *Little Boy* used all but a small fraction of the HEU that had been produced up to that time. There was not sufficient material in August 1945 for any additional uranium bombs. According to nuclear weapon historian

Chuck Hansen, "...most of the Oralloy was enriched to 89% U-235 content, some of it was enriched to only 50%, for an average enrichment of only about 80%."[28] Present day standards for weapons-grade HEU specify a 93.5% enrichment rate.

According to Los Alamos Archivist Roger Meade:

> The problems of the gun device were compounded by the necessity of fabricating the fissile materials into geometric shapes capable of withstanding the violence of being shot down a gun tube, being stopped abruptly in a target, and holding together in a supercritical arrangement long enough to detonate.[29]

Little Boy was dropped on Hiroshima on August 6, 1945, from the *Enola Gay*, a B-29 bomber flown by Colonel Paul W. Tibbets. The tail gunner, George Caron, said, "I flew with him for 2 1/2 years. In my opinion, he was the greatest airplane 'driver' the Air Force ever had!" Caron had such confidence in Tibbet's ability as a pilot, he told him, "Colonel, you know I'd fly with you on a carpet!"[30]

Unlike the later problem-plagued *Fat Man* mission, the *Little Boy* mission was flawless. Due to meticulous navigation on the part of Capt. Theodore J. "Dutch" Van Kirk, after a 1,700 mile, six and a half hour flight, they arrived at the target a mere 17 seconds off schedule! General Jimmy Doolittle referred to it as a "text-book" operation.

Both wartime *Little Boy* and *Fat Man* atomic bombs, though considered somewhat crude by modern standards, were masterpieces of handmade precision jury-rigging. These were intermediate devices standing somewhere between laboratory experiments and postwar ("WR" or War Reserve) production military weapons. The firing and fuzing systems had several built-in redundancy features, which were duplicated or quadruplicated to prevent any failures. The bombs were "over built" to help ensure absolute success. The most powerful "computer" used by the scientists and technicians to produce these weapons was, in reality, just a glorified adding machine. The bulk of the engineering and mathematical calculations were performed with nothing more sophisticated than ordinary slide rules!

The *Little Boy* bomb measured 120.0" in length, 28.0" in diameter and weighed about 9,700-lb.[31] The outer ballistic case center and tail sections were made from 0.375" thick hardened homogeneous armor steel. The conical section was 0.25" thick steel and the 30.0" square tail was made from 8 gauge steel plate.[32]

The nose section, consisting mainly of the target case, U-235 target discs, and tamper, represented more than half the weight of the bomb. It was the heart of the weapon. The tamper material surrounded the U-235 fissile material and served a dual purpose. Because it was made mostly from tungsten carbide, a very massive material, it provided inertial containment by helping to physically hold the fissile material together in a supercritical configuration during the rapidly expanding chain reaction. To a lesser extent it helped contain this nuclear chain reaction for as long as possible by reflecting escaping neutrons back into the chain reaction. The neutrons were simply deflected back into the chain reaction by the high-density nuclei of the tamper material. In turn, the heavy steel outer target case held both the uranium target and tamper together during the chain reaction. The goal was to make the assembly stay "as perfect as possible for as long as possible."[33]

The arming and fuzing systems for both *Little Boy* and *Fat Man* consisted of clock switches, safing and arming plugs, six barometric (baro) switches, and the Radar Network consisting primarily of four modified APS-13 tail warning radar devices (Archies) fitted with Yagi antennae. The firing and fuzing circuits were monitored by the Electronics Test Officer through the use of the Flight Test Box (FTB) located next to the radio operator's station in the forward section of the B-29.[34]

The Clock Box, named for the six 15-second clocks (timers) inside, was the main junction box, or central nervous system, for both the *Little Boy* and *Fat Man* weapons. It measured approx. 18" long x 9.5" wide x 6.5" high and contained several of the fuzing components and 14 relays along with electrical connections to the remainder of the fuzing components as well as the output cable that went to the X-unit (*Fat Man*) or propellant ignitors (*Little Boy*).[35]

The Clock Boxes were bench-tested before being assembled into both weapons. This was primarily a passive test of the electrical circuits and was performed with the Clock Box Tester. The two banks of pullout microswitches in the Clock Box and the Radar Relay Network (see below) were the only systems that could be actively tested. These microswitches had pullout wires and at the time of weapon release transferred the aircraft wiring, power, etc., to the internal weapon circuitry. The clocks were a spring-wound clock escape mechanism[36] mounted on a Lucite cylinder approx. 2" in diameter and 3" in height. They each contained a microswitch (spring-loaded switches) held in an "open" position with long brass arming wires connected to flexible steel cables. The cables had a loop at one end that would eventually be inserted into an electrically operated mechanism in the B-29 bomb bay. If the weapon ever had to be jettisoned in a completely inert condition, the arming wires would be dropped with the weapon. The microswitches had two sets of contacts. One set was closed (circuit completed) when the switch was "safe" and the other one closed when the switch was "armed." On the test bench the arming wires could be removed to test the armed condition and the wires reinserted and the safe condition tested.

All of the components that were external to the Clock Box (baro switches, radars, safing plugs, etc.) had electrical cables connected to the box. The interconnection of series and parallel was determined by the internal wiring of the Clock Box. The final firing signal was sent out from a connector on the box. In the case of both *Little Boy* and *Fat Man* test weapons, the Clock Box controlled signals of the internal fuzing devices, to the Brode Informers (radio telemetry devices) and to smoke puffs. The electrically fired smoke puffs were a visual indication that a test weapon had received a firing signal at the proper altitude above the target.

Thermostats within the Clock Box controlled electrical heating strips for both the Clock Box and the Battery Boxes. The heaters prevented the cold temperature of the bomb bay from affecting the operation of cold-sensitive fuzing components. The Clock Box was wrapped in 3/8" felt to retain the heat generated by the heaters. Power for the heaters was provided by aircraft power. There was no need for additional heating during the short drop interval and the power reserve of the internal fuzing and firing batteries was very critical.

The Radar Relay Network was a rather ingenious circuit that could detect when the first of four radars detected the proper burst height yet not close the firing circuit until the second radar confirmed it. Thus a combination of any two of the four determined the generation of the firing signal. Any one radar could not give a premature signal, yet any two radars could fail and the fuze would still operate properly.

The radars were modified RT-34/APS-13 tail warning radars, called "Tail Gun Charlies," that had been manufactured by RCA for Army Air Force fighter aircraft. Code-named "Archies," these 14-lb units were used for altitude determination. Referred to as a "poor man's radar set," these were developed under the supervision of Professor H. Richard Crane at the University of Michigan and later modified at the Signal Corp radar laboratory in New Jersey (Camp Evans) by senior electronics engineer William S. Wood. While relatively inexpensive, each one still cost about as much as a World War II era Cadillac limousine.[37] Four of these 7.5" high, 8.5" deep, 15" wide cases were used in both *Little Boy* and *Fat Man*. A 7-pin electrical connector providing for both a 24 volt DC input power and a 24-volt DC output-firing signal was located on the front panel along with an additional connector for the antennae cable. An Archie could be electronically adjusted to operate at a precise distance from its target, in this case the surface of the ground. These were calibrated to trigger at a distance of 2,000 ft from the ground. This calibration took place during the so-called "Dipsy Doodle" flights whereby the radars were mounted on test planes and the pilots would "porpoise" the planes up and down through different altitudes so the scientists could calibrate each unit. It was not a matter of sensitivity or to present a visual display, as was the purpose of most radar devices. A workbench modification of an internal electronic "delay line" was required. The delay line provided a "gate" of time within which the reflected radar signal would coincide. There were four heated[38] 4.75" x 6.875" x 7" battery boxes mounted next to the Archies containing a total of 16 Willard NT-6 six volt lead-acid storage batteries.

The antennas for the radars utilized the Yagi design. Invented in Japan by Hidetsugu Yagi during the 1930's, this antenna style consisted of three elements made from 0.375" diameter metal rods. The first was a 6.375" long rod called the "director." The next segment was the U-shaped "driven" element. It was slightly longer than the first rod. One end of the "U" was fastened to the metal mounting plate, while the other end was electrically insulated and connected to the coaxial cable of the radar. The third element was 8.0" long and called the "reflector." The director and reflector focused radar signals going out and coming back. This system projected a cone-shaped field of 400-420 MHZ frequency radio waves toward the nose of the weapon.

The barometric (baro) switches were aneroid, or pressure sensitive devices, which closed an electrical circuit to the "Archies" at a predetermined pressure or altitude. These were set to activate when the bomb fell below 5,000 feet. Although power was being continuously supplied to the "Archies" at release, the radars did not function because the baros were open, preventing one tube in each transmitter and one in each receiver from operating. Until they closed at about 5,000 feet, the receiver could not receive jamming signals and the transmitter signal could not be detected by the enemy. Even though the baros were accurate and had been carefully adjusted, the aerodynamics of both weapons was such that it was difficult to obtain an accurate atmospheric reading. There was severe buffeting and shock waves at different parts of the weapon. Some locations would give an abnormally high reading, while others would give a low, unrealistic reading. After many drop tests, the optimum location of the eight baro ports on both *Little Boy* and *Fat Man* was finally determined. The baro ports were connected to the six baro switches by metal tubing utilizing standard AN fittings. Tests were also conducted to ensure that a .50-caliber antiaircraft bullet could not accidentally enter the bomb through one of the baro ports, tumble around, and cause a possible baro failure.

The primary function of the baros was to determine if the weapon was at roughly the right altitude in order to pass the ultimate final firing decision to the highly accurate

"Archies." If the radars were turned on at a much higher altitude, it would have given the possible enemy radar jamming equipment a longer interval to detect the radar frequency and jam the altitude-determining devices. Each of the four Archies was set at a slightly different frequency to lessen the possibility of failure if it turned out a particular frequency was being jammed. In addition, the onboard radars might pick up radiations from Japanese radar to cause premature firing of *Little Boy* too high above ground. The monitoring of this 400-420 MHZ frequency range on both strike missions was the responsibility of the Electronic Counter Measures (ECM) officer, 1st Lt. Jacob Beser. He was the only person to fly in both strike aircraft, *Enola Gay* and *Bockscar*.[39]

It is evident that the more devices, clocks, radars, batteries, baro switches, X-units (used in *Fat Man*), inverters (convert DC current to AC), etc. that were used, the more certain that at least one would operate when needed. This is referred to as a parallel mode and consisted of two banks of pullout switches, six clocks, four radars, six baro switches, two X-units, etc. However, parallel devices only speak to the certainty-of-operation side of reliability. The more devices in parallel increase the likelihood of one faulty device failing prematurely. The solution to this is to group devices, in a bank, in series with another bank of devices. In the situation of the clocks, one bank of four clocks (in parallel) was in series with a second bank of four clocks (in parallel). There would have to be one premature in bank "A" and one premature in bank "B" to give a malfunction. Yet any one good clock in "A" and one good clock in "B" would give a proper function. In the case of a malfunction there would still be the remaining "series" functions of the baros, radars, etc. to prevent an overall failure of the fuzing system. This combination is called "series parallel" connection.

When the bomb was released from the bomb bay, the closing of the pullout switches started the first link of completing the overall fuzing circuit. The primary function of the 15-sec. delay in the operation of the clocks was to ensure the safe separation distance from the releasing aircraft. In the unlikely situation where several other components failed, the radar waves could have reflected off the aircraft resulting in a premature detonation.

Three (two in *Fat Man*) wood handled, 1.25" diameter, 3.11" long green Amphenol "safing" (testing) plugs, or circuit interrupters, prevented the bomb from going off prematurely. When the green plugs were in place, one of their functions was to place a short circuit across the weapon side of the wiring, i.e., these not only opened the connection to the firing signal, they shorted out the firing side from any spurious signal. These 5-pin AN (Army-Navy) plugs, which isolated the fuzing circuits from the firing circuits, were inserted through 1.3" diameter holes in the side of *Little Boy* and replaced, in-flight, with red "arming" plugs by the Electronics Test Officer Lt. Morris Jeppson. The two large pins on the bottom of the red arming plug were connected inside the plug by a copper jumper wire, thus closing the firing circuit. In the postwar stockpile units, these plugs were secured to the bomb by wire clips that snapped over the ends of the plugs. These clips were designed to prevent the plugs from accidentally falling out when the bomb was released.[40] Weaponeers Capt. Wm. Parsons, Jeppson, and Edward Doll each kept plugs after the war.[41] Doll was in charge of the *Project Alberta* fuzing team. Parson's green and red plugs are on display at the Navy Museum in Washington, DC. Both Edward Doll and Morris Jeppson signed the tags, dated August 7, 1945, and attached to the plugs. It states, "I certify that this is one of the three green safety plugs used on L-11 at Hiroshima, Japan. This was the first atomic bomb ever used in the history of mankind."

Jeppson later speculated:

> If I had removed the green safety plugs and then simply tossed the red ones onto the bomb bay doors, the bomb would have been a dud and there would have been no evidence! The Nagasaki bomb used the same fuzing mechanism and I'm willing to believe that a dud would have forced some high-level reconsiderations. Possibly the invasion of Japan would have happened.[42]

Philip Barnes, Electronics Test Officer on the Nagasaki mission, wrote:

> The title assigned to those of us who were trained at Wendover, to test the fusing circuits of the bombs, was ambiguous at best. This included [people such as] Bruce Corrigan, Morris Jeppson, Leon Smith, Larry DeCuir, Richard Podolsky and myself. We were given wings to wear because we flew with the flight crews, but no one knew what to call us. I have felt that the title Electronics Test Officer is the most fitting for what we were testing. The title of Weaponeer initially was applied to Parsons and Ashworth who were the bomb commanders on each flight. The application of this title to Ensign Anderson, who tested the firing circuits, and to Leon Smith, who tested the fuzing circuits for the ABLE test at Bikini, did not come into being until Operation CROSSROADS.[43]

From the very beginning, Navy Captain Wm. Parsons was in charge of the Ordnance Division at Los Alamos (Project Y). In the fall of 1944 he was named the Associate Director and subsequently made Officer in Charge of *Project Alberta*. He knew more about the *Little Boy* weapon than anyone else did. It was his brainchild. Parsons oversaw design, development, and testing, and ultimately supervised its assembly on Tinian. He had also designed the pumpkin test bombs. *Bockscar* Weaponeer Fred Ashworth said later, "Parsons was an absolute genius. In my opinion, he was the one person most responsible for getting the *Little Boy* out of the lab and into reality!"[44] Ashworth added that Parsons was a firm believer in the concept that "There's no end to the good one can do, if he cares not who gets the credit." Although he remained in charge of the overall *Little Boy* program, in 1943 Parsons turned over the day-to-day operations to fellow Navy Commander A. Francis Birch who became the project group leader.

The front end of *Little Boy* was the massive 28.0" diameter target case. Several smaller 24.0" diameter target cases had been tried and then ultimately rejected.[45] The first larger diameter target case manufactured was used four times in firing "proof" tests, between December 1944 and March 1945, at the Los Alamos Anchor Ranch Proving Ground.[46] Known as "Old Faithful," it was the best and toughest one made and eventually used in the Hiroshima bomb. It had survived all of the proof tests without cracking. Some of the earlier cases had not only cracked, but disintegrated and the "guts" were strewn all over the mesa. "A major part of the testing consisted of just avoiding a fracturing of the target."[47] After each test, a massive D-8 Caterpillar bulldozer had to be used to pull the gun apart.

The 36.0" long two-piece case was forged from heat-treated 4340 high-alloy steel and weighed over 5,000-lb. The case held the uranium target surrounded by the neutron-reflecting tamper material and the "anvil" (see below). Fully loaded it weighed over 6,000-

lb. During testing, natural uranium (tuballoy or U-238) served as surrogate fissile material. The front of the case was closed off with a 9.25" thick, 15.0" diameter nose nut[48] and the aft end was sealed off by the target-case to gun-tube adapter. Three inches of Acme threads were then machined into the center of this adapter to hold the 10.5" diameter gun tube (see below).[49] A straight-walled 22.0" long cavity had been bored all the way through the target case. It was machined so the front end behind the nose nut was 14.0" in diameter for a length of 4.0" and then tapered outward until the back end where it touched the gun-tube adapter was 15.0" in diameter.[50] To accommodate the gun-tube adapter, a 5" long cavity had been bored into the aft end of the target case and machined with Acme threads at the rate of two threads per inch.

According to *Project Alberta* SED T/Sgt. Gunnar Thornton, when it finally got down to deciding which *Little Boy* unit would be dropped on Japan, they were faced with a classic dilemma in quality control:

> There were two bomb carcasses sitting side by side. One of them had parts in it like the target casing that had survived and we felt quite good about. There were some things that you couldn't reuse anyhow and there were other parts, as we got better at it that you could reuse. What we did was we very selectively used parts that were 'Old Faithful' type parts. The bomb next to it was made out of new parts to exactly the same specifications...as the one made out of 'Old Faithful' type parts. So there we stood, you see. What'll we do? Maybe the 'Old Faithful' parts were on the point of breaking and would break the next time. On the other hand, maybe this new one had some defects in it and it would break so what'll we do? We just stood there, maybe half a dozen of us, Birch, Larry Langer, myself and a few others and we said '... which one should we use?' Birch said 'What do you guys think?' Well, everybody voted for 'Old Faithful.'[51]

The tamper material, while basically tungsten carbide, had about 6% by weight of cobalt mixed in with it. These pieces were fabricated in the Sigma building at Los Alamos by compacting the tamper powder in a hydraulic press under high pressure and then sintering (diffusion bonding) them at high temperature in a furnace with a controlled atmosphere. The main tamper rings were 13" in diameter[52] with an 8" bore. The massive finished pieces were machined with diamond-tipped tools and were the largest sintered pieces ever produced up to that time.[53] Tungsten carbide is a hard, tough, but brittle metal with a high density of 14.9 g/cm³ [8.64 oz/in³].[54] It is currently used for such things as the cutting surface on drill bits and on turbine blades in jet engines. The tamper material was dark gray in color with occasional flecks of green bonding material. It was referred to as Watercress, a code-name derived from its chemical symbol WC. A heat-treated liner sleeve made from K-46 tool and die steel surrounded the tamper liner rings. Three WC liner rings were hydraulically pressed into this K-46 liner sleeve and then the completed liner assembly was pressed into the target case through the 15.0" opening in the aft end. A slight taper had been machined into this liner assembly for easier removal during the testing phase. Screwed into the aft end of the target case adapter was the 6.5" smooth bore Type B gun.[55] "It weighed only about one-half ton, was 6 ft long, and had a large thread on its muzzle."[56] This forged steel gun had a 10.5" OD[57] and was manufactured by the Naval Gun Factory in Washington, DC utilizing the mono-block method. This process is also referred to as cold working (auto-frettage). It was made stronger by radially expanding it under pressure until the interior bore had been permanently enlarged. The gun was annealed (tempered) and then machined to its final dimensions. Type A guns were made from high-alloy steel, but were not radially expanded. Because it only had to be fired once, the walls of the relatively lightweight gun could be made a mere 2.0" thick. The forward end of the gun tube exterior was stepped down with a lip for a length of five inches including three inches in the middle of square-type Acme threads machined at two threads per inch to match those in the target-case to gun-tube adapter.[58] With the gun securely attached to the target, it was a closed-end system sometimes referred to as a "blind target."[59] A Los Alamos engineer involved with the rival implosion bomb program later quipped, "Whenever they fired the gun, it never missed the target!"

As early as 1943, some Los Alamos engineers were concerned about the problem of venting the air ahead of the projectile as it proceeded forward down the gun.[60] Thornton later explained, "The air, which had just atmospheric pressure to start with, was compressed to practically nothing. It was such a non-problem that no one paid any attention to it."[61] However, it must have ultimately been a problem since the target-case to gun-tube adapter plate was machined with four deep channels cut into the front surface at the point where it contacted the aft end of the WC tamper cylinder in order to vent the air away from the front of the projectile as it passed into the target case.

During the testing phase for the earlier plutonium "Thin Man" gun design, the engineers utilized a 17-foot long, 5.0" smoothbore gun. Part of this testing involved the application of a sabot, which is still considered a standard item for armor-piercing shells. It allows the use of a projectile that is smaller than the gun bore. The sabot, usually plastic, is wrapped around the smaller shell and falls off after the projectile leaves the gun. According to retired physicist Clay Perkins, "Its main function is to allow the transfer of the higher energy inherent in the larger gun to the smaller projectile. This system is often used against heavy tank armor to obtain very high velocity impacts."[62] The Los Alamos scientists initially considered using this technique because they thought the plutonium projectile needed to travel at over 3,000 feet per second to achieve a successful critical assembly before pre-detonation occurred. The original design called for the projectile to pass through the target freely.[63] The sabot would be stripped off inside the front of the bomb just before the projectile reached the target. The plutonium gun-bomb design was finally abandoned on August 14, 1944. According to Thornton, "This part of the design was discarded [early] and there were chunks of the carcass still sitting around at the testing areas when I arrived...in February 1944."[64]

The large gun formed the central spine of the bomb. A 1.0" thick, 27.25" diameter metal center-bulkhead was slid over the aft portion of the gun. This center-bulkhead was secured to the gun by means of a locking collar located in the conical section of the bomb. The arming, fuzing, batteries, and electrical components were attached to both the gun and the forward wall of the large center-bulkhead. The five 28.5" long armor plates that formed the central section of the bomb case were bolted between the nose section target case and this center-bulkhead. There were also ten 0.75" diameter holes on this plate that were utilized only during the testing phase to accommodate cabling that passed through these holes then into the tail where these were attached to tail plate-mounted radio telemetry informer units that relayed data through tail antennas to ground-based observers using radio receivers.

Bent-metal conduit tubes connected the holes in the bulkhead to holes in a 16.5" diameter plate so that the wires could be passed through more easily.

The armor plates made for *Little Boy* suffered from the same heat-treating warpage problems as the *Fat Man* armor plates (see *Fat Man* section below). When they tried to assemble these plates on *Little Boy*, the holes in the plates would not line up with the holes in the target case and center-bulkhead. Each hole had to be reamed or re-drilled.

Thornton recalled the alignment problem:

> We didn't have time to fit these things up. The urgency was such that you just plain went ahead. The idea was to get that thing ready and drop it on the first day, at the very first hour as you possibly could...so out came these armor plate things and we would take them out and clamp them up and, lo and behold, it doesn't exactly fit the curvature and the holes don't line up.[65]

Thornton was lying on his back under *Little Boy*, while one of the other assembly team members, Larry Langer, was handing bolts to him. After Thornton put in the final bolt, Langer leaned down and said, "Congratulations Gunnar. You've just put the last bolt in the first atomic bomb!"

The electrical and arming connections were attached to these plates. The 14 pullout wires were threaded through eleven 0.375" holes in the 9.75" wide top plate. The three pullout electrical plugs were also attached to the aft end of this plate. These electrical plugs, along with the pullout wires, were pulled out of the bomb when it was released. Four 3.125" long U-shaped holes in the forward end of the four remaining plates allowed the electrical connections from the Archie radar antennas to enter into the interior of the bomb. The rear portion of the 23.5" long cast aluminum radar antennae bases covered up these holes. Metal plates with the Yagi antennas were attached to these bases after the bomb was loaded on board the *Enola Gay*. This was done not only because these antennas might have been damaged during the loading procedure, but more importantly because the size and shape of the antennas was considered top secret. Any person knowledgeable in electronics could probably have determined the Archie radar frequency range by seeing the antenna. This would have left the weapon vulnerable to the possibility of radar jamming (see above).

The 24" long, two-piece conical section was bolted between a flange machined into the aft portion of the large center-bulkhead and the cylindrical tail section. This conical section contained the six 0.625" and two 1.5" holes that served as the air intakes for the baro switches. 3.0" long steel baffle plates were welded behind these holes to help direct air into them. The air drawn in through these eight intakes was then, in turn, drawn into six holes in the center-bulkhead plate and into the six baro switches mounted on the reverse side of this plate.

A circular steel plate was positioned inside the 17.0" diameter tail cylinder at the front of the tail tube and another towards the rear of the tube. These allowed the tail to be slid over the 10.5" diameter gun tube during assembly. The forward plate was positioned 26.5" in front of the aft plate and was welded to the front of the tail tube. Three long 0.75" diameter armored metal tubes were positioned between holes in both forward and aft plates and the large center-bulkhead. These were secured with small locking collars around the tubes at both this bulkhead and a 0.75" thick, 16.5" diameter plate positioned just in front of the tail tube. This plate, in turn, was bolted to the forward tail tube plate. The tubes had an interior diameter of 0.40" and each contained and protected one of the three wires that went from the safing/arming plug sockets back to the breech primers. Three 1.0" diameter steel rods were positioned next to these tubes. These were screwed into holes in the large center-bulkhead and were attached to the 16.5" diameter plate by two nuts. The rods were used to both align and anchor the tail assembly at the proper distance from the center-bulkhead. In addition to the tubes and rods, there were also ten 0.75" diameter holes around the forward steel plate welded to the front end of the tail tube. The aft plate was positioned 16" forward from the end of the tail at the very end of the 72" long gun tube and was secured to the tail tube with four 5/8-18 socket-head bolts that were 2.25" long. These bolts are visible on the exterior of tail tube and are located 14.5" forward from the end of the tail. Along with the three breech primer wiring tubes, this aft plate also had ten 0.75" diameter holes spaced around the perimeter on a 13" diameter circle. The holes in both the forward and aft plates were used in conjunction with the holes in the previously mentioned large bulkhead during the testing phase to run cables from the fuzing circuits out the tail of the bomb.

The entire tail section slid over the gun tube and was secured with six bolts to the aft end of the conical tail section. The breech was located inside this tail section. A 0.25" thick, 16.875" diameter rear armor plate was secured to the back of the tail tube by using eight 1" long 1/4-20 bolts. A second 0.375" thick inner armored plate, positioned about eight inches in front of the tail plate, was bolted to a 15" O.D., 14" I.D. armored tube that extended back from the breech. The forward end of this tube was slid into a flange on the aft plate inside the tail and was secured by the same four 5/8-18 socket-head bolts mentioned above. This smaller armor plate served as one more layer of protection for the breech and was secured to the aft end of the tube with six bolts. Access to the breech was gained by removing these two plates during the arming process. To aid in this process, the bomb was loaded in the *Enola Gay* bomb bay with only half the screws needed to secure these two plates.[66]

The barrel was closed off at the aft end by a threaded breech plug located 12.5" forward from the rear tail plate. This plug was originally a very heavy solid piece but, for a number of reasons (see below) including safety concerns, the design was changed so the propellant powder could be loaded into the gun after takeoff.[67] The plug was redesigned by Navy Lt. Cdr. A. Francis Birch, the leader of the *Little Boy* group, into a two-piece plug. The outer stationary part of the plug (bushing) was screwed permanently into the aft end of the gun. The smaller removable inner plug, about 4" in diameter and 8" long, could then be easily screwed into this outer bushing. The inner plug weighed between 15-lb. and 20-lb. and contained the three Mark 15 Mod 1 Navy gun primers and firing leads used to ignite the powder.[68] A breech wrench was used to secure the inner plug.

On board the *Enola Gay*, Weaponeer Parsons, assisted by Jeppson, inserted the four cylindrical silk bags of WM slotted-tube Cordite powder[69] through the inner breech plug. During the testing phase there had originally been just a single large powder bag, but the charge was later separated into four smaller bags with the re-design of the breech plug. The bags were packed into the gun in a circle behind the projectile. Cordite was a commonly used smokeless gun propellant invented by the British in 1890. It is very lightweight with a density of about 1.66 g/cm^3 (0.96 oz/in^3). The WM Cordite mixture (65% nitrocellulose/30% nitroglycerine/3% mineral jelly/2% carbamite) was extruded during manufacture into the shape of small diameter slotted tube, spaghetti-like, granules. This design increased the surface area of the granules resulting in a very rapid burning rate with high peak pressure of 75,000 psi. The Cordite used in the wartime *Little Boy* was obtained from Canada.

According to one source, the propellant for the postwar stockpiled weapons was manufactured in the US by the Picatinny Arsenal.

When the breech primers set off the red-colored black powder igniter patches at the rear of the Cordite-filled bags, the resultant explosion propelled the projectile about 50" down the gun and into the target at close to 1,000 fps (feet per second). Before they were loaded into *Little Boy*, the powder bags were stored in a Navy powder can that was lashed, along with the breech wrench, inside the bomb bay of the *Enola Gay*.

The 16.25" long projectile consisted of nine washer-like, Oralloy rings at the front end with a WC filler plug and thick steel section behind it, assembled in a steel can of 0.0625" wall thickness and weighed about 200-lb.[70] The nine 6.25" diameter uranium projectile (female) rings with a 6.75" total length and a 4.0" diameter hole in the center fit snugly over the (male) target cylinder discs during critical assembly thus forming a solid core. The inner cylindrical surface of each ring, along with the outer cylindrical surface of each target disc was plated with a 0.005 in. layer of cadmium.[71] These rings were pressed into the front of the projectile during final assembly. Because the amount of enriched uranium differed with each batch shipment received at Los Alamos from Oak Ridge, none of the rings and discs installed in the combat *Little Boy* was the same thickness.

Wide, finely machined cast-copper obturator sealing bands surrounded the projectile in order to provide a snug fit to the smooth bore of the gun.[72] During assembly on Tinian, the *Project Alberta* engineers hydraulically pushed the projectile into the breech end of the gun until it seated up against the detents or "stoppers."[73] These had been utilized in hopes of preventing the projectile from moving forward into the target (self-assembly) in the event the plane crashed during takeoff. This might have resulted in a "high order" nuclear event (explosion). Airdrop tests had been made to see if it would self-assemble after impacting with the ground when dropped from over 30,000 feet. It did, although it may not have come out full-yield. That is why *Little Boy* did not need contact nose fuzes like *Fat Man*. According to Thornton, "This was an important feature of that configuration and things like shear pins (stoppers)...were fine-tuned to make that possible."[74]

The projectile, when driven over the uranium target discs, formed a supercritical mass that was "tamped," or held together, to start the explosive nuclear chain reaction.

The six Oralloy target discs, surrounded by the large tamper liner sleeve assembly, were located in the interior of the target case just forward of the gun. When assembled together, these washer-like discs formed a 4.0" diameter, 6.75" long cylinder.[75] It was held together by a large diameter solid U-235 "bolt" that was pushed into this cylinder at the back end and then was, in turn, attached to the rear end of the steel bolt that protruded out the target case front end. In front of this cylinder was a thick WC insert base that was pressed into the front end of the 6.5" diameter bore in the larger 13.0" tamper sleeve. The tamper piece and target cylinder could slide forward into the anvil when struck by the projectile (see below).

The uranium target discs arrived at Tinian on July 28, 1945, as the sole cargo aboard three C-54 planes. Commander Birch accompanied the cargo. The guards on these planes were told the material was dangerous so they stayed as far away from the lead containers as possible during the long journey across the Pacific from Los Alamos. When all six discs were delivered to Birch in the assembly building, he removed them from their containers, then casually stacked them together, one on top of the other. One of the wide-eyed guards asked nervously if that wasn't dangerous. Birch turned to him, with a twinkle in his eye, and said, "Of course it is!"[76]

The center of the core was 22" back from the target case nose.[77] In the front-end of the target case, just forward of the small, movable tamper piece and uranium target cylinder, was a cylindrical forging of shock absorbing ductile metal referred to as the anvil.[78] It absorbed as much of the kinetic energy of the projectile's collision with the target as possible (non-elastic collision) thereby helping to keep the target material from being physically altered or fractured before "critical assembly" could take place. The anvil would "squish" (deform) during impact by bulging out on the sides into what Gunnar Thornton later referred to as "that beautiful pancake shape...like the side of a barrel." He continued, "It turned out to be a surprisingly untroublesome aspect of the tests. I thought we were going to have to do a lot more fiddling around on that particular thing."[79]

Four polonium-beryllium "initiators" were most likely equally placed radially on the front end of the projectile WC filler plug next to the uranium projectile rings.[80] Polonium mixed with beryllium is still a widely used neutron generator. Polonium is a very active alpha particle emitter and the beryllium served as the alpha particle target used to produce the neutrons. The alpha particles are absorbed by the beryllium, which then produces neutrons plus some residual nuclei. Beryllium is also a neutron reflector and is used in present-day nuclear devices as a tamper material. Chain reaction initiating neutrons are emitted when these two elements combine. The polonium and beryllium were arranged to keep the neutron levels low enough to prevent a premature explosion yet release a sufficient quantity of neutrons at the precise moment.

The cylindrically shaped initiators were reportedly about 0.5" in diameter and 0.5" long. The polonium was kept separate from the beryllium by a piece of gold foil that was punctured by the impact. Initiators were assembled in a "hot-box" (glove-box) at Los Alamos. The parts were all laid out in the box, cleaned with solvents, and then assembled using tools as small as tweezers.[81] When these initiators were crushed by the impact of the projectile, the polonium mixed with the beryllium thus releasing a flood of neutrons to start the fission reaction.

The target assembly and tamper liner were accessed through the thick 15.0" diameter threaded nose nut at the front of the target case. This large nut was removed by using a series of spanner wrenches and weighed about 450 lb. Two 2.0" diameter plugs (threaded at 12 threads per inch for a length of 0.75" at the front end) were removed from the nosepiece using a small spanner and then a larger steel spanner bar, attached to nose nut handling bolts, was inserted into these two holes.[82] During the testing phase at Los Alamos, difficulty in removing this large nut after a test (due in part to galling) sometimes required that a heavy weight be dropped from a crane onto this bar just to loosen the threads.[83] Indeed, galling was such a problem (because the threads were too finely machined), this was one of the reasons the breech plug had been redesigned. Had Capt. Parsons been unable to reinsert the breech plug during the in-flight arming process because of galling, the Hiroshima mission would have been terminated!

Recalling some of the relatively unsophisticated working methods used at the time, Thornton explained, "When I think of all the things we did with sledge hammers, monkey wrenches, and soldering guns back then...they were very dangerous conditions."[84]

A 1.0" diameter cadmium-plated steel draw bolt (threaded at 12 threads per inch) went from the front of the active Oralloy target insert cylinder, through the tamper insert base and anvil, to right on through the center of the front target case nose nut (also threaded at 12 threads per inch). This bolt screwed into the front end of the target cylinder uranium bolt. The tamper insert base, anvil and anvil shim had been slid over this steel draw bolt, which served to hold the entire insert assembly in perfect alignment. It was secured to the outside of the nose nut by large elastic lock-nut which, when tightened, drew everything together.[85] The large nose nut acted like a backstop and had to be massive because this is what the entire insert assembly was pushed into when struck by the projectile. The bomb interior was, according to one of the engineers, "highly polished and beautiful to look at."[86]

In order that no contractor had the complete design, three manufacturers split up the work. The Naval Gun Factory made the gun and breech; Naval Ordnance Plant in Centerline, Michigan, made the target case, its adapter to the muzzle threads, and its suspension lug; and Expert Tool and Die in Detroit, Michigan, made the bomb tail, faring, and various mounting brackets.

Many tests were conducted to determine the reliability of the numerous mechanical, electrical, fuzing, and nuclear components of both the *Little Boy* and *Fat Man* bomb designs. These tests were conducted at several places that included: Los Alamos and Kirtland Field in New Mexico; Muroc Dry Lake (Edwards AFB), Inyokern (China Lake), and Salton Sea Test Base in California; Wendover Field in Utah; and at Tinian Field in the Pacific. The water table was so high at Inyokern that some *Little Boy* test units were never recovered because the water kept filling in the hole.

The Y-1852[87] *Little Boy* combat unit used exterior case design number L-2-B.[88] This design, frozen in early 1945, replaced several earlier case designs, like the L-2-A, which was a larger 30.0" in diameter.[89] These earlier designs were close enough to the final design to be used in the initial drop tests at Wendover. Four other *Little Boy* units (L1, L2, L5, and L6) were dropped as test units at Tinian. Unlike the Y-1852 combat unit, these were the Y-1792 design. Some LB dummy units utilized a 10.75" thick solid steel target case (no WC tamper material or K-46 liner) with an 18" long, 6.5" bore so it could use the same projectile as the Y-1852. These dummy units and Y-1852 designs also both shared the same 15.0" diameter nose nut projectile backstop and 16.5" diameter target-case to gun-tube adapter.[90] "The unit used for combat delivery was known as 'L11.' It included Gun #27 (fired on Rd. 303A), Rear Assembly #41, and the 2-piece target C-O known as 'Old Faithful'. This target had been proof-tested in Rounds 42B, 45B, 271A, and 285A (16 Dec 44, 18 Jan 45, 6 Feb, 15 Mar), with no sign of damage to the case."[91]

Such was the confidence of everyone in the success of the *Little Boy* design that no full scale proof-test of the nuclear components was ever conducted. This gun-type weapon, though incredibly inefficient (only a reported 1.38% of the U-235 fissioned)[92], still produced an explosion with a force of about 16 ± 3 Kilotons[93] or 32,000,000-lbs. of TNT. However, because this design used so much of the precious HEU fissile material, it was never used again. According to journalist Lansing Lamont, it was "perhaps the most outrageously expensive and wasteful weapon ever built for one combat mission."[94]

The *Little Boy* bomb components were delivered to Tinian over a several week period in July 1945. "The projectile was loaded on 30 July in the usual manner and rammed home. The same day the [target] insert was loaded, initiators installed, and the anvil and nose nut assembled. The active insert assembly was secured with a lock nut."[95] This lock nut is visible on the outside center front of *Little Boy*.

Due to the difficulties in obtaining sufficient fissile material from Oak Ridge, the target and projectile active pieces had been manufactured at different times and the scientists had not been able to conduct final safety and criticality tests at Los Alamos. It was not until assembly at Tinian, when the steel target case, tamper, initiators and all of the critical material were finally put together at one time, that such testing could take place. The assembly team had to improvise field test procedures using whatever electronic equipment was at hand at Tinian. They were relieved when the results indicated the assembly would be successful. "We had the initiators inside and then we started to put the projectile in. There was no increase in the neutron level, which indicated we weren't even close to getting a subcritical multiplication."[96]

On July 31 the Archies, clock box, baros, and firing lines were installed and checked.[97] Because of a forecast of bad weather over Japan, the bomb was held in storage for a few days. After the bomb had been assembled, a lot of people put their names and sentiments on the bomb. One of these reportedly said, "A present for the souls of the *Indianapolis*' crew." This referred to the cruiser USS *Indianapolis*, which brought the main parts of the bomb to Tinian. These included the target case, barrel, and projectile, which were loaded at San Francisco's Hunters Point Naval Yard in the predawn hours on July 16 at the very same moment the Trinity test was underway. Unlike the target discs, which were later flown to Tinian on three separate planes, the assembled projectile was shipped in a single lead-lined steel container, which was bolted down and locked to the floor of Captain Charles McVay's quarters. After they were underway, McVay told the crew that what they were carrying would help shorten the war. The crew speculated as to the contents of the secret cargo and one of them even joked that the large crate probably contained toilet paper for General McArthur.

Michael Kuryla was a coxswain aboard the *Indianapolis*. "The *Little Boy* crates and uranium were loaded aboard in the early morning."[98] He stated that two so-called artillery officers came on board with the mysterious cargo and accompanied it on the long voyage to Tinian. "We suspected they weren't really artillery officers since they were wearing their collar insignia upside down. When we asked them what kind of guns they were assigned to they sort of hemmed and hawed and finally just used their hands to show approximately how big they were."[99] These two "artillery officers" were, in fact, Los Alamos chief medical officer Dr. James F. Nolan and Major Robert R. Furman, General Groves' special projects officer.

The *Indianapolis* wasted no time traveling from San Francisco to Tinian. One of the crew commented later they moved so fast they were like a motorboat on the water. As a matter of fact, they set a speed record that still stands. Sadly, four days after dropping off the precious cargo at Tinian on July 26, the Japanese submarine *I.58* commanded by Mochitsura Hashimoto torpedoed and sank the *Indianapolis*.

Kuryla and another shipmate had just finished their evening watch and, because it was a warm night, decided to sleep outside on the upper deck. He described what happened after the first torpedo struck the ship. "The next thing I knew there was an explosion and the whole deck stung our bodies. We went flying in the air and landed back down on the deck. All of a sudden, Kaboom, there was another one!"[100] As the ship started to roll over rapidly on her starboard side, Kuryla recalled:

> As she was going down, I inhaled all the air I could into my lungs. I took my hands and feet, as she was going down on top of me, and pushed down and swung to my left. All of a sudden it sucked me back to the deck. So I kicked again and it sucked me back again. That's when I felt, Jeez, maybe this is it! They say your life goes before you. I saw my mother, my dad, and my six sisters on Homer Street in Chicago. I said an act of contrition and just blacked out as the water hit my nose. Next thing I knew, I'm on the surface. I saw the stern of the ship going down, the screws turning, and the guys hanging onto the screw guards. It just bubbled up and hissed as it sank.[101]

The ship went down in 11 minutes at 12:14 AM, July 30, 1945, without being able to send an SOS. By the time the rescuers arrived 96 hours later, 883 sailors had drowned or been eaten by sharks. This tragedy was the worst sea disaster in the history of the U.S. Navy.

The *Little Boy* Assembly Team Leader Commander Birch saw the graffiti and ordered all of it removed from the casing. A conservative person, he felt they were participants in a "grim, dirty business" and such graffiti was inappropriate. However, some of this did reappear later and is clearly visible on photos of the bomb in the loading pit on Tinian.[102]

Little Boy sat patiently waiting for five days in the air-conditioned Tinian assembly building until ready for its final unveiling on Sunday, August 5, 1945.

Chapter 4

Hiroshima

"My only thought at that time was whether or not it was going to be a large-order explosion. The longhairs had told us we had to be eight miles away when it went off, but I don't think any of us really believed that."

Thomas W. Ferebee – July 11, 1998

On Saturday, August 4, 1945, an afternoon briefing was held on Tinian. It was attended by the seven crews that would be going on the mission to drop *Little Boy*. While not mentioning that it was atomic, Capt. Parsons and Col. Tibbets told the crews for the first time what type of bomb they would be dropping. Pictures were shown of the Trinity test that had taken place a few weeks before in New Mexico. They were told the three target cities would be Hiroshima, Kokura, and Nagasaki and there would be no fighter escort on the way in. It was to be a surprise. They would be going out in a few days whenever the weather permitted. On the way back, there would be rescue planes and submarines to help them in case trouble developed.

The briefing ended about 45 minutes later and they were told not to talk about anything they had just heard, even among themselves. They went to dinner, but as one of the crew said later, "Our food had no taste."

The next day, everyone busied themselves by preparing for the mission. They checked and rechecked everything. As Major Charles Sweeney's assistant Flight Engineer on both combat missions, Ray Gallagher said:

> We had been in training for a year. We could do it with our eyes shut. The most distressing feeling is when you know that you are definitely going out. All the bravery in a man, more or less, falls to the side. As a group you're brave, but you have your inward thoughts and they may be selfish. They basically boil down to this: are we going to make it and come back?[103]

When you were going to go out on a mission, the only things you could take with you were the things that you needed to do your job, your watch, and your dog tags. Anything personal has to stay behind. As you left your Quonset, you passed a person who had a barracks bag on a bed in front of him. This was someone who would not be going on the mission. When you passed him, you dropped your wallet into the bag. He would hold it until you came back. It is as if you took "home" and put it behind you. You are on your way. There is no turning back.

"There are no more cowards. We all traveled as a group. We were talking, trying to hold a conversation. We got to our briefing and from that moment on, it's a 'Go.' There's no stopping you," said Gallagher.

On Sunday afternoon at 2:00 PM, it had just stopped raining when *Little Boy* was finally wheeled out of the assembly building and loaded onto a trailer. By 2:30 PM, it had been pulled out to the loading pit. After *Little Boy* was hydraulically lowered into the pit, the *Enola Gay* was slowly pushed backwards over the pit by using a Cletrac MG-1 aircraft tug. It took about an hour to carefully raise the bomb into the plane, secure it to the bomb shackle, and attach all of the cables, antennas, and pull out wires. By 6:00 PM, it was all ready. The final crew briefing was scheduled to be held at midnight.

As the *Enola Gay* was being taxied back from the loading pit to its revetment, an incident occurred when the plane's number one prop chewed up several yards of the revetment's coral while being swung around to face back out toward the entrance. Jean S. Cooper, the engine mechanic for the #4 engine of the *Enola Gay*, recalled what happened:

> When Walter McCaleb, the crew chief, was swinging it around in the revetment, he swung a little too wide and clipped the coral and bent the tips of the prop. Nothing to do but change props with the *Little Boy* aboard and the revetment full of colonels, majors and even a few generals. We had to push them out of the way to get the crane in and the other equipment so we could work on the prop. I think that was the fastest prop change in history. We just barely managed to have it done in time for takeoff.[104]

Acting on a last minute request from N.Y. Times science reporter William Laurence, the *Enola Gay* Co-Pilot, Capt. Robert Lewis, kept a log of what went on during the flight. Many of these notes were hand written in almost complete darkness.[105]

At 2:45 AM, August 6, 1945, the *Enola Gay* took off from Tinian followed a few minutes later by Sweeney in the instrument plane, Captain George Marquardt in the photo plane, and Captain Charles McKnight in the back-up plane. The three weather planes had taken off an hour earlier. Because the *Enola Gay* was so heavy, they used almost every foot of the runway and barely cleared the end of the field.

At 3:00 AM, Parsons opened the hatch and both he and Jeppson climbed through it. There was an unexpected toolbox on the catwalk as they made their right turn after entering the noisy, dimly-lit bomb bay. With the wind whistling through the bomb bay doors, and using Parsons' flashlight for illumination, they both steadied themselves as they cautiously inched their way along the very narrow catwalk situated between the port side of the bomb and the outer bomb bay wall. Finally reaching the special 10-lb. removable aluminum catwalk platform that had been installed in the bomb bay at the rear of *Little Boy* after it had been attached to the bomb shackle the previous day, they started the complex 20-minute arming procedure. Jeppson stated later, "It was pleasantly cool in beside the bomb."[106]

As the *Enola Gay* flew low over the Pacific, Parsons unbolted and removed the rear tail plate and interior heavy armor plate. While Jeppson held the flashlight, Parsons laid down on the platform on his left side propped up on his left elbow and stuck his arms, and sometimes his head, inside the tail then disconnected the three primer wires, unscrewed the breech plug and set it down on a rubber pad he had placed inside the tail. Then he delicately inserted the four powder bags, screwed the heavy breech plug back into the rear of the barrel, reconnected the primer wires, and finally reattached the two rear plates. The last step was to remove and secure the removable catwalk. If it had been left in place, the position of this catwalk very near the tail of *Little Boy* might have interfered with the bomb when it was finally released. All this had to take place before the plane could be pressurized later for the long climb up to cruising altitude. About 6:00 AM, the four planes rendezvoused over Iwo Jima. As they looked down on Mt. Suribachi, they were reminded of the 26,000 Americans that were killed or wounded capturing the island just five months before. Because the back-up plane was not needed, McKnight stayed behind at Iwo.

After circling Iwo, they turned, climbed to 9,300 feet, and headed towards Japan. At 7:30 AM, Jeppson climbed back into the now-cold bomb bay. After carefully making his way halfway along the port side of *Little Boy*, he turned to his left and leaned forward bracing himself against the bomb. With only the four bomb bay lights for illumination, he spent the next several moments exchanging the green safing (testing) plugs with the red arming plugs. Putting the green plugs back in his pocket, he left the bomb bay.[107] Jeppson recalled thinking, "My job and responsibility is DONE!"[108] *Little Boy* was now fully armed and the *Enola Gay* could be pressurized in order to start its long uphill climb to 32,700 feet. Lewis wrote in his log that "the bomb is now alive and it's a funny feeling knowing it's right in back of you. Knock wood." Jeppson wrote later:

> When Parsons and I left the bomb bay the three safing (I call them testing) plugs were in place. The time was around 3:30.
>
> From that time on I periodically monitored the Flight Test Box, testing the fuzing system, and recorded data on typed clip-board (what happened to them?)
>
> Finally, before the plane began its move to bombing altitude around 7:30, I climbed into the bomb bay and switched plugs-green to red. The bomb was now armed. I reported this and test results to Capt. Parsons, who advised Tibbets.
>
> After this no further testing was done, as I recall. There is a critical time interval between 3:30 and 7:30 when testing of the fuzing system determined whether or not the weapon should detonate in the air above Hiroshima. This is why the term testing plugs is used (a term originated by Phil Barnes)[109]

Both Parsons and Jeppson made frequent, careful checks of the Flight Test Box (FTB), which monitored all of the bomb's many circuits. Jeppson later recalled, "Since I detected no problems in monitoring, Capt. Parsons left me alone."[110]

Radio Hiroshima announced an air-raid alert at 8:09 AM. The weather plane, *Straight Flush*, had been sighted and it was assumed an attack of some sort was imminent.

At 8:25 AM, the radio operator, Richard Nelson, picked up the message from the weather plane over the primary. It stated: "Y-3, Q-3, B-2, C-1." This was translated to read, "Cloud cover less than 3/10ths at all altitudes. Advice: bomb primary." Nelson then sent a one-word coded message to Iwo Jima. "Primary."

At 8:31 AM, the all-clear signal was sounded in Hiroshima. At about 9:00 AM, the crew of the *Enola Gay* spotted their target. Tibbets, Parsons, Van Kirk, and Bombardier Major Thomas W. Ferebee conferred and all agreed that it was indeed Hiroshima. The three planes headed straight in with the *Enola Gay* in the lead, the instrument plane to the left, and the photo plane on the right. Five minutes before the bomb was dropped, the photo plane commanded by Capt. George Marquardt made a turn so that it was in position 10 miles away to take photos when the bomb went off.

They reached the IP (Initial Point) at 9:12 AM, just as the radio operator at Radio Hiroshima was writing down the message that three planes had been spotted. As he was rushing to a studio to announce the warning, the *Enola Gay* was six miles overhead. Lewis wrote that, "As we are approaching our IP, Ferebee, Van Kirk, and Stiborick are coming into their own, while the Col. and I are standing by and are giving the boys what they want." He concluded with the comment, "There'll be a short intermission while we bomb our target."

Seated all by himself in the immense bubble nose of the *Enola Gay*, Ferebee had a breathtaking panoramic view as the morning sunlight bathed the doomed city. However, as Bombardier, he had seen this identical view over sixty times before. So had the rest of the flight crew. As seasoned combat veterans of the long air war in Europe and North Africa, to them it was just another city, another target. The only difference this time was that it was a bigger bomb.

About 90 seconds before the bomb's release, Tibbets ceded final command of the *Enola Gay* to Ferebee. "It's all yours," he said, releasing his grip on the controls. Ferebee made careful last-minute maneuvering corrections to the Norden bombsight, which in turn was connected to the huge B-29's autopilot, nicknamed "George."

Ferebee started the sixty-second signal tone at 9:14:17 AM indicating the beginning of the automatic release sequence. The AP (Aiming Point) was the T-shaped Aioi Bridge over the Ota River that runs through the center of the city. He selected this because it was easy to spot from 31,000 feet. The entire city of Hiroshima was the target. Over the years, Ferebee had been reported to have been committed to an insane asylum or gone crazy with remorse for what he did. He strenuously denied this in 1995 when he affirmed in his charmingly thick, Mocksville, North Carolina drawl, "It's not true. I've never felt any remorse and never will!"[111]

At 9:15:17 AM [8:15:17 AM Hiroshima Time], the tone stopped and the bomb was released from 31,600 feet[112] just as the Radio Hiroshima announcer was starting to give the air-raid alert. As if a giant hand had slapped the bottom of the plane, the nose of the massive B-29 suddenly leapt upward in reaction to the release of the enormous weight of the bomb.

When *Little Boy* was clear of the plane, Tibbets immediately put the *Enola Gay* into the 155° diving right-hand turn that would put them at a safe distance away from the explosion. Ferebee stated later, "Quick as I saw the bomb leave the aircraft I turned and said, 'It's clear,' and then the pilot immediately started the turn."[113] Ferebee looked back over his shoulder and noted that the bomb wobbled a bit then picked up speed as it raced downward toward the doomed city. In a few short moments, the course of human history would be irrevocably changed.

As soon as *The Great Artiste* Bombardier Kermit Beahan saw the bomb fall from the *Enola Gay*, he dropped three parachuted instrument packages from his plane. Sweeney immediately started his sharp left turn.[114] These aluminum blast pressure gauge canisters transmitted primary and reflected acoustical pressure wave signals back to the scientists in *The Great Artiste*. This data was used later to help determine the blast yield. Luis Alvarez, Harold Agnew, Bernard Waldman, and Lawrence Johnston developed the technology for this system. Said Johnston, "Luis Alvarez was given the job, by Oppenheimer, of going along on the mission and measuring the output of the bomb."[115] A FM transmitter in the canister transmitted the signal to a receiver in the instrument plane. The signal was displayed on an oscilloscope and recorded on 16-mm. movie film. This system was also used on the Nagasaki mission. Johnston was the only person to have witnessed all three Trinity, Hiroshima, and Nagasaki explosions.

Exactly 44.4 seconds later, *Little Boy* exploded at an altitude of 1,968 ± 50 ft.[116] George (Bob) Caron, the tail gunner, was the first one on the *Enola Gay* to actually see the flash of the explosion. "It was all over the whole sky. I got the brunt of it. I thought I was blinded, even with those special goggles on. I couldn't see the actual explosion, the turret was in the way."[117] Caron also saw the shock wave coming through the air. It looked like a spherical, shimmering bubble of air coming right towards him. He did not know what it was at first. After it slammed into the plane, Tibbets yelled "Flak!"[118] Caron was able to warn everyone before the second reflected shock wave hit.

Jeppson wrote later that, "To my relief less than a minute later the plane, now in a 180° rolling away turn was slapped by a shock wave and about two seconds later by a second shock wave. The second one, obviously reflected from the ground, indicated that the bomb had in fact detonated in the air above ground – as it should have."[119] He added, "The destruction on the ground was evident from spreading ground clouds and visible fires. I felt regret that people were enveloped in that destruction."[120]

The crews all looked down on the spectacle that was unfolding below them. It seemed almost impossible to comprehend. A city of almost 300,000 was essentially destroyed. Tibbets wrote in 1946, "No one spoke for a moment, then everyone was talking...Tom Ferebee wondered aloud whether radioactivity would make us all sterile. Lewis said he could taste atomic fission. He said it tasted like lead."[121]

Since the end of the war, the Japanese government stated they presumed 140,000 people died either directly or by the end of 1945 because of the atomic bomb. However, in 1995 they downgraded that longstanding, oft-quoted estimate by almost 40%. Based on an extensive four-year survey, the government placed the total number of confirmed deaths by the end of 1945 at 87,833.[122]

A three-mile diameter expanding dark gray cloud was enveloping the city. Fires were breaking out everywhere. The city itself looked like bubbling black tar. In the center of the destruction a turbulent, bubbling cloud, purplish-gray in color, with a fiery red core, was rising into the, now-familiar, mushroom shape. Caron described it as a "peep into Hell!" Ferebee stated later, "It was exactly the same as you've seen it in pictures, only that from being there you could actually see parts of things moving up in the cloud, parts of buildings or just rubbish of all kinds."[123] Lewis wrote in his log, "There in front of our eyes was without a doubt the greatest explosion man has ever witnessed." He continued:

> I am certain the entire crew felt this experience was more than any one human had ever thought possible. It seems impossible to comprehend. Just how many Japs did we kill? I honestly have the feeling of groping for words to explain this or I might say My God what have we done. If I live a hundred years I'll never quite <u>get these few minutes out of my mind</u>. Look at Capt. Parsons, why he is as confounded as the rest and he was supposed to have known everything and expected this much to happen (original emphasis).[124]

Lewis stated years later, "People get the wrong meaning, that we immediately felt sorry. This was not the intent. The intent was that it was so enormous – human beings developed something to destroy a whole city at a time – it was utterly incomprehensible."[125] At this point, Tibbets announced over the intercom that they had just dropped the first atomic bomb in history.[126] Within a few minutes, the cloud had risen to almost 40,000 feet. Most of the crew thought that this would surely mean the end of the war.

Ferebee later explained both he and Tibbets had not worn the dark goggles, which would have protected them from the intense flash of light that accompanied the explosion. Both were momentarily blinded. However, that was short-lived and soon they were flying parallel with *The Great Artiste*. Ferebee wrote later, "Paul, after pulling out of the escape turn, leveled off and then turned south for all [of us] to observe the city from our right for approximately two minutes. Then he turned slightly left and headed back to Tinian."[127]

Tibbets called back on the intercom. Referring to the hard 155° turn, he asked, "How was that ride back there, Bob?" Caron, a Brooklyn native, replied, "Colonel that was better than the 25-cent Cyclone ride at Coney Island!" Tibbets answered, "Well, pay me the quarter when we land." Caron replied, "Hell, Colonel, you'll have to wait until payday."[128]

The radio operator, Richard Nelson, broke radio silence to send a series of three coded messages back to Tinian after the bomb was dropped. The first message sent was from Tibbets. It was a normal strike report and stated they were returning to the regular base (Tinian). The second, more detailed report was from Parsons to Ramsey. It said (in code), "82 V 670. Able, Line l, Line 2, Line 6, Line 9." The third was a clarification message. When these were combined and summarized by Los Alamos scientist John Manley back in Washington, the following message was transmitted from General Groves to Oppenheimer. It stated, "Clear cut results, in all respects successful. Exceeded TR (Trinity) test in visible effects. Normal conditions obtained in aircraft after delivery was accomplished. Visual attack on Hiroshima at 052315Z with only one-tenth cloud cover. Flak and fighters absent."

Over the many years since the war ended, Tibbets bristled at any suggestion it was a mistake to use the bombs. Responding to Monday-morning quarterbacking by some critics he commented, "They never had their balls on the anvil. They weren't there."[129] He also said, "I am convinced. I've been convinced, by Japanese, that we saved more lives than we took. It was a devastating thing. It came as a tremendous surprise. It shocked people." In an impassioned response to a question concerning the ill-conceived 1995 Smithsonian Institution National Air and Space Museum *Enola Gay* exhibit, Tibbets stated:

> They tried to show the Americans, and us (509th) in particular, as a bunch of people who were out to slaughter the Japanese, the poor people...that bothered me because, I don't know how many of you have read your history and know what they did in China...you talk about slaughter, they did it by the millions and we did it by the thousands. *In wartime, people are going to get killed!* That's been happening since the cavemen were throwing rocks at each other. The fact that we killed so many people so quickly was just unheard of, it was terrible. But on the other hand, *that had to be done, and it was done, to save millions of lives*![130]

Captured Japanese military personnel and scientists, who had been working on their own atomic bomb program, were asked after the war if they would have used their bomb against the Allies. They replied, somewhat puzzled, "Why wouldn't we have?"[131]

In a remarkable postwar interview, Emperor Hirohito revealed his feelings about the use of the bombs. In response to a journalist's question, he stated, "I feel it is very regrettable that nuclear bombs were dropped, and I feel sorry for the citizens of Hiroshima. But it couldn't be helped because it happened in wartime."[132]

Perhaps one of the most poignant statements came from the *Bockscar* assistant Flight Engineer Ray Gallagher during an interview with a Japanese war correspondent. Gallagher had flown on both atomic missions. When asked if he was sorry they dropped the bomb, he stated:

> You know, at that time there was a monster that was loose and that monster was War. He was killing everybody. He was killing people in your country, our country, and all over the world. Something had to happen. We did it, we had it, and we used it. Do you think for one minute that if you had it that you wouldn't have used it?[133]

Gallagher continued, "God was with me that day. You know, a lot of people were killed. A lot of people were injured. There was a lot of heartbreak." At that point he had difficulty speaking. There was a long pause. Finally, in a voice cracking with emotion, he added, "...but we did all right."[134]

When they returned to Tinian at 2:58 PM, there was a crowd of about 200 there to congratulate them. Thousands more lined the taxiway. As Tibbets stepped off the plane, General Spaatz immediately awarded him the Distinguished Service Cross. Until they could be debriefed, the crew was under orders not to speak to anyone. After the debriefing, they were released. They were then checked out by the doctors after which some of the men ate dinner, some celebrated, and others returned to their barracks and went to sleep. Most of them slept straight through to the next morning.

At about midnight on August 7, the crews were shown photos of the damage that had been inflicted on Hiroshima. The extent of the destruction was incredible. After the briefing, they went back to their Quonsets and tried to get some more sleep. When they got up the next morning, they hoped they would hear the news that Japan had surrendered. Unfortunately, this did not happen. Early in the afternoon, they were told there would be another briefing at midnight. They knew this could only mean they would be going out on a second mission. They would be dropping *Fat Man,* the second atomic bomb.

Chapter 5

Fat Man

"The planned system for the functioning of the FM was considerably more complex."
Harlow Russ – 1984

Fat Man[135] was the code name for the implosion weapon dropped on Nagasaki on August 9, 1945. The explosion was equal to a force of 21 ± 2 Kilotons[136] or 42,000,000-lb. of TNT. Putting it simply, that was roughly equivalent to 2,100 fully loaded B-29's dropping 168,000 500-lb bombs on the same target, at the very same instant![137]

An explosive chain reaction occurred when the nuclear fuel, in this case a sub-critical mass of plutonium (Pu-239), was compressed by the process of implosion. This is the opposite of an explosion. The implosion process was about 16 times more efficient than the gun-type gadget.[138] However, it was also considerably more difficult to engineer a successful implosion device.

In the implosion design, the plutonium core (with an initiator inside) was surrounded by a series of shells. The first of these was an 8.75" diameter natural uranium U-238 (code-named tuballoy, tube-alloy, or Tu) tamper sphere surrounded by a 0.125" thick brownish-black shell of thermoset plastic heavily loaded with very dense neutron absorbing boron-10.[139] Boron-10 is almost unique in its ability to absorb thermal neutrons. Rods made with boron are used to control neutrons in nuclear reactors because they can absorb slow (thermal) neutrons and not fast neutrons. An 18.5" diameter aluminum "pusher" shell in turn surrounded the boron layer.[140] The last layer was two thick shells of explosive blocks (charges). These two shells were made from two different kinds of High Explosive (HE), fast burning Composition B-2 (RDX/TNT-60%/40%) and slower burning Baratol 70 (barium nitrate/TNT-70%/30%).[141] RDX was the name for a British explosive. The initials stood for Research Department, compound X. Only a third of the explosive energy was directed inward, so the explosive charge design was critical.[142] The entire arrangement was contained inside a cork-lined, 7-piece Dural (Duralumin or 356-T6 alloy) sphere surrounded by an armor steel bomb casing.

The 64 explosive charges were arranged into an inner and outer shell. Both of these were in the configuration of a soccer ball with 32 sections in each layer. This was referred to as the Y-1561 design.[143] Several other geometric patterns were considered. This included the Y-1222 and Y-1291 explosive charge design in the shape of a 12-pentagon dodecahedron utilized during earlier implosion experiments. Each of the 12 pentagonal faces was further subdivided into six smaller pentagons – five asymmetrical pentagons surrounding a central symmetrical pentagon, adding up to a total of 72 blocks. A photograph of a partially assembled sphere using this explosive charge arrangement first appeared in the original edition of James Kunetka's book City of Fire (see bibliography). However, the Y-1222 and Y-1291 designs used only one layer of non-lens explosive charges held together by an outer Dural sphere made from 12 pentagonal shaped pieces.[144] While the HE section in this design was different, the interior pit components (initiator, plutonium, tamper, boron, and pusher) were essentially the same as those used in both the Trinity and Nagasaki implosion devices.

According to Los Alamos Explosives Division (X-2A) Chief Engineer Robert Henderson:

> Early in 1944 a bright young T-4 Tech Sgt., Leonard Della Moretta, was assigned to my group in X-Division. He was a whiz at Spherical Geometry and I gave him the job of coming up with a block design for the *Fat Man* HE charge. A 12-pentagon dodecahedron is the largest configuration of equi-sided, obtuse angled figures that can be wrapped around a sphere. Twelve pentagonal blocks, even in two layers, would be too heavy for safe manhandling. Della Moretta conceived the idea of inserting an irregular shaped hexagon at the corner of three adjacent pentagons. This resulted in 20 hexagons and 12 pentagons, all with obtuse corner angles, ideal for physical strength and resistance to chipping of the edges. The heaviest block could be readily manhandled. He then calculated the angles between adjacent block faces and produced detail drawings of their configuration to be used in fabricating molds for casting the explosives.[145]

Regarding the 32-point design, SED Della-Moretta replied, "Bob Henderson is too damned generous. He modestly disclaimed his own original thoughts and tactful guidance, and gave all the credit to his men when they did a good job for him.... At that time, they had been working on 72-point designs, all calculated by Bob [Friedman]."[146] Della-Moretta, whose brother Art went ashore with an engineering detachment at Omaha Beach during the D-Day invasion and later survived the Battle of the Bulge, went on to state:

> Bob Friedman started and I assisted him in calculating the 32-point design. Gradually I began doing more of it. These calculations had to be re-worked quite a few times because improved explosives were introduced with different refractive indexes [and] because of differing ratios of flame spreads of the fast and slow lens components. We had to be careful because the lens action ceased when it spread so far that the lens curve became tangent to the ray from the ignition point. This depended on where we started the curve and the speed-ratio.[147]

Addressing the question of who came up with the idea for the 32-point design, Della-Moretta wrote, "The trouble with lumping credits onto one person is that all of us were thinking about it and whoever voiced a thought may not have been the first to think about it. Like an audience in a burlesque theater, the first bold one who shouts 'take it off!' may not be the only man in the theater who had such thoughts."[148]

Each of the 32 "lenses" (shaped charges) in the outer shell was made of Composition (or Comp) B [1.6 g/cm³] with a slightly parabolic shaped inclusion of Baratol [2.4 g/cm³]. Although the outer lenses were two different sizes and shapes, all the Baratol inclusions were probably the same shape and contour. The lenses were 9.0" thick[149] and each of the outer straight-line edges of both pentagonal and hexagonal lenses was 11.25" long. Despite the fact this lens was opaque, the trigonometric calculations required to determine the proper shape for the inclusion were the same as for a two-element, transparent glass lens. The wave shaping principles involving different refractive indexes were identical. After the lens design was frozen at the end of February 1945, any alterations in the explosive wave configuration were accomplished by adjusting the barium nitrate/TNT ratio in the Baratol. The inner shell of charges consisted of 32 blocks of 8.875" thick solid Comp B.[150] Each of the larger hexagonal inner charges weighed about 47-lb. while the smaller pentagonal charges weighed 31-lb. Total HE thickness was about 18" with an overall diameter of 54.375" (when fully compressed by the cork lining).

While the *Manhattan* scientists had tested some nonlensed configurations (see above), the lensed HE design provided the greatest probability of success.[151] Some current nuclear devices use a nonlensed configuration. They also use what are called Insensitive High Explosives (IHE). It is almost impossible to accidentally detonate these explosives. The current generation of Plastic Bonded Explosives (PBX), e.g., PBX 9501, PBX 9502, LX-17, or LAX-112, are cast or pressed into a rough shape. Pressing produces homogeneous, high-density PBX parts. These are then machined into spheres or cylinders depending on the design of the nuclear device. Examples of inert pressed and machined IHE hemispheres are on display in the Bradbury Science Museum at Los Alamos.[152]

The casting of the explosive charges was an extremely demanding and frustrating procedure. Avoiding low-density bubbles, cracks, uneven density, and other imperfections was an almost impossible task. Jacketed and steam heated, stainless steel candy kettles were used to melt the explosives. For a detailed description of the problems and procedures, readers should refer to both Critical Assembly and Manhattan District History: Non-Scientific Aspects of Los Alamos Project Y 1942-1946 (see bibliography). Many tens of thousands of castings were made without a single accident.

SED Technical Sergeant McAllister Hull ran the production line, which produced the finished lenses:

> I used a stirrer, gradually pulled up as the casting cooled from the outside, to keep the Baratol mixture uniform and the interior cavity free. I determined the rate at which to pull up the stirrers by casting 10 inner lenses simultaneously, then sawing them in half at five-minute intervals to see where the solid line had reached. The stirrer was pulled up at a rate to keep the blades ahead of the solidification curve inside the lens.[153]

Uneven cooling of the HE after casting had been a major problem. A water-cooled jacket incorporated into the casting mold casing was eventually used. This allowed water to be circulated at different levels around the casting during the cooling process. Starting with hot water and then gradually reducing the temperature could eliminate surface bubbles on the finished castings. Built in the C-Shop at Los Alamos, the construction of these molds was an intricate procedure. It involved the use of unique no-shrink bismuth alloy (Cerro-Tru) used in the die making industry. They would need four different sizes; one each pentagonal and hexagonal inner charge and outer lens molds.

According to Robert Henderson:

> All we needed now were four master aluminum samples of the HE blocks, machined to their exact dimensions. The HE casting molds would be made

> of 1/4" steel plate with elaborate copper cooling coil circuits brazed to the inner surface of the steel pots that would permit experimental determination of the cooling cycles required to guarantee quality HE castings. With these aluminum master plugs suspended in the steel pots we poured the Cerro-Tru into the space between the steel pot and the aluminum master pattern. Lifting the aluminum master out, we had a perfect mold for casting the HE in the carefully controlled way needed for quality HE blocks.[154]

The Chrysler Corporation in Detroit had a unique milling machine that was electronically numerically controlled. Named the "Kellermatic" after Chrysler's President K.T. Keller, it was ideally suited for producing the aluminum masters for the HE molds. Pre-empting the use of this milling machine meant temporarily shutting down the assembly line producing engines for the B-29. Chrysler was able to produce the four aluminum masters in about three days.[155]

The final two production outer lens molds had a fixed, curved bottom and two tops; one for the Baratol insert and one for the Comp B outer HE. Vaseline was utilized as a release compound because the HE had a tendency to stick to the sides of the molds.[156] To make the outer lens charge, the Baratol inclusion was cast first. The parabolic-shaped outer radius was produced by placing the top inside the mold and the molten Baratol was poured through a hollow cylindrical section above this top called a riser. After it solidified, the HE was taken out of the mold and the riser "spud" was removed by machining with curved beryllium-copper forming cutters.[157] Next, it was placed back in the mold for overcasting. The Comp B, which had a slightly lower melting point, was then poured over the Baratol to fill in the remainder of the mold. The two explosives were thus bonded into a single HE lens block. Finally, the Comp B riser spud was removed from the finished lens. If needed, the planar surfaces of both the Baratol and Comp B charges were machined "wet" under running water. This cut down the chances of the explosive igniting due to friction created during the dangerous machining process.[158] "The high explosive components of the lenses were machined to tolerances of better than one mil."[159]

Los Alamos SED machinist Ralph Sparks explained:

> I made some of the beryllium-copper forming cutters that were used out at S-Site to make the curvature on the top of the lenses...there was a spud there on the top where you poured the liquid material and then you'd cut that off, but it was never perfect. So they'd come in with this large spade-forming tool and smooth off the top to get the perfect radius...they made them a little high so they could smooth them with that tool. They did this with a big radial drill.[160]

The Comp B used in the lenses had a detonation velocity rate of around 7,800 m/sec. Depending on the formula used, the rate for Baratol ranged from 4,600 to 5,250 m/sec.[161] When the 32 outer lenses were all detonated simultaneously, the inwardly directed explosive detonation wave was shaped (focused) as it wrapped around the inner inclusions of denser, slower burning Baratol. This changed the shape of the wave from a convex to a concave-collapsing wave. When this spherically configured wave reached the inner shell of 32 fast burning Comp B charges, it sped up and concentrated before slamming into the aluminum pusher shell and then into the uranium tamper. Any hydrodynamic irregularities or instabilities in the shock wave were smoothed out as it "pushed" through the relatively soft aluminum sphere.

The aluminum pusher was machined with a particular resonant thickness matched to the acoustic impedance of the detonation wave (which behaved in a manner similar to a sound wave). This was critical because it tuned the shock wave so that it was amplified as it passed through the heavy tamper sphere. The alpha-phase natural uranium (U-238) used for the tamper had a density of about 19 g/cm³ [11 oz/in³]. After the shockwave passed through the tamper, it compressed the slightly subcritical spherical mass of plutonium to about half of its original volume.[162] This caused the plutonium to increase to over twice-normal density by reducing its volume without decreasing mass. Simply put, this meant the neutrons only had to travel half the distance to reach another plutonium nucleus. The rapid increase in density made it instantly supercritical and it exploded in a nuclear chain reaction.

The main purpose of the tamper was to reflect any escaping neutrons back into the expanding chain reaction. The massive density of the uranium used for the tamper also served an inertial function by helping to physically contain the rapidly expanding chain reaction until the required amount of 80+ nuclear fission reactions (generations) had occurred. The U-238 used in the tamper had an additional benefit. When struck with a large quantity of energetic neutrons from the fissioning plutonium, the U-238 would fission thus providing as much as 20% or more to the total yield of the weapon.[163]

Two fatal "criticality excursions" (accidents) involving tampers took place shortly after the war ended. These were the only radiation-connected fatalities to occur at Los Alamos during the entire *Manhattan Project.* Determining the proper amount of tamper material that should surround a fissile mass has always been a matter of trial-and-error. The thickness of the tamper is dependent on both the type of material used for the tamper and the type and quantity of fissile material the tamper surrounds. During the testing phase at Los Alamos, these potentially dangerous criticality experiments were referred to by the scientists as "tickling the dragon's tail." The easiest way for some of them to visualize any possible radiation exposure was to think of it as "a three-dimensional sunburn."[164]

The first of these accidents occurred on the evening of August 21, 1945; about a week after the Japanese announced their intention to surrender. Los Alamos scientist Harry Daghlian had just attended the weekly Tuesday night colloquia that ended at 9:10 PM and afterward went down to the Omega Site Laboratory at 9:30 P.M. in Pajarito Canyon where he was anxious to do some critical assembly configuration work and take some measurements. Daghlian had already performed two critical assembly tests earlier in the day and was scheduled to perform a third test the very next morning, but for unknown reasons decided to do it that evening. As with just about everything, there is the "right way" to do something and then there are shortcuts. The scientists were supposed to follow specific safety rules, including not working alone at night. However, the enormous pressures to shorten the war by even a day were felt by all and shortcuts became commonplace. Daghlian was taking such a dangerous shortcut at 9:55 P.M. when his luck ran out.

When making a critical assembly, the scientists were supposed to safely slide the last pieces of tamper in from the side instead of the top. Nevertheless, it was late in the evening, Daghlian was tired, and that is when mistakes are most likely to occur. A heavy 2.125" x 2.125" x 4.25" brick of tungsten carbide tamper weighing 4.4-kg [9.7-lb] somehow slipped from his left hand and fell onto the top of a 6.19-kg [13.6-lb.] plutonium sphere assembly, which was just short of criticality. Daghlian had already built the assembly up five layers and had added an additional five more bricks on the sixth, but the next brick proved to be too much and, when it dropped from his hand, the assembly instantly went prompt critical.[165] He reacted instinctively by quickly pushing this last brick back off the assembly with his right hand. At that point, however, Daghlian also felt a tingling sensation in that hand and noticed a blue glow surrounding the assembly to a depth of about two inches. Unfortunately, he received a 510 R (Rads or Rems) fatal radiation dose and died almost 26 days later at 4:30 PM on September 15.[166] Scientists later speculated that if Daghlian had left immediately, instead of slowly removing many of the remaining blocks over a period of about 100 seconds, he probably would have survived. An SED guard, Pvt. Robert Hemmerly, was seated about 12' away from Daghlian with his back turned when the accident occurred and also noticed the blue flash in the room.

The second accident took place exactly nine months later on Tuesday, May 21, 1946. Testing was being undertaken for the upcoming CROSSROADS tests in the Pacific (see below). One of the tests involved the use of a new type of tamper material and the very same 3.62" diameter plutonium hemispheres (nicknamed "Rufus") Daghlian had used. This test took place inside Building 1 at the Pajarito lab site. The plutonium had been carefully placed into the lower half of a 13.83" diameter beryllium hemisphere.[167]

Critical Assembly Group leader Louis Slotin was showing his replacement, Alvin C. Graves and six other scientists, how to perform a hands-on critical assembly. Like Daghlian before him, he also disregarded proper safety procedures by utilizing potentially dangerous shortcuts. The 35-year-old physicist was in the process of lowering a smaller 9" diameter beryllium tamper over the plutonium and beryllium assembly. Two one-inch square metal spacer blocks on each side had been used to hold the tamper halves apart. Both spacers were removed and Slotin used a screwdriver in his right hand to keep the tamper shell from closing completely. One edge of the upper hemisphere was resting on the lower shell. His left thumb was inserted through a 2.5" diameter opening in the polar region of the upper hemisphere. As Slotin carefully brought the beryllium hemispheres closer together by manipulating the screwdriver, the increasing sounds emanating from speakers attached to neutron counters told him the assembly was rapidly approaching criticality. This indicated that the tamper was too thick and was therefore reflecting more neutrons than necessary back into the growing chain reaction.

It was exactly 3:20 P.M. when Slotin's luck also ran out. The angry dragon awoke and rose up to slay him. In an instant, the screwdriver unexpectedly slipped, the tamper sphere assembly closed and went prompt critical. A blue ionizing flash extended up to 8" beyond the tamper, around both the hole in the upper tamper hemisphere and the equatorial gap, and a surge of heat instantly filled the room. The flash lasted only a few tenths of a second. The same blue flash had occurred during Daghlian's accident. Slotin immediately threw the upper tamper hemisphere to the floor, but it was already far too late. He had suffered a lethal exposure to both gamma and neutron radiation. It was as if Slotin had been fully exposed to an exploding atomic bomb at a distance of less than 5,000 feet. It took only seven days for him to die.

McAllister Hull recalled, "I was one of the people to calculate Louis' dose from the induced radiation in his fountain pen [gold point]. I estimated ≅900 R.... 500 R kills half of a radiated group."[168] Hull's wife worked in the Los Alamos travel office and arranged travel for Slotin's family to come from Canada. After this second accident, all hand-operated criticality testing was permanently banned. These tests have subsequently been performed by remote control at a safe distance behind massive radiation shielding.

Unlike the *Little Boy* gun-type assembly, the *Fat Man* implosion device or gadget had been tested. This was the Trinity test that took place on July 16, 1945. The design of the bomb was refined over a period of time by conducting drop tests. The bombs were painted with a mustard yellow rust-preventing zinc-chromate primer. This color made them easy to track during these tests. These tests were used to refine the mechanical, electrical, fusing, and ballistics of the *Fat Man* design. They referred to some of these test shapes as "pumpkins." These were filled with cement to approximate the expected weight of the final bomb. Later, some of these pumpkins were filled with Comp B and dropped on targets in Japan.[169]

The *Fat Man* bomb measured 128.375" in length, 60.25" in diameter, and weighed about 10,265-lb. Inside the 0.375" thick outer steel ballistic case was the large, 7-piece, cast Dural sphere. This sphere, with a 0.5" thick rubberized-cork compression lining supplemented with rubber pressure pads,[170] contained about 5,300-lb. of Comp B and Baratol. In the center of the HE was the nuclear "pit" consisting of the spherical aluminum pusher and the tuballoy tamper with the plutonium core. Except for some minor differences, the sphere assemblies used inside both the Trinity and Nagasaki devices were essentially the same.

Plutonium can exist in six distinct allotropic forms (phases), with a different density for each phase. This makes it the most complex and difficult to work with element in the entire periodic table. Delta-phase plutonium was used "primarily because of the added likelihood of an effective reaction, and in part because of the metallurgical difficulties with the alpha-phase."[171] The scientists tried alloying the plutonium with a number of different elements in an effort to make it more malleable. Aluminum was tried, but it emitted neutrons when struck with alpha particles and would therefore lead to a possible pre-initiation of the core. The next element below aluminum on the periodic table was gallium. It did not have the same nuclear characteristics as aluminum so the metallurgists gave it a try. They soon discovered this alloy was quite stable at room temperature.[172]

Delta-phase plutonium normally has a density of 15.92 g/cm³ [9.2 oz/in³]. However, when it is alloyed with 3 atomic % (0.8 % by weight) gallium,[173] delta-phase plutonium has a lower density of 15.76 g/cm³ [9.11 oz/in³].[174] The two-piece plutonium core used for the Trinity and Nagasaki devices weighed 6.19-kg [13.6-lb.].[175] In his July 25, 1945, diary entry description of the Trinity test, President Truman essentially de-classified the quantity of plutonium in the device by writing:

> An experiment in the New Mexico desert was startling-to put it mildly. *Thirteen pounds* of the explosive caused the complete disintegration of a steel tower 60 feet high, created a crater 6 feet deep and 1,200 feet in diameter, knocked over a steel tower ½ mile away and knocked men down 10,000 yards away (emphasis added).[176]

Los Alamos nuclear weapon designer Theodore Taylor once explained how the tremendous amount of energy in this small quantity of plutonium was released during a nuclear explosion:

> It had to do with binding energy, and it was that when *Fat Man* exploded over Nagasaki the amount of matter that changed into energy and destroyed the city was one gram – a third the weight of a penny. A number of kilograms of plutonium were in the bomb, but the amount that actually released its binding energy and created the fireball was one gram. *E* (twenty kilotons) equals *m* (one gram) times the square of the speed of light.[177]

After each hemisphere was roughcast, it was placed in a hard steel die and hot-pressed into its final shape.[178] Next, the planar surfaces were machined so the two hemispheres would mate without any air-gaps. Finally, the hemispheres were nickel-plated (Trinity sphere was silver-plated).[179]

Los Alamos physicist Robert Christy described how the solid core design came to be used:

> It was my suggestion that led to it. Earlier designs of the implosion bomb had been a relatively thin shell of plutonium, which would then be blown in by the implosion. It was assembled in the center with ideally very high density and spherical shape. But, there were constant worries at the time that, because of irregularities in the explosive, it would end up in a totally unacceptable form. They were worried it wouldn't be spherical and that it might end up with jets coming in and it wouldn't even go off. These worries were very real. They wanted to be sure it would not fail. It would be a very bad thing if they had a failure. So I suggested if they took the hole out of the middle, and just made it solid, it couldn't very well be made non-spherical. There was a very small hole for the initiator that was required.[180]

A spherical modulated initiator[181] utilizing the "Urchin" design was placed in the hole in the very center of the 3.62" diameter plutonium hemispheres.[182] Sometimes referred to as the "screwball," this initiator consisted of a smooth, hollow, two-piece, nickel-plated beryllium shell that had 15 parallel, wedge-like grooves machined into its inner surface. The surface of the grooves was first plated with a 4-mil layer of gold followed by a 30-curie layer of polonium. Inside this ball was a solid beryllium ball that was also covered with gold and 20-curies of polonium.[183] The gold plating kept the alpha particles from contacting the beryllium. Both the solid ball and the surrounding initiator shell were then plated with a layer of nickel to prevent the polonium from migrating. When crushed by the implosion, the initiator emitted a modulated burst of neutrons that started the nuclear chain reaction at the right instant just like the *Little Boy* initiators had done. Because the polonium used in the initiators had a half-life of only 138.39 days, this meant these had to be replaced frequently in the postwar production units. In the case of *Fat Man*, the initiators were flown to Tinian, along with the plutonium, to ensure they were fresh.

The Trinity Pit Team or G-1 consisted of Robert Bacher, Harry Daghlian, Bernard Feld, Marshall Holloway, SED Herbert Lehr, Boyce McDaniel, Philip Morrison, Raemer Schreiber, Louis Slotin, and Cyril Smith. Schreiber and Morrison would later repeat the same task at Tinian on the Nagasaki bomb. At Trinity, the capsule[184] (see below) assembly took place inside what had been the 16' x 18' front master bedroom of the abandoned McDonald ranch house two miles from the Trinity tower.

Both the plutonium core and polonium-beryllium initiator were warm to the touch because of the energy given off by the alpha-particle emission from both items. It was uncomfortably warm to hold the plutonium for any length of time with a bare hand. Weapons-grade plutonium (WGPu) generates 2.4 W/kg-Pu[185], therefore approximately 15 watts of heat (100°-110° F) was generated by the 6.19-kg core. Philip Morrison wrote later "The heat of the loaded initiator is certainly real and obvious to the touch."[186] Morrison would later become the *Project Alberta* Pit Team leader on Tinian. This warmth caused a minor problem during the Trinity test. The Pit Assembly Team had performed a dry-run of the capsule insertion (minus the active material) prior to the actual assembly at the base of the Trinity tower. Everything went according to plan and the capsule slid smoothly into the pit. The only problem they encountered during this trial insertion was lightning striking the ground from an approaching storm just a few miles away. Herbert Lehr remembered being pretty nervous about the lightning because he was lying across the top of the HE filled sphere at the time. "[Marshall] Holloway told me not to worry because if it ever hits, you'll never know about it!"[187]

When the actual plutonium-filled capsule was being slowly lowered by chain hoist into the interior of the gadget, the heat from the plutonium had caused it to expand and it would not go in all the way. After waiting several anxious minutes, the capsule cooled and contracted sufficiently for it to finally slide into place. Raemer Schreiber explained this problem:

> At Trinity, the capsule did stick as it entered the uranium tamper. There was great consternation, particularly since these two identical pieces (without the plutonium core) had traveled down from Los Alamos as a single assembly. Then someone, possibly Marshall Holloway, identified the problem: warm capsule in cold tamper. We waited several (very long) minutes with the two pieces in contact, and then the capsule slid home with no problem.
>
> The high explosives assembly, which surrounded the tamper, had been stored in an unheated magazine at Los Alamos and was still cold at assembly time. The capsule had been removed and taken to the McDonald ranch house where we inserted the initiator and plutonium core, both of which were quite warm. So the capsule warmed and expanded during the several hours between capsule assembly and the insertion.
>
> The same problem did not occur at Tinian because the HE assembly was exposed to ambient air at 80+ degrees and the capsule was in an air-conditioned Quonset until the time of insertion.[188]

Morrison wrote, "If there is anything I recall with vividness and internal certainty it is the minute or so adjustment by metallic contact of the expansion interference we felt on first loading the core plug into the Trinity HE device."[189] Herbert Lehr stated "...when we loaded the slug into the bomb, I was there assisting, we found that the slug would not fit into the hole in the uranium [tamper] sphere. After trying a few times to insure we were aligned perfectly, it was Bob Bacher who said let it sit there for a bit and slowly, as the temperature of the slug and the sphere equalized, the slug slid perfectly into the hole." Bacher said, "Just take it easy." Lehr continued, "Bacher was smart enough to remember the bomb had set out in the desert night and cooled down, while the heat generated by the plutonium warmed the slug."[190] After it first stuck, they slowly released the tension on the chain hoist. Lehr recalled, "As I remember, it "dropped" about a quarter of an inch or so and then it dropped another inch or so. Finally, the last two or three inches, it dropped all the way in. It was a slow deal and just a matter of temperature equilibrium."[191]

According to Pit Team member Boyce McDaniel, "I remember stepping outside the tent to take a look at the usual midafternoon thunderstorm. It was really a very short time that it was stuck, since by the time I went back in it had already started to go in."[192]

Because the capsule wall was thinnest at the waist portion, any heat transfer from the plutonium sphere inside would have caused a slight expansion bulge to occur in the cylinder. This is the part that stuck during the assembly.[193]

What has never been mentioned in any of the many previously published accounts of the plug-sticking problem was the fact this had first occurred earlier back at Los Alamos. Three tuballoy tamper plugs and spheres had been manufactured to extremely close tolerances by machinists in the tuballoy shop. Ralph Sparks had carefully measured each of the plugs and the openings in the spheres. "Dr. Bacher stood over me as I measured them." Sparks sorted them to give "about a 3 or 4 thousandths clearance" for each sphere-plug matched pair and marked them with a center punch.

Considered a brilliant machinist by those who knew him, "Sparky" headed up the prototype shop located in the Gamma building not far from Robert Bacher's office. Bacher was in charge of implosion studies and Gadget design. "I reminded Dr. Bacher that I was measuring them and they were all the same temperature. Any temperature differential would cause a problem." Sure enough, when Sparks first attempted a plug insertion, without the active material inside, it stuck. As it turned out, the plug had expanded slightly because it had been sitting in the hot New Mexico sun on a little platform just outside the assembly building. Bacher was notified of the problem and he was very concerned. So they waited and when the plug cooled down, it dropped in of its own accord. According to Sparks, "The first one I went to put in, the darn thing stuck. I waited for a while, but nothing really changed. Then I realized, it was just an interference fit."[194] When this sticking surfaced later during the Trinity test, it was Bacher who remembered this temperature differential as being the source of the problem.

At Trinity, Boyce McDaniel carefully monitored the neutron count as the capsule was being lowered millimeter-by-millimeter because this was the first time the active material had been inside the explosive-filled sphere. Mock HE had been used back at Los Alamos during the trial assembly, but it did not have the exact same nuclear characteristics as the real HE. "It was lowered in increments with measurements of the multiplication in-between...we had neutron counters leaning up against the HE, close to it, and a guy with a headset listening to the count."[195]

Two weeks later, Raemer Schreiber arrived by plane at Tinian on July 28 with the plutonium core. The core hemispheres, separated by a thin gold foil gasket, were nestled inside a spherical cavity bored into the center of a carefully machined, un-padded, two-piece magnesium field case designed by Philip Morrison and built by Ralph Sparks.[196] The same case had been used during the Trinity test.[197] Magnesium was used because it was strong, lightweight, dissipated heat rapidly, and did *not* behave like a tamper by reflecting neutrons back into the core. Two large blocks of magnesium, 4.5" thick, 8" square, and with cooling slots cut in the sides, were used to form the case. Also inside were three initiators fitted inside small aluminum cylinders that were slid into holes drilled into the corners of the lower case half. "I bored four holes in the case...I made them about an inch and a quarter. They had a little aluminum cup to hold the initiator and that would drop down in the hole."[198]

The exterior of the case was studded with 20 shock-absorbing bumpers, an idea suggested by Dr. Bacher's associate, Roy Thompson. These were simply 1.5" diameter single-hole rubber test tube stoppers, obtained from the Los Alamos chemistry lab that were frozen in liquid nitrogen, drilled, counter-bored, and screwed to the case. Although the plutonium core was sub-critical, they did not want to transmit too many shocks to the inside. "We held it about three feet off the floor, dropped it, and it just bounced."[199] A round top thermometer used to monitor the temperature of the plutonium was inserted into a hole drilled into the top half of the case. The 3" stem of the thermometer came to within about 0.06" of the plutonium. The case was finished off with a carrying handle scavenged from the electronics shop. A specially designed wrench used to open the case was attached to the outside.

According to Schreiber:

> The PU core and initiators that I carried out to Tinian were taken by GI sedan convoy to ABQ [Albuquerque], then we had two Green Hornet C-54's to Hamilton AFB, Hickam, Kwaj [Kwajalein], and Tinian. We lost an engine departing Hamilton and had to return and transfer to the spare. Somebody else, probably Major de Silva, was in charge. I was just the passive custodian of my little magnesium carrying case.[200]

During the flight to Tinian, they ran into a storm. Schreiber was sitting in the co-pilot's seat and one of the guards came forward and tapped him nervously on the shoulder. "Sir, your box is bouncing around back there and we're scared to touch it." Schreiber went back, corralled it, got a piece of rope and tied it to one of the legs of the cots.[201]

Lawrence Johnston recalled that at Tinian:

> We had the core for the Nagasaki bomb in our Quonset hut. They had a 24-hr. guard on it...After the Hiroshima explosion, the guys that had been guarding this thing all along suddenly realized that it was the guts for the next bomb and they were sort of 'freaked-out.' It was in a magnesium container and you could feel it was warm. The outside of the container was about five degrees centigrade warmer than the ambient temperature in the hut. They had a thermometer sticking out of this container so you could monitor it and that would tell you that nobody had stolen the core out of it.[202]

This heat also created problems in the postwar stockpiled weapons because the heat caused a chemical reaction to take place in the HE. The core-heating problem meant the active components of the pit could only be inside the bomb for a little over a week.[203]

Both the Trinity device and the combat unit F-31 *Fat Man* used on Nagasaki were design Y-1561. This replaced many other designs, like the Y-1222, which had been eliminated in late 1944. The Y-1222 design was considered too impractical because over

1,500 bolts were needed during final assembly. The simpler Y-1561 Dural sphere design needed only 90 bolts.

The Y-1561 sphere assembly for the F-31 combat unit, and two others (F-32, F-33), were completed over a period of several days in the assembly area at Los Alamos. These trap-door models (see below) were shipped to Tinian assembled, except for the plutonium capsule. When the units arrived at Tinian, they were partially disassembled. The Dural sphere was removed from the ballistic case so the capsule could be inserted and the detonators, cables, fuzing assemblies, etc. could be attached. Without the 0.5" thick cork lining, the large multi-piece spherical Dural shell had an interior diameter of 55.25."[204] Dural (Aluminum-2024 or Duralumin) is a very strong, lightweight alloy of aluminum, copper, manganese, and magnesium with a density of 2.71 g/cm³ [1.6 oz/in³].

The Y-1561 sphere design consisted of two 53.3" diameter polar caps and an equatorial girdle of five segments sometimes referred to in reports as zone plates, side plates, or belly segments. The earlier Y-1291 case design consisted of two polar caps and three spherical zone plates instead of the five used in the Y-1561 design. Both polar caps weighed 158-lb. each and the remaining five segments weighed an average of 166-lb. for a total weight of about 1,146-lb.[205] These seven pieces, all 1.0" thick, were bolted together to form the sphere. There were eight 3.0" cubes that were part of the five zone plate castings. These were the sphere lugs used to attach the forward and aft outer ballistic case ellipsoids. The case halves were lined up with holes in the cubes and bolted together.

Two removable metal plates were bolted 180° apart from each other on the sphere. These plates were secured with four bolts screwed into raised circular portions cast into two of the zone plates. Large tongs, attached to an overhead crane, engaged metal studs attached to each plate thereby allowing it to be rotated during assembly. The plates were removed before the outer ballistic case halves were attached.

Both *Little Boy* and *Fat Man* used the same style steel lift lug. In the case of *Fat Man*, this lug was bolted directly to a pad cast into the upper zone plate on the Dural sphere. The underside of the lift lug crossbar utilized a phosphor bronze insert "to forestall any chafing on the bomb release."[206] In the movie footage of the bomb loading on Tinian, one of the *Project Alberta* team can be seen straddling *Fat Man* in the loading pit. He was using emery cloth on this insert to ensure that there were no burrs on the lug.

The ballistic case was supposed to be made from 0.375" thick homogeneous armor-plate. This, however, did not happen. When assembly team members Art Machen, Vic Miller, Harlow Russ, and Roger Warner went into the pre-assembly shop on Tinian to make a trial fit of the spherical Dural case and the armor ballistic case they discovered a problem. The armor case was found to be warped and out-of-round. The case assembly holes would not line up with the holes in the sphere lugs. This had been a continuing problem with the heat-treated armor steel cases. Despite repeated attempts to correct the problem, including re-drilling the holes, they were forced to use a regular steel case. It was then given a coat of pumpkin colored paint and set aside to dry. This took place on August 7, 1945.[207]

This change was first mentioned in Harlow Russ's book <u>Project Alberta</u> (see bibliography). According to Philip Morrison, "If he's [Russ] right, then they replaced the Nagasaki *Fat Man* armor case with a soft steel case which was a major...a huge operational change!" However, Morrison went on to say that this was something that would be quite likely to happen in this kind of improvisatory atmosphere, a "one-only piece assembled by people with a sense of urgency!"[208]

Referring to the differences between the Trinity device and the Nagasaki bomb, Morrison stated, "There were some changes of importance...because it was all based on conjecture as to what would endanger, what would raise the probability of error, things like that. The fundamental thing was, of course, very much the same."[209]

Because of the haste in the way the Trinity test was approached, many things the scientists would have liked to do had to be scrapped. Little details that people had thought of weeks in advance, like something being safer to do, were held over and incorporated into the Nagasaki bomb.

The sphere assembly procedures used for both the Trinity and Tinian devices were basically the same. To start the sphere assembly a polar cap was first laid down, and then team members began placing the HE inside. The first thing to be put in was a pentagonal shaped outer lens. Then the other lenses and inner charges were assembled around this central block all the while making sure the detonator holes in the lens blocks were kept in alignment with all the holes on the outer Dural sphere.

The Comp B HE was the color of cheese and in the words of one of the engineers, "Looked so good, you wanted to take a spoon and dig in."[210] According to McAllister Hull, "My initials, MHH, were on each lens, meaning I had supervised its casting and had inspected it for surface defects."[211] The surface of each HE block had been sprayed with a coat of the best "Bar Top" varnish available.[212] Varnish was used to help make the surface of the HE more resistant to damage during handling. This changed the HE to a mottled brown color. Vinylite tape was used to cover and protect the edges of the blocks.[213] Some of the blocks were lifted into place by use of a chain hoist with a vacuum cup on the end. Many hands were under each block in case the vacuum pump failed. This special vacuum cup was designed over a period of time by Bob Henderson, Richard Bice, and Larry Cherry.

HE Assembly Team member SED Alvin Van Vessem remembered that "The inner blocks were easy to handle, but those lenses...we had quite a struggle. They were normally handled by one person. They were unwieldy to handle by more than one."[214] Van Vessem told about the time they were assembling an implosion unit in the Two Mile Mesa assembly building at Los Alamos. A visiting officer was brought in to observe the procedure while all the soldiers were very busy carrying the heavy lenses to the assembly.

> A little later in the day, my boss, Captain Schaffer, came along and said 'I've had a complaint. That officer came in here and you didn't call all the fellows to attention.' I said, 'Well sir, if you want me to do it, then I'll do it. But you better have somebody ready to clean their britches when we drop 130 lb. of HE!'[215]

The blocks were held in temporary alignment by inserting large cork plugs through the sphere detonator holes and then into the shallow detonator holes in the HE.[216] Pads, made of 0.0625" thick felt, had been glued on both the inner and outer curved surfaces of the Comp B inner charges to help cushion and absorb any shocks during assembly and transportation. Felt was used because it was better able to conform to the spherical surfaces. The felt also kept the blocks from touching each other and the aluminum pusher sphere.[217]

Using Goodyear rubber cement, thin blotter paper spacers were glued onto flat surfaces of the HE "at the last possible moment."[218] Blotter paper was utilized as a gasket material because it was a more resilient interface than HE. It served the purpose of filling any gaps and voids between the HE blocks. The scientists thought an air gap larger than 0.03" could lead to an increase or decrease of detonation depending on the orientation of the gaps.[219] Johnson's Baby Powder had been used by the assembly team at Wendover to reduce the friction between the HE and the cork lining.[220] The lenses were held in temporary alignment during assembly by pieces of Scotch tape. A Los Alamos representative had been assigned to work with the 3M Company in Minnesota to develop tapes that were used for various purposes.[221]

The HE assembly was one of the most difficult and time-consuming parts of the implosion device. Like shim stock, the blotter paper came in different thicknesses. When the crews were performing the first assemblies, if they got to the end and had difficulty putting in the last blocks, then the HE was removed and the whole process repeated using a different thickness of blotter paper in-between the HE charges. Crews at Wendover, Los Alamos, and Tinian all had difficulties with this portion of the assembly. It was finally decided that all implosion spheres would be so-called trap-door assemblies (see below) built at Los Alamos.[222] This would allow the fissile material to be installed after all of the HE had been assembled. According to one source, Carl Betz designed the trap-door modifications to both the pusher and tamper.

As the HE was placed inside, the central band zone plate sections of the sphere were built up around it. To hold the lens blocks in place before these middle plates could be attached, a series of elaborate little jigs, devised by Richard Bice, were attached to the polar cap. When enough blocks had been put in place, the central plates were attached and held loosely in place with long assembly bolts. At this point, some of the jigs could be removed and were replaced by thin, knife-like fixtures that went in-between the gaps in the plates. Because of the HE, no air impact wrenches could be used to tighten down the bolts. This meant each bolt was slowly tightened about one turn with a standard hand wrench, and then the next one was turned a little, and so on until all the bolts had been secured. As the bolts were being tightened, the assembly fixtures were removed.[223] The bolts were replaced later by standard high-strength bolts after everything had been tightened down. Because there was normally a gap of about 0.1875" between the sphere segments, the cork sphere lining had to be compressed pretty far for the case to be assembled properly.

George Kistiakowsky showed up in the assembly building the day they were tightening the bolts on the Trinity unit. Kistiakowsky was in charge of the Explosives Division. He asked if there was any way this process could be speeded up. Alvin Van Vessem replied, "Well sir, under the rules that we have, the only way I know to speed it up is for you to get one of those wrenches and help us. So he did!"[224]

According to *Manhattan Project* explosives engineer Edward Wilder, "Pieces of the outer metallic configuration were put in place as the outer configuration of the sphere was built. This allowed us to put the pieces of HE in place against the outer metallic sphere."[225] This proceeded until enough HE blocks had been assembled so the 18.5" diameter aluminum pusher shell, with the boron covered tuballoy tamper sphere inside, could be lowered into place.[226] After it was inserted, the rest of the HE blocks were placed around it and the remaining pieces of the case were bolted into place to hold everything together. The specially prepared Dural case used for the Trinity test had 1" holes drilled at the corner intersection of each casting thus allowing further final inspection of the completed assembly. Nothing was left to chance.

The 9" diameter boron-covered uranium tamper sphere had been previously inserted into the 293-lb. pusher shell with the use of a portable hoist. The upper and lower boron shells had already been glued on the tamper sphere before insertion into the pusher. The upper boron shell had about a 5" hole in the top to accommodate the "capsule" (see below). Finally, the upper pusher sphere was lowered in place. The 158-lb tamper was a solid sphere with a 5" hole bored all the way through for the capsule. The "capsule" consisted of a two-piece cylindrical uranium tamper plug, the plutonium-initiator assembly, and about a 5" diameter boron disc. Morrison referred to the capsule as the "thing with the funny ends."[227]

According to Sparks, the upper and lower pusher shells were machined with alignment grooves:

> In the finished face, a square bottom groove one inch wide and a half-inch deep was cut. This was to act as registration groove to keep the two hemispheres concentric with each other. The other hemisphere would have a raised ring, one inch wide and half inch high, at the proper diameter to fit the groove in the other hemisphere. There was just a few thousandths of an inch clearance on the ring and groove to facilitate an easy but accurate assembly of the hemispheres.[228]

The upper and lower halves of the 18.5" diameter aluminum pusher were secured by four, equally spaced locking rings, called "cups." Circular trepan grooves had been machined into both halves of the pusher at the parting plane. The 2" to 3" diameter aluminum rings, which had been machined to match the curvature of the sphere,[229] were carefully pushed into the grooves and secured with aluminum fastening screws threaded into holes tapped into both halves of the pusher. Care had to be taken not to mix the screws because they were not interchangeable. For assembly/disassembly purposes, a larger hole had been drilled and tapped into the rings. This allowed an extraction tool to be screwed into the rings to aid in their removal (if necessary). The smaller fastening screws did not contact these larger threads.[230]

The upper half of the aluminum sphere had about a 5" diameter hole machined into it. The aluminum "trap-door" plug inserted into this hole during final assembly was 4.75" long. Great care had to be taken when this plug was screwed into the hole. About 1" of course-threads (3/8-16) had been machined into both the plug and upper hemisphere. "There was at least 3 thousandths slop in the threads." In order to make sure there would be no problems during final assembly, "we had to put the plug in and out 12 times with Bacher looking over our shoulders."[231] Sparks suggested they use a lubricant on the threads because of the possibility of galling. Pit Team member Marshall Holloway who felt the lubricant might interfere with the neutron flux during the chain reaction immediately rejected this idea. Sure enough, the second time they screwed the plug into the sphere, it stuck tight. Sparks had to wrap a thin aluminum strip around the exposed threads and then use a long handled Stillson wrench to loosen and remove the stuck plug. At this point, Bacher approved the use of a special lubricating mixture of thin grease and zinc oxide for application to the threads during all subsequent assemblies. Two unthreaded spanner holes had been machined into the outer curved surface of the plug. A long rod with a t-top handle was attached to this plug to help during the assembly. After final assembly, these holes were filled with aluminum plugs held in place with Scotch tape.[232]

For shipping to both Trinity and Tinian, an alignment plug[233] had been screwed into the aluminum trap-door opening instead of the real aluminum plug. It kept the tamper aligned with the pusher and the HE in order to guarantee a successful capsule insertion. The real aluminum trap-door plug replaced this temporary plug during final assembly. This alignment plug went into the tamper about two inches and had "a good bevel on the end to help it slide into the tamper."[234] The top surface of this plug had a 2" diameter brass disk about 1" thick. This disk, sometimes referred to as the "key of the pit," was screwed into the top of the plug and replaced an eyebolt used to lift the aluminum sphere during the assembly process. It aligned the pit with the bottom of a large, pentagonal dummy plaster plug,[235] which replaced an inner charge and outer lens during shipping. These two HE blocks, left out and replaced during assembly by the plaster block, were packaged and shipped separately. A 2" diameter hole in the inner surface of this plaster block fitted over this alignment screw.

The capsule assembly procedure at both Trinity and Tinian was basically the same. "It was done slowly, deliberately, and with due caution."[236] First they opened up the two halves of the uranium tamper plug, placed the one of the halves in a little cradle on the assembly table, and then suspended the other half over this with a chain hoist. During the Trinity assembly, Pit Team member Louis Slotin nestled the initiator into the center of one of the plutonium hemispheres, then placed the remaining plutonium hemisphere on top of the first one. Robert Bacher described the initiator insertion in a 1986 interview:

> What we were really afraid of was that a jet would come down between the two hemispheres and predetonate the thing, and we didn't want to do that if we could have possibly avoided it. So, in the region around where the initiator went in, we crumpled some gold [foil] and put [it] in there, extraneous matter, not very much but enough; it does not take much gold foil to stop a very fine jet.[237]

About noon on 15 July 1945, Cyril Smith, the head of the Los Alamos Metallurgy Division, carefully inserted the completed sphere into a spherical cavity that had been machined inside the exact center of both halves of the tamper plug. Finally, the remaining half of the tamper plug was lowered into place. The scientists then spent several hours making sure there were absolutely no cracks or air-gaps in the entire capsule assembly before they were finished. They used pieces of 0.0005" thick gold foil as gasket material to insure an absolutely tight fit. The foil had been brought to the McDonald Ranch house about 1-2 weeks prior to the test.[238]

The capsule was held together by domed uranium rings (hollow washers) fitted into trepanned grooves machined into both curved ends of the uranium plug at the parting line and "fastened with uranium screws so that the whole thing was essentially monolithic."[239] The assembly team also screwed a metal eyebolt into one end of the assembled capsule that allowed it to be subsequently lowered into the pit with a chain hoist.[240] The completed capsule was 8.75" long, 5" in diameter, and weighed about 105-lb.[241] According to Herbert Lehr, "It was a very simple assembly."[242]

Morrison recalled that, "The thing (pit) was rather complicated. It wasn't complicated in a functional way, but the parts fit together like a little puzzle."[243] The fact, for instance, that the Nagasaki plutonium was plated with nickel and not silver meant that a number of other operational changes were made to take that difference into account. The silver coating on the Trinity sphere had been applied using a chemical solution. Bubbles, or blisters, developed in this coating after just a few days. These caused a problem with the fit of the two hemispheres. Some of the blisters were ground-off back at Los Alamos by Ralph Sparks with a 600-grit India stone.[244] Because the Nagasaki plutonium was coated in a vacuum with a 5-mil (0.005") layer of electro-deposited nickel, the problems that had occurred with the Trinity plutonium were eliminated. Gold foil was also used as gasket material between the hemispheres during the capsule assembly. It served to eliminate any air-gaps in the assembly that might have caused premature initiator activation while the plutonium was being imploded by the spherical detonation wave.[245]

Morrison explained, "The homogeneity of the whole system was highly critical. You don't want airspaces. [The gold foil] isn't just to take up something [space], it has a real dynamical function. We did have the gold at Tinian, but I don't remember how much we used, if any."[246]

In a project sometimes punctuated by strong personalities, petty jealousies, and monumental egos, Philip Morrison was genuinely admired by many associates who considered him to be "one of the good guys."[247] A remarkably thoughtful and articulate scientist, Morrison spent the last half century trying to eliminate nuclear weapons from the world's arsenals.

When the *Fat Man* was ready to be made "live" at Tinian, a very complicated procedure had to be followed. Assembly involved many people moving carefully, deliberately, and with extreme caution. Even though the detonators were not yet installed, the quantity of HE made it one of the largest blockbusters in the US arsenal. The smallest spark could prove disastrous. The floors utilized copper sheets secured in place over a special sub-floor consisting of iron filings imbedded in concrete that was poured over a grounded copper wire grid to prevent any chance of an accident.[248] Only shoes without nails could be worn. Even the soles were impregnated to prevent a static buildup. Nothing that could cause heat or a spark could be brought into the room. They also used special non-sparking beryllium and copper tools, examples of which are on display in the Bradbury Science Museum.

The Tinian Pit Team consisting of Charlie Baker, Mort Camac, Jesse Kupferberg, Philip Morrison, and Raemer Schreiber went to work.[249]

Mort Camac later recalled his role in the Pit Team:

> Most of the time our group worked as a team and we shared in the work. The parts of Fat Boy that our group handled were small, few, and inert. We checked the plutonium coating by rubbing it with a napkin and then checking the napkin for radioactivity and never measured any radioactivity. When our group put the parts into Fat Boy, I had the job of taking notes of our activity. When the planes with the nuclear bomb took off, I was at the center of the runway with a radiation detector. If the plane had an accident, then I would search for radiation at the plane. I was placed on the runway because I was the youngest member of our group.[250]

The upper Dural polar cap had been removed with a jib hoist before the Pit Team arrived and replaced by a cover with a pentagonal hole. This served to protect the exposed

HE blocks and keep them from shifting. According to Tinian technical team member Art Machen, when he removed the polar cap, "There was a note inside that said 'Give our regards to Tojo.'"[251] The dummy plaster shipping block was then removed through the hole and a tapered pentagonal copper funnel placed in the cavity to protect the adjacent HE charges from any damage.[252] The 2" alignment key was unscrewed from the alignment plug. Then a long t-handled clamping spanner wrench was inserted into two holes in the plug, which was then unscrewed and removed from the top of the pusher. The cylindrical hole in the uranium tamper was thus clear for the insertion of the tamper-plutonium-initiator capsule.

When the assembly team looked down inside the tamper, they noticed a small message at the bottom written by Ralph Sparks in red crayon on the inner surface of the boron shell. It read simply, "No Smoking!"[253]

After the capsule insertion, the eyebolt was removed, replaced with a solid threaded uranium plug, and the remaining 5" diameter thin disk of boron was secured in place (also with Scotch tape) on top of the capsule. Schreiber recalled, "It (boron) wasn't attached to anything, it was just laid in there...before we put in the [aluminum] plug."[254] The aluminum trap-door plug was screwed into the pusher, the funnel removed, and the two live HE charges inserted. Repeating the safety procedure used at Trinity, the HE blocks were secured to the jib hoist with fiberglass tape during insertion in case of a vacuum failure. The cover plate with its pentagonal hole was removed and the regular polar cap reinstalled with 30 high-strength bolts. The sphere was then rotated 90° so the polar caps faced the front and rear of the bomb.[255]

A stainless steel hypodermic tube with a piano wire insert had been slid through the outer Dural case and in between the HE blocks during the sphere assembly until it came into contact with the pusher. This hypodermic tube was tapered at the top, middle, and bottom with a crimped end in contact with the pit.[256] After the polar cap was installed, the tube extended through an opening in the cap, the piano wire was removed, and a 0.040" diameter, 32" manganese wire was inserted into the tube and then removed about every six hours and replaced with a new one. The induced radioactivity in the old wire was measured by a special counter made for that purpose. This allowed physicist Robert Serber to monitor neutron activity in the pit. According to Schreiber, "Low activity was good. We were concerned that a flaw in the Pu [plutonium] coating or other chemical reaction could increase the chance of pre-initiation and decrease the yield. This monitoring was continued at intervals as long as the tube was available."[257] An increase in neutron activity might also have indicated an initiator rupture and this could have led to pre-initiation. A section of the actual manganese wire used for the Trinity, Nagasaki, and CROSSROADS *Fat Man* devices is on display in the Bradbury Science Museum. After this work was completed, the rest of *Fat Man* could be assembled.

Inside the nose of the bomb was the Raytheon Model II X-unit, which consisted of electrical condensers and four low-inductance triggered spark-gap "switches."[258] The purpose of this device was to create the high voltage current necessary to fire the detonators. This Firing Unit was about 32" in diameter, 8" thick, with a 0.5" thick backplate. It was a hermetically sealed unit utilizing a large O-ring and was evacuated by means of a valve before the bomb was closed up. This reduced the possibility of high voltage arcing taking place inside the unit. It was contained inside a one-piece Dural tub[259] that was bolted to the "B" plate. This plate was mounted on a cone attached with 10 bolts to the forward polar cap.

The cone was formed from several pieces of aluminum sheet riveted together. The postwar production cones were made from a 0.20" thick one-piece stamped aluminum sheet.[260]

Voltage was applied to Bendix Mk II phase inverters and step-up transformers. This was used to charge the 64 Sprague 1 uF condensers (capacitors) contained in four boxes mounted inside the X-unit. Since the spark-gap switches were placed between the 64 condensers and the 32 Model 1773 exploding bridgewire (EBW) booster detonators, there were effectively two X-units, each consisting of 32 condensers and two spark-gap switches.

According to Manhattan Project scientist Donald Hornig:

> I came to Los Alamos to measure the shock wave from the bomb when it could be tested. That was still a long way off in the spring of 1944 when I learned of the problem in an implosion of igniting explosive lenses with a high degree of simultaneity. That led me to suggest that we might be able to develop triggered spark gaps for that purpose. They could replace the explosive switch proposed by Luis Alvarez which had the handicap that since it blew itself up it couldn't be tested before use...My suggestion was made after one of Oppenheimer's seminars. He was intrigued and immediately assigned me the task of trying to develop suitable triggered spark gaps.[261]

Hornig went on to describe the spark gap switch:

> The triggered spark gap consisted of a glass tube about 2" long and 1" in diameter. The trigger electrodes were centered along the sides and connected to the air core transformer. The leads to the high capacity, high voltage circuit were attached at the ends. The tube had heavy glass walls so that firing it would not shatter it. If I recollect correctly it was filled with nitrogen at a pressure of about 2 atmospheres but we also experimented with helium and argon. I believe spontaneous breakdown of the tube occurred at about 15 kV.[262]

The X-units were tested by using the newly-developed high-speed rotating mirror camera (RMC). The output signal from the X-unit was sent to parallel leads inside the camera. According to *Project Alberta* Firing Team member Larry DeCuir:

> The relative timing was checked by inserting the ends in a parallel line and firing the unit with the prism rotating at a high rate of speed. If the cable ends arced simultaneously [on the film] the streak beginnings would be on lines parallel to the axis of the cylindrical chamber."

As Firing Team member John Tucker recalled:

> I was the one that set up the rotating mirror camera, set up the shots with each of 3 X-units, fired them, developed the film, read the film, and determined that one unit was somewhat better than the other two. That was the unit that we used on the Nagasaki bomb. I had seen a RMC once at Anchor Ranch during shot set up and test. I did not have the faintest idea

> that that would be one of my jobs later on. No one ever said that I should pay special attention.

Although there were 32 detonators, each Model 1773 detonator contained two bridgewires housed in separate PETN (pentaerythritol tetranitrate) initial pressing wells (cavities). This redundancy was believed necessary because of the high detonator failure rate. A separate cable routed to a connecting point on the Firing Unit supplied the electrical energy to each bridgewire. Power from an inverter in the airplane was used to maintain an electrical charge in the X-unit condensers until just before the bomb was dropped, then two banks of four 4" x 2" x 3" Willard NT-6 six volt lead-acid storage batteries took over.[263] The inverters, transformers, and batteries were mounted to the "A" plate attached to the inside of the 29.9" diameter front nose cap opening.

When activated by the fuzing assemblies, an electrical discharge of 5.6 kV was sent from the X-unit to the detonators.[264] These 2.5" long machined aluminum (Aluminum-6064) detonators contained two 0.0015" diameter x 0.10" long bridgewires (85% silver/15% copper) that were exploded by the electric current. Postwar detonator designs utilized gold bridgewires because the silver/copper wire became unstable over an extended period of time.[265] Two small 0.1875" long initial pressings of PETN were contained in 0.30" diameter x 0.25" deep side-by-side cylindrical cavities located in the base of the detonator barrel directly above each of the bridgewires. Testing had shown that explosives would be more likely to initiate if confined in a small, tightly confined space. The initial pressing (IP) cavity was there to "provide an exact volume, for a precise weight of PETN, pressed to a density that was as reproducible as was possible from pressing to pressing. Without this precision, the transmission times (see below) would have been too variable, and the desired simultaneity could not have been achieved."[266] They also made sure there was sufficient space between the outer edges of the electrodes and the metal wall of the IP cavity in order to prevent possible arcovers and degradation of electrical initiation energy.

PETN, a relatively sensitive secondary explosive, is still used extensively in detonating devices. It was prepared for loading into the detonator by a special process of purification and recrystallization that resulted in a white crystalline powder.[267] A measured amount of powder was poured through a funnel and then carefully pressed to a specific density in both cavities by means of a punch after the bridgewires had been installed in the base of the detonator. According to John Tucker, "To my knowledge, one of the better kept secrets has been the optimum PETN initial pressing density."[268] Compacting the PETN into pellets, which would then be inserted into the detonators, was considered but proved to be too impractical. The problem was the unevenness of the pellet density, its fragility, and the fact that it would be next to impossible to insert into the narrow bottom of the detonator. When explosive powder is pressed into a pellet, the end next to the moving consolidation ram is denser than the other end. The denser end is also slightly more difficult to initiate, plus a higher density pellet might damage or break the bridgewire during insertion. Due to its sensitivity, there was also the possibility, albeit slight, that the pellet might detonate during the assembly process.

Detonator research team member Sigmond Harris recalled:

> I was told from the beginning that it was very sensitive and that you couldn't set it off with a mechanical impact. I was a little skeptical so I took a PETN

> pellet outside, put it on a steel plate, and hit it with a hammer. Well, the first time nothing happened, it just crumbled. I hit it again and it exploded! Everybody came running out wondering what happened. With explosives, you can't believe everything that anybody tells you.[269]

The two initial PETN pressings detonated another larger PETN pressing located in the 0.75" diameter initiator tube just above the two cavities. This pressing was contained just below a 0.89" diameter aluminum spacer (mixing tube) with a conical-shaped cavity in the center. This spacer was screwed into a threaded (7/8-20 NF thread) section in the middle of the detonator barrel that was 0.38" long. The large portion of the cone faced the bottom of the detonator. At the time, it was thought necessary to collimate the detonation wave (see below) by using this cone-shaped spacer because the bridgewires were off-center. This feature was found to be completely unnecessary and subsequently eliminated in postwar detonator designs. After the detonation wave emerged from a small, centrally located hole in the upper end of the cone, it detonated a larger 1.0" diameter tetryl (2,4,6-trinitrophenylmethylnitramine) booster pellet that extended slightly past the end of the 0.75" long upper cavity in the detonator barrel. Tetryl, a light yellow crystalline solid, is no longer commonly used as a booster explosive "because pellets made from this material are soft and rather friable even when certain binders are used. Also, if the density were too great, the pellet would not be initiated promptly or reliably by a low density PETN consolidation."[270] An effort was made to keep the lower density ends of the pressed tetryl pellet next to the PETN initiating explosive. George Kistiakowsky, head of the Los Alamos Explosives Division, wrote that he did "not think that Tetryl mixed with grit would be safe to rub between two steel plates with a vigor greater than that of a southern belle."[271]

The bridgewire effectively exploded (burst) from the sudden, large thermal impact generated by the electrical pulse, and the energy released by this explosion promptly initiated the PETN surrounding the bridgewire. An explosive detonation wave formed in the PETN and accelerated outward from the bridgewire until it reached a steady state velocity. The time required for the wave to pass completely through the PETN was known as the "transmission time through the PETN."[272] The supersonic detonation wave then proceeded through the larger PETN pressing located in the initiator tube, next through the tetryl booster pellet, and finally emerged from the end of the detonator. The total time from the bridgewire burst to emergence from the detonator was known as the "total transmission time."[273] The emerging steady state velocity detonation wave initiated the outer lens charge. This wave had a smooth, symmetrical shape in addition to the proper degree of simultaneity. The rule of thumb is that an explosive component must be long enough for the initiating shock wave to reach full detonation velocity in that component before it reaches the next component to be initiated.

Tucker explained:

> The length of each explosive component must be long enough to reach a full detonation, steady state velocity at its output end. This is necessary to promptly initiate the next component in the explosive train. If this and prompt initiation at the bridgewire is not achieved, timing errors will result.[274]

The 1773 was the first detonator stockpiled for the *Fat Man* bomb. After the 1773, the 1E20 came into usage on later postwar models of the *Fat Man*, MK-4, and MK-6 weapons. The 1E20 had new cabling and new quick connect/disconnect plugs. An example of an early design of the 1E20 is on display in the Bradbury Science Museum. The connectors shown on the display detonator were an early design of the ones eventually used on the production version. The 1E20 was an attempt to make detonator installation considerably faster with less skilled people. It was followed by the 1E23 that was used on the MK-7 and other later implosion weapons. These designs all utilized the exploding bridgewire. The 1E23 used a single initiation system, which meant it had a single bridgewire instead of two. This was made possible by considerably improved detonator simultaneity and a decreased detonator failure rate. Current nuclear devices use what is referred to as a solid-state, multi-layered, thin-film "slapper" to detonate the explosives.[275]

John Tucker wrote that, "The use of the exploding bridgewire, instead of a hot wire, to initiate an explosive like PETN directly, and achieve a build up to high order detonation in a very short time, was a new and novel idea."[276] Another novel idea was that, because the bridgewire exploded, they did not have to use a more dangerous shock-sensitive primary explosive such as lead azide or mercury fulminate in a spark-gap detonator design. While still sensitive, the detonators were not as shock sensitive as if they contained these primary explosives. Acting on a suggestion from SED James Lyons, Sr., the scientists even tried doping lead azide with chemicals such as calcium carbonate (chalk) in an effort to decrease sensitivity.[277] According to the patent (see below), "Another and far more important advantage results from the use of a detonating, e.g. high explosive material in place of a deflagrating primer material. This advantage is the reduction in the time delay from milliseconds to microseconds."

These detonators ignited the outer HE lenses. It was critical to the success of spherical implosion that all of these detonators exploded simultaneously. If the initiation of even one of these detonators was delayed, the implosion would not work. In order to eliminate any possible chance of a misfire, each 1773 detonator had two bridgewires and two firing cables attached to it instead of one.

Over a year of intense research, development, and testing had gone into the development of the bridgewire detonator. Starting in early 1944 people such as SED Robert Alldredge, Hugh Bradner, Leon Fisher, Sigmond Harris, Lawrence Johnston, Edward Lofgren, SED James Lyons, Sr., SED William McDonald, and other members of the South Mesa detonator group working under the direction of Luis Alvarez, performed much of the pioneering experimental work on the development of the detonator. Johnston was director of detonator R & D and was subsequently awarded a patent (U.S. 3,040,660) for the exploding bridgewire detonator. Honest in his dealings, he was a deeply religious, Bible-reading Christian who did not raise his voice or use profanity. He was the person who held the detonator R & D together and deserves the credit for pushing the group to a successful design. Both Johnston and Alldredge shared credit for the spark-gap detonator patent (U.S. 3,361,064).

Utilizing the so-called "Edison" approach, the scientists went through hundreds of combinations of bridgewire lengths, diameters, and materials in their rigorous search for the right detonator design. Harris explained, "We worked pretty much by trial and error."[278] It was not until a few weeks before the Trinity test that the detonator design was declared acceptable.[279] At that point they had exploded over 300 detonators in a row without a failure.

John Tucker, who would later write a classified history of the detonator for Los Alamos, commended the efforts of the scientists. "I don't think that many people appreciate the amount of work that went into the development of this detonator. In normal times it would have taken 10 to 20 years to go from a completely new detonator concept to an item manufactured for stockpile use. They did it in a little over a year."[280]

Robert Alldredge described a meeting that Luis Alvarez asked him to attend shortly after he first arrived at Los Alamos in August 1944. Alldredge had worked on explosive devices R & D at DuPont's Eastern Laboratory. Some of that work had been on devices suggested by George Kistiakowsky. At the meeting, Alvarez wanted Alldredge to support Alvarez's view that detonators could be made so accurately that 16 and 32 of them would all explode within an interval of one millionth of a second, simultaneity that calculations indicated would be necessary for a successful implosion bomb. Without that simultaneity an implosion bomb would "fizzle". Kistiakowsky believed that spark-gap-lead-azide detonators would be best.

Present at that meeting were Robert Oppenheimer at the far end of the conference table, Kistiakowsky, Robert Bacher, Norris Bradbury, Luis Alvarez, Kenneth Bainbridge, and Robert Alldredge at the opposite "low" end of the table. All the department heads were heatedly discussing whether or not an implosion bomb would even work. Bainbridge argued very strongly with Alvarez about the provided schedule of the detonator development. Alvarez quoted from a memo. Bradbury asked his secretary, a SED WAC, to locate that memo. It proved Alvarez to be correct, and that there was time in the schedule for Lawrence Johnston and Alldredge (the entire South Mesa detonator R & D group at that time) to develop micro-second-simultaneity detonators. Robert Oppenheimer looked over at Alldredge and asked him if detonators could be made that could all go off within a millionth of a second of each other. Having just come from DuPont and with the brash enthusiasm of a 22 year-old, he replied "Absolutely!" Oppenheimer pressed him further, "And how do you intend to do that?" Without missing a beat, he confidently declared:

> What we're going to do is make the bodies very accurately, we're going to sort the thousands of them out into groups that are identical in dimensions, we're going to leave a face on one end of the detonator body from which we can use a dial indicator for accuracy in measuring, we're going to weigh out the explosives to plus or minus a milligram and load them in there, we're going to press them to the same pressure each time, we're going to use the dial indicator again to determine the actual length of that little explosive train, we're going to sort them out into groups that are all identical all the way along the line, and then finally we're going to fire them!

There was silence in the room. Finally, Oppenheimer turned to the others and told the group, "We'll proceed with Lui's approach (implosion bomb)!"[281]

The day after the meeting, Alldredge met with Ralph Sparks. He discussed the need for some plastic detonator bodies to test. Sparks located a lathe, and plastic rods, and in a single Sunday produced dozens of the very first bridgewire detonators. He also machined dozens of spark-gap detonators. The "gap" was produced by milling a slot across a copper bar in the plug. Alldredge remarked recently, "We did not go through 'channels'. We commenced immediately to make detonators that would work. I recall that Larry Johnston was amazed that I was moving so quickly on it."[282] By November 1944, they were producing detonators that were all firing within a one microsecond "window". After the initial development work by Johnston and Alldredge was completed, the responsibility for the final design and testing of what finally turned out to be the 1773 detonator was turned over to the group headed by Explosives Division (X-2A) Chief Engineer Robert Henderson.

Although EBW detonators are readily available today in the commercial explosives industry, 50 years ago the 1773 detonator was a major technological innovation. These units were referred to as "handlebar" detonators[283] because the two bridgewire fuze "sidearms" and the firing cables attached to them were 135° apart from each other and thus resembled the handlebars of a bicycle. The 2.0" long aluminum sidearms contained the 0.064" diameter high voltage copper lead for the detonator. The material that encased the lead had been a large developmental problem. They finally settled on nylon because all the other materials tried had voltage breakdowns. The assembly of this part of the detonator was touchy. Each bridgewire had to be carefully soldered in place. When the sidearm was screwed into the detonator to hold the bridgewire assembly in position, too much applied force or pressure would compress the nylon core. If this happened, the electrode spacing in the nylon core would be shortened and the bridgewire would bend and, in some cases, break.

Said Tucker, "They only allowed one or two people to make the assembly of the cable to the detonator sidearm because it was such an art."[284] According to James Lyons, Sr., "Two young Indian ladies worked on the detonators with Bob Alldredge and me. Rufina (Ruth) Ladabour from the Tesuque Pueblo and Eva Gwin from the Santa Clara Pueblo were our co-workers."[285] Almost 50 people worked in the Detonator Group at South Mesa in Los Alamos. One of these was Barbara Todd Lincoln Scott, a direct descendent of President Abraham Lincoln.

The tetryl booster pellet in the 1773 was covered over by a thin copper booster cap crimped into a groove machined 0.2" from the end of the detonator. They used copper for the cap because tetryl is such a soft material. If placed in contact with the comparatively rougher surface of the Comp B, the tetryl might have eroded. The copper cap also held the explosive train in place so there were no spaces or gaps between any of the components inside the detonator. A gap, regardless of how small, anywhere in the bridgewire to the high explosive to be initiated, represented a time delay in transmission time and affected simultaneity to possible detonator failure.

The 1.125" diameter 1773 detonators were pushed into brass "chimney" sleeves[286] inserted through the 2.0" diameter booster (detonator) holes in the Dural sphere. The detonator sat in a shallow square-cut circular hole that had been machined into the apex of the outer HE lens. Thin cork pads under the chimneys were secured to each lens block with cement.[287] The 1773 detonators were then held in place in the chimneys by flat metal leaf springs screwed to the outside of the Dural sphere.

The scientists also had to ensure that there would be sufficient contact pressure (even at the - 40° temperature of the B-29 bomb bay at 30,000 feet) on the lenses to forestall any possibility of shifting due to temperature changes, vibration, or oscillation. They solved this problem by incorporating 10" diameter donut shaped rubber pads surrounding each detonator. These pads pressed down on both the detonator chimney and the lens itself. The pads were glued in place on the interior surface of the Dural sphere and were slightly thicker than the adjacent cork lining.

When the detonator exploded, the copper cap was driven into the outer surface of the explosive lens thereby creating a short duration, high-pressure pulse in a small region of the Comp B that initiated the detonation wave in the outer lens. The current generation of slapper detonators utilizes this same principle. While most scientists today would agree this high-pressure "slap" initiates the HE, even after over 50 years of intense study, it is still not a completely understood phenomenon.

The detonator cables were made from standard copper conductor RG-54-A/U coaxial cable that consisted of a multistrand center conductor and a braided outer conductor. The inductance in this cable is 0.09 uh per foot. These cables were attached to the outside of the Dural sphere by 110 rubber-lined wire harness clips and then routed through ten 7.875" diameter holes in the aluminum cone. To help ensure the simultaneity of the explosion, the detonator cables were all the same length and had been carefully calibrated to the same identical output impedance.[288] These cables were secured to the cone by metal harness straps that straddled the large holes and then connected, using simple hand crimping tools, to the ring of firing terminals in the aft portion of the X-unit. The firing terminals were crafted from aircraft sparkplugs since these could easily withstand the high voltages used in the firing circuit.[289] The detonator cables were not hard wired to the X-unit. Any excess cable length was coiled up inside the cone. Although the cables were attached to the X-unit before the cone was bolted to the polar cap, this was still a difficult job because of the narrow working space. It was hard to keep track of where all 64 cables were going. The Electrical Detonator Team consisting of Henry Linschitz and SED T/Sgt. Vincent Caleca did this demanding and complex work. Linschitz explained that since "the arrangement of the cables was rather complicated, Caleca and I had practiced the job intensively on mock-up units." He added, that at Trinity, "We were anxious to do the wiring job accurately and quickly."[290]

In addition to six regular detonator holes, the forward polar cap also had four extra 1.5" diameter holes. These were for the detonators attached by a Primacord (PETN in a flexible tube) fuze train to four standard mercury fulminate A.N. 219-2 contact fuzes on the nose of the bomb. These fuzes were sometimes referred to as "daisy cutters." When the bomb was released, safety wires were pulled out of these fuzes. Aluminum propellers on the front of the fuzes were spun off by the rushing air thereby exposing the contact plungers. In case all of the main fuzing devices failed and it struck the ground, these contact fuzes would self-destruct the bomb in a non-nuclear explosion. The pumpkin bombs were detonated by using three of these contact fuzes.

The fuzes were attached to 5" long, 3.3" diameter steel tube fuze pockets welded to the front portion of the forward ballistic case. The holes in the sphere were directly behind the fuze pockets. The fuzes, like the Archie antennas, were installed in the test units after the bomb had been safely loaded in the plane.

Lt. P.J. Chaussy, 1st Ordnance Squadron, said later, "After we loaded the bomb in the plane, we screwed four regular, typical mechanical bomb fuzes on *Fat Man*. The arming wires were then hooked onto the B-29 bomb bay."[291] However, a last minute decision was made to remove the Primacord fuze trains connected to the sphere on the F-31 unit. These fuzes were also eliminated in some of the postwar units and the four extra sphere holes were subsequently plugged.

An aluminum cone was also bolted to the aft polar cap. The Fuzing Team, led by Edward B. Doll, installed the radars, timers and baroswitches to the "C" plate bolted to this cone. These were the same kinds of fuze assemblies that had been used on *Little Boy*. These fuze assemblies were connected to the X-unit by a master firing cable threaded through the very narrow space between the sphere and the ballistic case. An interesting problem would develop later with this cable. A large circular manifold ring made from 1.5" OD stainless steel tubing was attached to the perimeter of the "C" plate. The air from the baro ports (see below) was directed to this manifold and then to the baro switches.[292]

The forward and aft ballistic case ellipsoids were then bolted to the eight sphere attachment lugs. The six baro switches, Clock Box, and Archie fuzing assemblies had already been attached to the "C" plate (see above) and the entire bomb was then sealed off by the "D" plate. This plate was bolted to the rear of the aft case and utilized a large black rubber gasket for sealing. The only openings in the entire case were the six 0.312" and two 0.75" baro holes in the aft case. Air that passed through these holes also passed through a silica gel desiccant package that removed any moisture.[293]

The 59" sq., 425-lb. tail assembly, nicknamed the "California Parachute," was bolted in place on the rear of the aft case. It was made from 0.20" thick aluminum plate. To improve ballistics, it utilized drag stabilization, a design modification that used baffles in the tail. Capt. David Semple, Norman Ramsey, Navy Capt. William Parsons, and Sheldon Dike had suggested these changes.[294]

To keep the tail from catching on the vertical guide rails in the bomb bay after it was released, rubbing blocks were attached to the upper forward side edges of the tail. These 0.75" thick, 12.0" long blocks protruded slightly from the tail flanges and were made from a smooth, low-friction material called Micarta.[295] The 19.5" diameter "E" plate closed off the rear of the tail.

After the case was assembled, the eight sphere lug joints were covered with 14.25" long formed sheet aluminum covers referred to as "bathtub fittings."[296] These served to seal and streamline the case and were attached to threaded holes in the eight waist section cubes by two machine screws.

At this point, the assembly was rolled out of the assembly building. *Project Alberta* personnel applied sealant to the case joints at the nose cap, equatorial joint, bathtub fittings, and the joint where the tail was attached to the bomb case. This process was called "cocooning."[297] Strips of tape were first applied to all the openings and cracks in the ballistic case. Next, red-colored M-190 Pliobond was sprayed over the tape. Finally, blue-colored O.S. 3602 strippable plastic film (Glyptol) was sprayed on an area of approximately one foot on either side of the joints.[298] These sealant coats were colored red and blue to ensure proper coverage. To complete the assembly, the case was then evacuated by use of a one-way "breather" valve attached to the "D" plate. This evacuation, and the use of the desiccant package, ensured that none of the mechanisms would freeze when the bomb was dropped from 30,000 feet.

Before it was rolled out to the plane, everyone in the area signed the bomb, including Admiral Purnell, General Farrell, and Captain Parsons. There were almost 60 signatures, messages, and poems on it.[299] *Project Alberta* engineer Harlow Russ stenciled a side profile of the bomb with the letters F.M. inside and the letters JANCFU on the nose of the bomb. These letters stood for "Joint Army Navy Civilian." The last two letters stood for the same thing as the last two letters in the standard military vernacular situation description, "SNAFU."[300] This almost proved to be an accurate prediction of events surrounding this mission.

In addition to the problem with the armor case, several other things happened. Earlier, one of the plutonium hemispheres had to be remelted and recast back at Los Alamos because it was underweight.[301] Then, when the F-31, F-32, and F-33 *Fat Man* pre-assembly units were being transported from Los Alamos to Tinian,[302] a problem developed with one of the three B-29's as they were departing from Mather Field in Sacramento on July 29. The planes (50-MO-44-86346, 50-MO-44-86347, 30-MO-42-65386) were piloted by Herman Zahn, Jr, Edward M. Costello, and William Hartshorn, respectively.[303]

The *Laggin' Dragon,* piloted by Costello, was the third plane to take off. In addition to carrying the F-31 *Fat Man* preassembly (minus the fissile material and detonators) in the front bomb bay, they also had a 10' statue of Christ in the rear bomb bay that was being taken to Tinian for one of the chaplains. They had just cleared the ground and had started the gear up when one of the outboard panels blew off on the right side.

The life raft and other emergency gear stored behind the panel flew out and wrapped around the tail of the plane. This caused a lot of vibration, shaking and rattling in the plane. Because they were nose heavy, the only people in the front of the plane were the pilot, copilot, and Flight Engineer. Everyone else was in the rear of the plane for takeoff.

After they became stabilized a little, Costello called back to Lt. John Downey, the Bombardier, to come back up front to get ready to salvo the bomb in case they got into any further problems. He cut the safety wire on the toggle switch and sat there nervously waiting for the word to throw the switch. Fortunately, that word never came.

They managed to get enough altitude to make a turn and head back to the landing strip. After making contact with the control tower and declaring an emergency, they were asked what their weight was. They said that they weighed about 136,000 pounds. The tower told them to fly around until they were down to about 120,000 pounds to protect the runway. Costello said, "Fly around, Hell! I don't know if I can get around <u>this</u> time." It took the combined efforts of both the pilot and his burly co-pilot, Harry Davis, to land the plane. After making the necessary repairs, they took off at about midnight for Hickam Field.[304]

F-33 was later dropped near Tinian on August 8 as the last test unit. It was the first HE-filled *Fat Man* to be tested in the Pacific using a fully operational X-unit. F-32 was held at Tinian in the event a third bomb would have to be dropped on Japan. It was returned to Los Alamos in October 1945 and disassembled. The fissile material for F-32, though en-route by car in the US, never made it to Tinian.[305] 509th pilot Don Rehl had been scheduled to bring it to Tinian.

During the final assembly of the F-31 bomb on Tinian, an inspection mirror was dropped inside the ballistic casing and had to be "fished" out. Around midnight on August 7, Navy Ensign Bernard J. O'Keefe discovered that the plug ends on the master firing cable were reversed. Rather than having the bomb disassembled, which would have taken hours, he and an army technician removed and re-soldered the connections.[306]

Maj. Charles Sweeney's plane, *The Great Artiste*, was still loaded with instruments used during the Hiroshima mission. When Tibbets picked Sweeney to be the commander for the second mission, the decision was made at that time for him to switch planes with Capt. Fred Bock. His plane, *Bockscar,* would be used to drop the bomb and would be flown by Maj. Sweeney. Capt. Bock and his crew would fly *The Great Artiste.*

After the bomb had been towed out to the loading pit on the afternoon of August 8, 1945, it was raised into the plane utilizing the same procedures used earlier with *Little Boy.*

By 8:00 PM, all of the antennas, pullout wires, electrical connections, and swaybraces had been attached.

The stage was set. *Fat Man* was ready.

Chapter 6

Nagasaki

"I've never seen anything like it!
Biggest explosion I've ever seen.
Those poor Japs. But they asked for it."
2nd Lt. Fred J. Olivi – August 9, 1945

The final crew briefing took place at 12:30 AM, August 9. Assistant Flight Engineer Ray Gallagher, expressing his own sentiments in a postwar statement, said:

> The feeling in our hearts, when we heard about the briefing, was very, very low. We had already witnessed what had occurred in the air. They must have known we're going to come back and surely they'd be ready for us. At a quarter to twelve, we were getting ready to leave our Quonset. As we walked past the last bed, the barracks bag was laying there. When we passed the bag and dropped our wallets inside, truthfully, I never thought I'd pick it up again.[307]

The briefing was short. This time there would be only two targets, Kokura and Nagasaki. Because of a large, severe weather front, the rendezvous would be over the island of Yaku-Shima instead of Iwo Jima. After the briefing, they went to eat. Once again, according to Gallagher, "it had no taste."

As with the Hiroshima mission, there was no fighter plane escort, which might have brought unwanted attention to the B-29's. A P-38 fighter pilot, interviewed on the CBS *Sunday Morning* television program in 1995, tearfully claimed he accompanied the planes to Nagasaki and had witnessed the mushroom cloud. This simply did not happen.[308]

They arrived at their plane at 1:00 AM and about an hour later they started the preflight preparations. The commander, Maj. Charles Sweeney and his Flight Engineer M/Sgt. John Kuharek started up the engines. Said Sweeney, "I had my choice of any Flight Engineer I wanted and I chose him. We worked closely as a team. He was personally hand-picked and a wonderful, wonderful guy."[309]

Ray Gallagher talked later about the preflight checks:

> I got up on the wing of the ship and checked all the gas tanks to make sure they were topped-off and that there was gas in all of them. The oil tanks were checked. The engineer got into his seat and made sure that all of his gauges were properly set. The pilot walked around his ship, back and forth, to make sure that there was nothing unusual. The crew chief came up and conferred with the pilot, copilot, and the engineer. In the meantime, the Navigator and the radar operator are already aboard ship checking out their equipment along

with the radio operator. After all of these checks have been made, we got out of the ship and were standing around.[310]

As the time for takeoff drew near, the crew said their good-byes and boarded the plane. The Flight Engineer started up the engines. They were running just fine, when the pilot and engineer started to confer over the intercom. Before they knew it, Sweeney instructed Kuharek to shut down all the engines and told everybody to get out.

The B-29 had been loaded with 7,250 gallons of fuel. As part of his preflight checks, Kuharek had been in the process of transferring fuel between the two extra 320 gallon Goodyear 2FI-6-4562 self-sealing auxiliary tanks in the rear bomb bay when a problem was discovered. A fuel transfer pump appeared to be malfunctioning. This meant the 640 gallons of fuel in these two tanks was not available for use. Because of a three-hour weather "window," there was no time to replace the pump, empty the fuel, or transfer the bomb to another plane. Critics of the mission contend there was no mechanical problem with the transfer pump and that it functioned perfectly after they came back to Tinian. They insist that the "problem" was due to the unfamiliarity with this plane's idiosyncrasies by the substitute crew. According to Ashworth, "If [this was] true, we could have used the fuel."[311] This fuel problem may or may not have existed, but in the crucial early morning hours just before takeoff, it was genuinely perceived by those present to be an actual last-minute malfunction.[312]

After a meeting with all of the people involved, the decision was reached to proceed with the mission. They would land at Iwo Jima for refueling on the way back.

Tibbets, explaining the fuel problem, wrote:

> In the preflight checks, the 'fuel transfer' problem was found. When Sweeney and Kuharek came up to me on the ramp and told me, I told them they did not need that fuel to fly the mission as briefed. The primary purpose of that fuel and tanks was to permit the airplane to take off and fly within the CG (center of gravity) limitations. Both agreed, so I said, 'GO.' [While] walking to the airplane, I instructed Sweeney to go to his rendezvous point, 'make one 360 degree turn and head out for the initial point,' whether his wing men were with him or not.[313]

Referring to veteran Bombardier Capt. Kermit Beahan's previous extensive combat experience, Tibbets went on to state: "I told him (Sweeney) to do what Beahan recommended. Sweeney said, 'If Bea wants me to fly it upside down, I'll try it.' With that they were on their way."[314] Most of the crew did not know about the fuel problem until well into the mission. This fuel situation would later become a major dilemma.

According to General Groves:

> One very serious problem came up just before takeoff, which placed [General T. F.] Farrell in the difficult position of having to make a decision of vital importance without the benefit of time for thought or consultation...the weather was not good, in fact it was far from satisfactory; but it was good enough in [General Curtis] LeMay's opinion, and in view of the importance of dropping the second bomb as quickly as possible, and the prediction that

the weather would worsen, Farrell decided that the flight should not be held up.[315]

Just before takeoff, Admiral W.R. Purnell asked Sweeney if he knew how much the bomb cost. Sweeney answered, "About $25 million." Purnell then warned him, "See that we get our money's worth."[316]

They finally departed at 3:48 AM. 3rd Pilot 2nd Lt. Fred Olivi made an informal diary of the mission. "No apparent trouble -- but we sweated it out and I mean just that. All hell will break loose if we lost an engine on takeoff -- I may as well kiss this world goodbye!"[317]

At 4:00 AM, Weaponeer Navy Cdr. Frederick Ashworth opened the round, padded pressurized door that led into the forward bomb bay from the cramped rear area of the cockpit. Bracing himself, he leaned forward and reached back into the cold bomb bay. He removed the two green, AN 3106 20-14P safing plugs in the nose of the bomb, replaced them with the red arming plugs, secured these with metal clips, and then closed the door. *Fat Man* was now "live." These were the same kind of plugs used on *Little Boy*. One of these green plugs is in the West Point Museum and the other is in the Truman Library. The tags, dated August 10, 1945, attached to the plugs were filled out by Electronics Test Officer Lt. Philip Barnes and signed by both Barnes and Ashworth. Both tags state, "I certify that this is one of the two Green Safety Plugs used on F-33 (sic) at Nagasaki, Japan on 9 August, 1945. This was the second Atomic Bomb dropped on the Empire."

Because it was a long flight, all three pilots took turns at the controls. Olivi talked later about the long flight to the rendezvous:

> Usually, when we went to the Japanese Empire, we went by way of Iwo Jima. We would fly at 9,000 feet but, because of weather conditions, they rerouted us to 17,000 feet by way of the Ryukyu Islands. It was a departure from the norm. After we got settled on course, Sweeney said that he was going to go back into the tunnel and get some sleep so I took over for a while and flew. Albury and Beahan slept. Van Pelt, Kuharek, and I were the ones who were taking care of the flying.[318]

During the flight, Olivi penciled, "Weather is bad so we're climbing up to 17,000' to clear it instead of the usual 9,000'. Cruise control chart not set up for 17,000 feet -- so that means we'll use a hell of a lot more gas than usual amt. at 9,000'."

St. Elmo's Fire danced eerily across the surface of their planes as they flew through the stormy darkness with their wing lights off so the Japanese could not spot them. Olivi continued, "04:30 -- stopped climbing -- level at 17,000' -- some of these damned cumulous and thunder clouds are rough as hell! But 'George' will win through! 05:30 This route straight to the Ryukus sure is long -- and tiresome! The usual way by Iwo is much better -- and something to look forward to at Iwo." Olivi then jotted down some quick notes, "Chuck and Bee [Beahan] are sleeping -- God I'm so tired I can barely keep my eyes open. Wish I could sleep too, but flying through these cumulous sure wakes you up in a hurry! Poor Jim [Van Pelt] he's in the same boat as I. He sure works hard at his navigating -- I take my hat off to him."

After Albury awoke, he and Olivi took turns flying until Sweeney came back up front and took over the controls. From then on, Sweeney and Albury shared flying duties. There was one Flight Test Box (FTB) onboard that was used by Lt. Barnes to monitor the separate bomb fusing and firing circuits. At about 7:00 AM, a red light on the box suddenly lit up unexpectedly. It was indicating *Fat Man* was now fully armed and could perhaps detonate at any moment! After almost ten frantic minutes spent studying the blueprints and digging into the FTB wiring, Barnes discovered the source of the problem. It appeared two switches had been improperly set. These were immediately reset to their proper positions and everyone breathed a collective sigh of relief.[319]

About 8:00 AM, Sweeney notified the crew he was starting the gradual climb to 30,000 feet and they should all put on their flak suits. Co-Pilot Charles Albury wrote, "As for the flak suits, the pilot [Sweeney] didn't put them on. We laid them on the floor between the two pilot seats over the door at the nose wheel."[320]

According to Ashworth's log, *Bockscar* arrived at the Yaku-Shima rendezvous point at 9:00 AM. In a preliminary draft version of Norman Ramsey's History of Project A (9/27/45), which made use of Ashworth's log times, 0900 was crossed out and changed to 0915(?).[321] According to Ramsey, this change was made before he received his copy of the log.[322] Olivi's handwritten notes made during the flight state, "Reached rendezvous point 09:10 Aug. 9. Bock is in sight and is joining up. Hopkins nowhere in sight. We'll circle rendezvous for 15 minutes -- he may come." Radio operator Sgt. Abe Spitzer wrote in 1946 that they arrived at 9:09 AM. Spitzer stated that their tail gunner had spotted *The Great Artiste* before they arrived at the rendezvous, but then lost sight of it. He also wrote it was maybe ten minutes before *The Great Artiste* was sighted again.[323] Pulitzer-Prize winning author William Laurence was the official observer flying inside *The Great Artiste*. He wrote in his 1947 book, *Dawn Over Zero* that they reached the rendezvous at 9:12 AM and immediately spotted *Bockscar*.

In Ashworth's report, written shortly after the mission concluded, he stated, "Skillful piloting and expert navigation brought us to the rendezvous without incident. About five minutes after our arrival we were joined by the first of our B-29's. The second, however, failed to arrive, having apparently been thrown off its course by storms during the night." Sweeney recounted, "One of the most beautiful sights, I remember, is Fred Bock joining up with me at that rendezvous point, which I wasn't sure I could find."[324]

Said Gallagher, "After arriving a little after 9:00 AM, about five minutes later along came one of the other ships off our right wing."[325] The photo plane flown by Maj. James Hopkins could not be found. They thought that it had been delayed or lost in a storm they had just gone through. It was, in fact, circling at a higher altitude.

Sweeney recalled the rendezvous:

> The second airplane showed up within a minute. We had navigated through the bad, black weather all night long. There was a terrible storm. We went at 17,000 feet because we wanted to get the smoothest air we could get and to conserve fuel. After five hours, we went up to 30,000 feet to rendezvous at Yaku-Shima. Bock was on my wing within a minute after flying five hours without seeing me, that's how good his navigation was! We made a perfect rendezvous. For some unknown reason, Hopkins was flying at 39,000 feet. My mission all along was to do this, to deliver this 'thing,' to do it for the nation, but also to do it for Paul Tibbets. I'll risk my ass, with a problem on fuel, just to get the delivery in. After that, then I'll worry about whether we

land in the ocean or not. I waited and waited for him (Hopkins) just to make the mission perfect.[326]

Bockscar Co-Pilot 1st Lt. Charles Albury described the difficulty of locating another plane at that altitude:

> ...the weather caused us to rendezvous at a high altitude instead of a low altitude of 7,000 ft. At thirty two thousand feet a rendezvous is almost impossible. Take a pencil, put the point down, move the pencil in a circle at the top. Note the difference of the circle about 2/3's the way down from the top (7,000 ft). Note the circumference of the circle at the top (32,000 ft). Quite a difference isn't it?[327]

RAF Bomber Pilot Grp Capt. Leonard Cheshire VC, an observer on Hopkins's photo plane, wrote:

> On arrival at the rendezvous point the three aircraft failed to make contact, which did not surprise me in the least, since instead of orbiting Yakushima in a tight circle, they flew around in dog legs some 40 miles long at varying heights. There being no adequate arrangements in the event of contact not being made and the leader not being willing to break radio silence although there was no conceivable reason why he should not, the three aircraft continued to orbit for an hour and ten minutes. The pilot of the photographicaeroplane, in which both Penney and myself were riding, then proceeded to fly around the approaches to Kokura wondering what he should do.[328]

Ashworth wrote later, "When only one plane showed up, I told Sweeney that I wanted to be sure that we had the instrument carrying aircraft with us." Of the two planes, the only one of any importance was the instrument plane. These instruments would help determine the bomb yield. Sweeney kept Ashworth in the dark as to which plane had rendezvoused with them. "Why Sweeney didn't tell me that the instrument aircraft was already with us, I don't know."[329] According to General Groves, "Although Sweeney had identified the one plane that did arrive he did not tell Ashworth. Unfortunately, because it did not come close enough, Ashworth was unable to determine whether it was the instrument-carrying plane."[330] Ashworth continued, "I still say that the question of what plane had joined us was an air operational detail that was rightly Sweeney's responsibility. I recall that finally I stuck my head up to the flight deck and recommended that we get out of there and get on with the operation."[331] It is Ashworth's opinion that this long delay could have cost them the mission.

Tibbets had instructed Sweeney to wait at the rendezvous point for no more than 15 minutes.[332] After waiting in vain for over 40 minutes, Sweeney and Bock finally pushed on to their primary target, Kokura. Olivi wrote in his diary, "09:50 Hoppy still hasn't arrived. We can't wait any longer. Our gas is going fast at this altitude and pulling this power setting -- (38-23-½) -- Going onto IP with Bock." William Laurence wrote that they departed at 9:56 AM.

Sweeney has been criticized over the years for waiting over the rendezvous point for as long as he did. Because Tibbets' mission had been a "textbook" flight, Sweeney obviously felt he was under tremendous pressure to also make sure his mission was perfect. However, because of the acute fuel situation, this unnecessarily long delay severely jeopardized any possibility of returning safely to an Allied base with *Fat Man* in case the mission had to be aborted.

Olivi wrote, "Time 10:20 Hit IP on the nose -- Jim is doing a good job, but our gas is still something to worry about -- weather report from weather ships claims clear weather. 10:40 Target is in sight but 7/10 clouds coverage -- Bomb must be dropped visually but I don't think our chances are very good."

When they finally arrived at 10:44 AM, smoke and industrial haze had obscured Kokura. Yahata had been firebombed by over 200 of LeMay's B-29's the previous day and the smoke had drifted over nearby Kokura. There was also a POW camp right next door to the main downtown power plant. An American prisoner in this camp reported later the Japanese had installed a large pipe that went from the power plant down to the river. He stated that whenever B-29's were sighted over Kokura, the steam in the plant was diverted through this pipe and into the river. This created enormous condensation clouds that also helped to obscure the city.[333] The lack of visibility was a problem because they were under very strict orders to make a visual, not radar, bomb run. They got into position to make the bomb run that would take about four minutes.

About a minute away from the drop, Beahan opened the bomb bay doors. *The Great Artiste*, the instrument plane to the right, immediately opened their doors in preparation to drop the three instrument packages. It seemed as if that minute lasted an hour. Beahan finally said, "No drop, I can't see the target." The smoke and haze had obscured the Aiming Point (AP).

They broke off the run and made a right turn toward the mountains. The antiaircraft guns had starting sending up flak. Ashworth asked Sweeney what he was going to do next. When he didn't respond, he suggested to Sweeney that they go around 120° and come in from a different direction. They tried a second time, but were still unable to drop the bomb. The flak was starting to get closer. Sweeney said, "I saw the flak on the first run. We were getting it on both sides. When I spotted it, I said I'll try to screw up their fuses. I climbed a few thousand feet. On the second run, I climbed another thousand feet. This gave Bee time to adjust his bombsight for that altitude. I was worried that they might hit us with a 'lucky shot,' so I kept changing the altitude."[334]

Ashworth, who was the Senior Officer Specialist on the mission, said they were not worried so much about the flak as they were about the possibility of fighter planes. He wrote, "Lieutenant Beser was scanning the radio frequencies to determine if the fusing was being jammed and reported activity on fighter director circuits indicating that we might have soon been the target of fighters."[335]

Kuharek kept Sweeney apprised of the decreasing fuel supply. The flak was now getting even closer. They went around another 120° and tried again, but the next run was also unsuccessful. After three unsuccessful attempts, each from a different direction and altitude, they finally made a decision to abandon the effort at 11:30 AM and proceed to their secondary target, Nagasaki (almost 100 miles away), which they would be passing over anyway on their way back to Okinawa.

Critics, including Tibbets, have argued that Sweeney should have aborted the mission after the first unsuccessful bomb run on Kokura. They have stated the extra attempts were a waste of precious fuel and time. In 1995, Ashworth rejected this Monday morning quarterbacking criticism of their three attempts. "No! This was totally justified. It was our primary target and it was entirely possible that the wind direction on the ground might have opened up the target."[336] However, in 1998, Ashworth had a change of heart. Responding, in part, to scathing comments made by Tibbets in the 1998 reissue of his autobiography, Ashworth wrote:

> After the first run and no drop, I did go up to the flight deck, and suggested to Sweeney that it might be possible to see the target if we approached it from a different direction. I think that both Sweeney and I believed that we had to make the best attempt that we could. After all it was the primary target. In hindsight, I am now surprised that Beahan, the highly competent Bombardier with extensive combat experience in the European theatre didn't have something to say about making the additional passes at the target.
>
> Also in hindsight that was a bad suggestion and I should have known it. I damn near got shot down in the South Pacific making a second run on a target. I had successfully hit it on the first approach, but I did not think that there was enough damage done. As far as I could tell there was only a small fire on deck of the ship that I was attacking after the hit with a 500-pound bomb. It is interesting to note that in Sweeney's book [*War's End*] he tells of advice from his Marine friend on Tinian, that he should never make two attacks on the same target.
>
> I say categorically that I did not order either the second or third attack as inferred by Tibbets. As a matter of fact I gave no orders to anyone on the entire mission The closest that I came to that was to agree with and confirm the recommendation of the flight deck people that we make a radar approach on Nagasaki. (original emphasis)[337]

Olivi wrote in his diary, "11:30 Made three runs on Kokura but couldn't drop our bomb. These damn clouds sure are making us sweat. Some flak -- no fighters -- as yet. Gas damn low! Going on to our secondary Nagasaki -- Our gas warrants one run visual or radar -- it's now or never! Less than two hours of fuel left."

Then, reflecting the mounting tension in the plane, Olivi wrote "11:32 Reducing power to save gas -- wonder if the Pacific will be cold? Our chances for ditching are -- good!!! Bomb MUST be dropped for more reasons than one -- Hope it goes off! It'll be a hell of a lot of sweating for nothing if it don't." He added, "11:40 Boys getting jittery. Can't blame them."

Bockscar Co-Pilot Charles Albury wrote, "On the way from Kokura to Nagasaki the clouds were building up to our altitude and we were flying in and out of the tops."[338]

When they arrived at Nagasaki at 11:50 AM, they discovered it was about 4/10ths cloud covered. These puffed clouds were between 8,000 and 10,000 feet and it was difficult to see through the breaks in them. Olivi wrote, "Target 8 min. off. Clouds are still over this target too."

Because they were running low on fuel, a decision had to be reached soon. The delays at both the rendezvous point and Kokura had now forced them into a critical position. There was now not enough fuel for them to bring the bomb back without ditching the plane in the ocean with the bomb onboard. This was certainly unacceptable. One way or another, they had to drop the bomb on Nagasaki.

As the mission commander, it had been Sweeney's responsibility to get both the plane and its payload to the target. However, the *Fat Man* was still Ashworth's responsibility. Whether they dropped it on Nagasaki, in the ocean, or attempted to bring it back was ultimately his call.

Sweeney laid out all the options for Ashworth. While he went back to make what must have been an agonizingly difficult decision, Sweeney wasted no time and set up the plane for a radar run at Nagasaki. Ashworth could see the *Fat Man* through the small window on the bomb bay door. Radio operator Abe Spitzer wrote in his mission diary that Ashworth decided initially against a radar drop and they should risk the very slim chance of being able to return to Okinawa with *Fat Man* given the limited fuel supply. He continued:

> We were five minutes away now! I could see the Comdr was struggling within. He seemed perplexed--what to do--diregard (sic) orders—risk a return to Okinawa and the lives of the men aboard--perhaps the loss of the bomb in the ocean to save our own necks--all that weighed heavily on his mind. Desperatly (sic) he made up his mind. Casting aside all consideration he informed the Major that he reversed his decision---it was Nagasaki, radar or visually but drop we will. We cheered! Nagasaki here we come--only three minutes out.

Even though a radar run was strictly against orders, Ashworth knew what he had to do. After a few long minutes, he came back up to the flight deck and told Beahan, "This is going to be a radar approach. If you can get a sighting, good, but if you can't, then release by radar. I'll take responsibility!"[339]

Co-Pilot, 1st Lt. Charles Albury, recalled the dilemma they faced:

> As far as I'm concerned, Sweeney was in command all the way...On the way to Nagasaki, Ashworth came up front and discussed the situation with Sweeney, Beahan, and myself. Ashworth asked for a few minutes to think it over. While he was back in the aft end of the cockpit, Sweeney, Beahan, and I discussed the situation. We had to get rid of the bomb in order to reach Okinawa. The bomb would be dropped by radar on Nagasaki rather than drop it in the ocean. While getting set up for the bomb run, Ashworth came forward and gave his consent for a radar drop.[340]

They knew that they had only one chance at a bomb run. Even if this run was successful, there was a good chance they would not make it back. There was not enough fuel to get to Iwo Jima. There probably was not even enough to get to their emergency refueling stop at Okinawa. The success of the mission now depended on the veteran Bombardier, Capt. Beahan. It was also his 27th birthday. The plane he normally flew in was named *The Great Artiste*, in part, because of his almost legendary skills as a Bombardier.

Half of the total effort of the *Manhattan Project* rested squarely on his shoulders. He knew he had only one chance and that it was certainly under the most pressing circumstances of his career. The pressure he felt must have been tremendous!

A radar-bombing run was started. Olivi wrote, "It's our last pass -- hoping for a hole to drop visual -- bombing run down to 190 to save gas. 11:56 No change in cloud coverage -- It's radar all the way so far -- still hoping for visual sight of target." He added, "Hope these glasses do the trick!"

During the five minute run, large holes poked through the puffed clouds long enough for Beahan to see the ground. This provided him with about 20 seconds of visual bombing condition and allowed him to search for a suitable aiming point. Said Sweeney, "At the last moment, while we were making the approach by radar, Beahan said, 'I got it! I got it!' So I said, 'Okay, you own the airplane.'"[341] Sweeney then relinquished control of the plane to Beahan.

Olivi recalled the final moments before the bomb was released:

> They started the bomb run immediately. The radar run was controlled by Van Pelt up in the front with his scope and by [Sgt. Edward R.] Buckley in the back with his scope. They were coordinating the run together along with Beahan. They made sure they were zeroing in on the right target. The run was about 95% complete when Beahan, up in the nose, hollered, 'I see it! I see it! I've got it!' and of course the bomb run was relinquished to him. He had about 45 seconds to set up the bombsight, to kill the drift, and to kill the rate of closure on the target. Then he dropped it.[342]

They had already passed over the original AP, which had been "in the city, east of the harbor"[343] and were now over the Urakami industrial valley of Nagasaki. Beahan picked a new AP (stadium) and released the bomb from 28,900 feet at 12:02 PM [Marianas Time].[344] Olivi wrote, "Bombs away! Bee had a 30 sec. Bomb run visually -- hope it's in!" Exactly 47 seconds later, *Fat Man* detonated at an altitude of 1,650 ± 10'.[345]

Dramatically for Japan, the war had finally come full circle. In an ironic twist of fate, the plutonium bomb that ended World War II wound up exploding almost directly over the large Mitsubishi armament plants that had produced the torpedoes used during the Japanese attack on Pearl Harbor.

Beahan wrote in 1984:

> We proceeded on the bomb run under radar control until about 20 to 30 seconds from bomb release when I saw a hole developing in the clouds over the target area. I took over control of the bomb run and selected an aiming point in the industrial valley of Nagasaki. Fortunately, the radar team had made an excellent initial bomb approach, and in the very brief time remaining I was able to synchronize the cross hairs of the bombsight on the target and release the bomb visually with "good" results being achieved. It was as if a great weight had been lifted from our shoulders since we did succeed in following the order "Visual drop only!"[346]

It was a performance which, in the opinion of Ashworth, "Could not have been duplicated by any, or perhaps a few, I don't know, Bombardiers in the Army Air Corps. He kept his cool. What he did was a one-in-a-million performance as far as I'm concerned."[347] Ashworth also stated that, "Van Pelt [Navigator] was calling up calculated dropping angles that were being calculated in his electronic bomb director so that Beahan could keep his telescope more or less synchronized."[348]

Said Ashworth, "They [bomb director group] were giving him information which permitted him to synchronize on something down there. Presumably he saw the stadium and I suspect he was familiar enough with the area, that's what good Bombardiers are supposed to do. He knew this was in the vicinity and said 'By God, I'm going to shoot at this thing.' We were supposed to be dropping it down around the dock area of the city."[349] He had missed the original aiming point by 1.3 miles. Ashworth continued, "By 'missing' the target, we destroyed the Steel and Arms Works, Torpedo Plant, damaged the docks, and hardly broke a window in Nagasaki City."[350] He went on to say that, "Major General Sweeney wouldn't be a General and Admiral Ashworth wouldn't be an Admiral if Beahan hadn't done the job that he did!"[351] The simple fact is they had gotten themselves into a real mess and Beahan, Buckley, and Van Pelt saved the mission.

Albury recalled, "To this day, I don't know if Beahan saw the Aiming Point. I do know, as he was making his last correction, the aircraft was in a slight turn and the bomb was released."[352] Because they had been making a radar run and since Beahan did not have any scope, the decision as to when to release the bomb would have been Van Pelt's. Olivi said, "I was back there in the radio compartment and when I turned around after we had just dropped the bomb, Van Pelt said to me, 'Fred, I almost dropped it! I almost dropped it!'"[353]

Sweeney immediately made the 155° diving left turn to escape the blast.[354] According to Fred Bock, *The Great Artiste* "was probably 100 to 200 yards behind, and a little below and to the right, of #77 at the time of the bomb release." He continued, "I distinctly remember seeing *Fat Man* fall from #77, at which instant the Bombardier on #89, Charles Levy released the three instrument packages from the bomb bay."[355]

Immediately after the instruments were dropped, Bock quickly made his right turn. Ray Gallagher recalled, "We had all our gear on, our glasses, and we turned into the center of the ship and waited for that reflection."[356] Co-Pilot Albury wrote, "The welders glasses cut down visibility so far, you could not see the flight instruments. Chuck and I both did not wear them. We found this out at Hiroshima."[357]

They were in the turn when the bomb exploded. Even with their dark, polarized goggles on, one of the crew described it as being 10 to 15 times brighter than the sun.

Olivi said later, "It was a bright bluish color." Referring to the mushroom cloud, he said, "It took about 45 or 50 seconds to get up to our altitude and then continued on up. We could see the bottom of the mushroom stem. It was a boiling cauldron. Salmon pink was the predominant color that I remember, but there were all kinds of damn colors in there."[358]

Sweeney swung the plane around so they could determine exactly where the bomb had gone off. At the time, Olivi wrote in his diary, "This plume of smoke I'm seeing is hard to explain. A great white mass of flame is seething within the white mushroom shaped cloud. It has a pinkish salmon color. The base is black and is breaking a little way down from the mushroom. 12:04 Still circling plume of smoke. Damn thing is getting too close for comfort. It's goodbye if we're ever engulfed in it!"

Olivi later described what he saw:

We couldn't see anything down there because it was smoke and fire all over the area where the city was. Everybody was concentrating down there and I remember the mushroom cloud was on our left. Somebody, I think it was Ray, hollered in the back 'the mushroom cloud is coming toward us.' This is when Sweeney took the aircraft and dove it down to the right, full throttle, and I remember looking at the damn thing on our left and I couldn't tell for a while whether it was gaining on us or we were gaining on it.[359]

Gallagher remembered the anxiety he felt looking out the small window next to him:

I couldn't see the cloud. I stood up and looked straight down. What I saw was the cloud underneath us. I hollered through my intercom mike to the pilot that if we didn't get out, we were going to get caught in our own bomb blast. Unfortunately, the pilot in his anxiety did not watch his turn of one degree-a-second and we weren't in our complete turn. When I told him that, he made the sharpest turn as he possibly could. The ship totally vibrated when he made his turn and as we pulled away, the tail gunner called out that the cloud was right at his level.[360]

Radio operator Abe Spitzer described these dramatic events back in 1946 when he wrote:

"Hey, Abe," said Barnes, the commander's assistant, who was at my side, "we'd better get the hell out of here. That stuff is dangerous." "Tell it to Sweeney," I answered, and I wasn't gagging. The major may have heard me, or, more probably it was coincidence, but he kicked the plane over into another dive, and we pulled away. Just in time, not a second too soon to avoid colliding with the great cloud of smoke which now continued upward, on and on...[361]

Albury explained, "Some say the mushroom cloud was about to get us, but this is not true. In a 45-degree bank it might have looked that way. The turn was on my side of the aircraft and I had a very good view of it without any goggles on. We were at least six to eight miles from it."[362]

Just after the bomb exploded, the plane was struck by five shock waves. The first one was definitely the worst. These shock waves were more noise than anything else. Because of the mountains, the shock waves were reflected back with greater intensity and numbers than the ones during the Hiroshima mission. The mountains also shielded the residential parts of the city from some of the blast effects. This was one of the reasons that the casualty rate was about half that of Hiroshima even though the bomb yield was higher. Albury wrote that, "The shock waves were more intense than at Hiroshima. Most people say three, but two lesser waves were barely felt."[363]

Grp Capt. G L Cheshire VC, the British observer on Hopkins's photo plane, wrote this report later for the RAF:

> Eventually, almost two-and-a-half hours after we had arrived at the rendezvous point, we noticed the explosion of the bomb some 80 miles to the west. The pilot said he was unable to go up to observe it since he was short of petrol. On my pointing out that we could always land on Okinawa he agreed to fly up and circle the target. We reached the target some 10 minutes after the explosion at a height of 39,000 ft. At this time the cloud had become detached from the column and extended up to a height of approximately 60,000 ft. From the bomb aimer's compartment, I had an excellent view of the ground and could see that the centre of the impact was some four miles north-east of the aiming point and that the city proper was untouched. Fortunately, however the bomb had accidentally hit the industrial centre north of the town and had caused considerable damage. Had it exploded in any other direction it would have falled in open country....[364]

Said Olivi, "I remember, just before the bomb exploded, the one thing that came into my mind was that we were going to kill a lot of civilians, women, children, and elderly people. On the flight back, I thought about it, about killing the people. I didn't dwell on it, because to me, I thought if they would have had it, they would have dropped it on us."[365]

After observing the destruction, they left the area and headed out over the ocean. Olivi wrote, "12:06 We're on our way to Okinawa. It'll be close but I think we're in. Sure hope so!!"

When they cleared the coast of Japan, Spitzer sent out a "Mayday" call. There was no reply. Thinking the mission had been scrubbed due to Hopkins' earlier scrambled message, the rescue planes and submarines had already gone back to their bases. They were hoping for help and there was none to be had!

The ride back was a real nail-biter. Kuharek estimated they had about two hours of fuel left and it was two hours to Okinawa. Sweeney dropped down to around 5,000 feet and he and Flight Engineer Kuharek played the engines as close as they could. Both of them employed every trick they could think of to save the remaining fuel.[366] Olivi wrote, "13:00 Okinawa in sight. Passed over Ie Shima where [Ernie] Pyle was killed. Gas is low but we're sure of making Oki." He added apprehensively, "Still 20 min. out --."

About five minutes away from Okinawa, and with all their fuel tanks reading empty, they tried raising the extremely busy control tower. This proved to be impossible because the tower was in the middle of handling an airfield full of B-24's and B-25's taking part in a bombing raid. Even Bock, who was close behind, could not get anyone in the tower on their radio.

Sweeney figured they only had one shot at a landing. As they made their approach, he saw that the runway was crowded with planes that were taking off. They still could not raise the control tower. A system of flares could be fired from the planes to alert the ground personnel to different types of emergencies. Sweeney yelled back to "Fire the colors-of-the-day!" When that failed to raise the tower, in desperation he yelled out to "Fire every goddamn flare in the airplane!"[367]

At the time, Olivi wrote, "13:20 Over Yon Ton but couldn't reach tower at V.H.F. There's heavy traffic going in -- we've got to -- we have no choice -- firing all our flares to let them know we're coming in regardless."

Olivi later described the tension-filled approach:

> It was a real busy field. We made our radio calls and we got no answer. We called it four times in the hopes of getting our landing instructions and letting them know our situation. They didn't come back to us and that's when Sweeney decided to declare a Mayday. He told me, 'Fire all the flares. We're going in!' I was in the Navigator/radio compartment. I took out the flare gun, stuck it out of the porthole at the top of the fuselage, and fired all the flares we had, one after another. There were about eight or ten of them. Each color indicated a specific condition onboard the aircraft.[368]

This got the attention of everyone on the ground and the field started to clear in a big hurry. Sweeney broke into the traffic pattern and cut out three or four aircraft that were already on their approach so he could make the landing.

Due to the critical fuel situation, Sweeney wanted to get the plane on the ground as quickly as possible. Because of this, he brought in the plane at a faster than normal speed. Just as they were landing, the #2 inboard engine sputtered and died while a B-24 was starting to takeoff right in front of them. It lifted off just as the B-29 landed halfway down the runway right behind them.[369] As soon as they touched down, Sweeney and Albury used both the brakes and reversible propellers to help slow down the aircraft. After this harrowing landing, Sweeney turned the plane off the end of the runway. He then followed a jeep that came out to escort them over to the hardstand. Later, it was discovered they had, not counting the useless trapped fuel, only about 35 gallons of fuel in all of the tanks. Some accounts state there was only a mere seven gallons. Either way, they were flying on fumes!

Albury wrote:

> As to the landing at Okinawa, #2 engine stopped just before touchdown. We immediately put the engines in reverse and slammed on the brakes. The aircraft veered to the left...Sweeney compensated by pulling back on #1 engine in reverse, and increased the brakes on the right side and [by] releasing some of the pressure on the left brakes. I know because I was on the brakes with him.[370]

In his diary, Olivi wrote, "13:30 Landed just as No. 2 conked. We didn't get here a moment too soon. Landing was hot (150) Thought sure we were going to take a couple of B-24's with us after landing."

Olivi later recalled the excitement:

> We hit the runway at about 140 or 150 mph, much too fast to hit the ground safely. We started to veer off to the left and, if it weren't for the fact that we had the reversible props, we would have taken out a whole slew of aircraft. They were parked away from the active runway, but they were still there. If we would have continued out of control, we would have smacked into them. Sweeney straightened it out and continued on down the runway. When we got to the first taxi strip, we turned off there to get to our hardstand and that's when the #2 engine quit.[371]

Said Sweeney, "After we got on the ground, one of the engines quit. I was so exhausted, that I just rolled it off the runway at the end and shut the other engines down. I climbed out and got some fresh air and told them to tow the plane in. I was just interested in refueling, getting the guys a meal, and getting out of there."[372]

Olivi remembered that Sweeney told everyone not to tell anybody what they did. He told them to say that they were here for a re-supply of gas and then they were going back to their home base on Tinian.

Gallagher said, "A Jeep came out to have us follow him and we went over and parked the ship off to the side. The kid in the Jeep got out and came towards the ship. As soon as he did, one of the men got out of the ship and told the kid to stay away from us. The kid couldn't understand why he couldn't come over and talk to us."

Gallagher continued, "He (Sweeney) gathered everyone around the wing. Commander Ashworth pulled out a group of maps and we all decided as to where the bomb actually went, as far as its touchdown point, and the direction of the explosion. He was the one that was going have to answer to the men from Washington when we got back to Tinian."[373] Ashworth and Sweeney then proceeded to General Jimmy Doolittle's office on Okinawa to send off a coded message describing the mission.

According to Ashworth:

> I needed urgently to send a message to General Farrell and Captain Parsons on Tinian to clarify the incomplete coded strike report that I had composed and was transmitted from the aircraft after the attack. I was told at the communications center that they were too busy to send my message. Whereupon I asked to be directed to General Doolittle's office. This was a double pyramidal tent. I knocked on the door and was invited in by General Partridge, Doolittle's chief of staff. I told him we had just dropped the second atom bomb on Nagasaki and of my need to communicate with Tinian, but he told me that I should talk to General Doolittle first. I went into his half of the tent, laid out our target maps, showed him where the designated aiming point was in the urban area of the city, and where we concluded the bomb actually hit. After studying the maps for a moment he said, 'General Spaatz will be much happier that the bomb went off over the industrial part of the city. There will be far fewer casualties.' With that he called the communications center and told them to send my message.[374]

Co-Pilot Charles Albury later described his feelings about the mission:

> At 24 years of age, I was not a great religious man. I did pray to God that each mission meant it would be the end of the war and we could return to be with our loved ones...I didn't have any lucky charms or things like that, but I did have God with me every step of the way and I'm thankful. I know God was with us on the Nagasaki mission, because He brought us in safely to Okinawa with no fuel left and one engine that quit on the runway.[375]

After some chow and refueling, they left Okinawa at 5:30 PM and headed out for the six-hour flight back to Tinian. Olivi wrote, "Hoppy and Bock are here too -- orders from base -- guess they want us all together. Can't say much for Okinawa -- mud -- heat -- and wrecked planes both ours and the Japs. Going to have some chow, while we gas up." After eating, he added, "Ate SPAM as I expected but it tasted good at that."

When they landed at 10:30 PM, they were exhausted having been in the air some 16 hours. Unlike the first mission, there were no cheering crowds to greet them, no hoopla, no cameras, no medals, no beer, and no hot food. The Hiroshima mission had received all the attention. This was typical, since nobody ever pays attention to a second "anything." Much like the unfortunate, forgotten occupants of Nagasaki, they were ignored. The crew scrounged some food, were debriefed, and crawled into bed.

Because of the last-minute switch in planes before takeoff, the wrong plane (*The Great Artiste*) was credited in press releases with dropping the bomb. This error occurred because the switch took place in the dark. The science writer, William Laurence, thought he was in *Bockscar* because Capt. Fred Bock and his crew were flying it. He wrote this in his book Dawn Over Zero. This mistake was not corrected for years. To add insult to injury, it even appeared in the official 509th Pictorial Album published in 1946.

Considering all of the problems, however, the mission was still considered a tremendous success. General Farrell referred to it as, "a supremely tough job carried out with determination, sound judgment and great skill. It is fortunate for the success of the mission that its leaders, Ashworth and the pilot Sweeney were men of stamina and stout heart. Weaker men could not have done this job."[376]

In his 1995 congressional testimony, *Bockscar* commander Charles Sweeney eloquently summed up his feelings about the mission by declaring:

> The world is a better place because German and Japanese fascism failed to conquer. Japan and Germany are better places because we were benevolent in our victory. The youth of Japan and the United States, spared from further needless slaughter, went on to live and have families and grow old. Today millions of people in America and Japan are alive because we ended the war when we did. This is not to celebrate the use of atomic weapons. Quite the contrary. It is my fervent hope that my mission is the last such mission ever flown. But that does not mean that back in 1945, given the events of war and the recalcitrance of the enemy, President Truman was not obliged to use all of the weapons at his disposal to end the war.[377]

They had been over enemy territory *longer than any plane in World War II* and had overcome almost insurmountable odds to bring success to a project that turned out to be the shortest time between development and combat use of any munition in the history of modern warfare! It is not that things went wrong on the second mission, but that so much went right on the first. *Enola Gay* Electronics Test Officer Morris Jeppson concurred. Thinking back on the number of things that could have gone wrong on the first mission, he stated, "It was very frightful. This (Hiroshima) was a very lucky mission!"[378]

At the same time the bomb was being dropped on Nagasaki, Russia declared war on Japan and sent troops into Manchuria. Admiral Halsey's Third Fleet, after nine days of silence, attacked the home island of Honshu with strong air attacks against scores of airfields. Despite all of this, the Japanese military still did not want to surrender. Their cabinet was evenly split between those who wanted to surrender and those who did not. While this internal power struggle was going on, the Allies stepped up the pressure and authorized additional conventional bombing raids to help convince the Japanese it was time to surrender.

On August 14, the largest bombing raid of World War II was carried out. A total of 1,014 bombers and fighter escorts were dispatched. This included seven planes from the 509th. The planes from the 509th each carried one "pumpkin." One of these B-29's, flown by Capt. Fred Bock, dropped what some believe to be the last bomb of World War II. It landed on the Toyota factory in Koromo, a suburb of Nagoya. The bomb, according to the chairman of Toyota, fell right on the money.[379]

On the way back from this mission, the crews heard President Truman announcing over their radios that Japan had surrendered unconditionally. World War II was finally over!

Tinian Pit Team member Mort Camac recalled a visitor they had on Tinian. "After the war was over, Admiral Nimitz visited our laboratory. We described what we did and that the explosion was equal to 20,000 tons of dynamite. He said 'you might believe it, but I don't' and he walked out."[380]

Six months after the end of the war, the military felt they needed to know more about the atomic bomb. Operation CROSSROADS would provide them with much needed information. This project would take place at Bikini atoll in the Pacific.

Of the two bomb designs, the Y-1561 *Fat Man* implosion device seemed to hold the most promise. Two tests, ABLE and BAKER, were scheduled to take place. ABLE would use a *Fat Man* dropped from the air. BAKER would use one exploded underwater. The *Fat Man* that was to be dropped during ABLE was painted pumpkin with black stripes. The name *Gilda* was written on the side of the bomb. It was named after a role that Rita Hayworth played in a popular movie. A picture of her was reportedly painted on the side.[381]

This bomb was dropped on the Bikini atoll on July 1, 1946, from a B-29 flown by Major Woodrow P. Swancutt. It was named *Dave's Dream,* after the Bombardier Capt. David Semple who was killed March 7, 1946, when a B-29 crashed in New Mexico during the competition to select the crews for this mission. Capt. Semple had wanted more than anything in the world to be able to drop an atomic bomb in combat. Phil Barnes wrote, "David Semple simply did someone a favor to fly with this crew when he replaced the individual who could not make the flight. Dave was one hellava guy! When I flew with his test crew, we didn't need a Navigator on the flight for Dave knew the West like the palm of his hand."[382]

This Y-1561 *Fat Man* exploded at 8:49:45 AM at an altitude of 518' over the lagoon and missed its target, the battleship USS *Nevada,* by 2,130'. The third *Fat Man* was used during the BAKER test. The bomb, nicknamed *Helen of Bikini*,[383] was exploded at 8:35 AM on July 25, 1946. According to Robert Henderson, this unit, minus the tail fin assembly, was enclosed in a steel "caisson fabricated from a submarine conning tower 'pressure vessel' with one hemispherical head removed and flanged to permit rolling the bomb in on a wheeled cradle."[384] This was positioned 90' below the emplacement ship *LSM-60* and between the battleship USS *Arkansas* and the aircraft carrier USS *Saratoga.* The explosion sent 2,000,000 tons of water and sediment more than a mile into the sky. Both CROSSROADS weapons had yields of approximately 23 Kilotons.[385]

Over 90 target ships had been anchored in the lagoon during the CROSSROADS tests and 13 of these were sunk. One of the ships sent to the bottom was the last surviving Japanese battleship, the *Nagato.* In 1941, it served as the flagship for Admiral Isoroku Yamamoto while directing the attack on Pearl Harbor. It was while he was on the bridge of this ship anchored in Hashirajima Bay that he heard the radio transmission, from one of his pilots, of the famous words "Tora, Tora, Tora!" The *Nagato* was one of the first battleships to be equipped with 16" guns. Some naval historians think that one of these large shells, modified to be dropped as a bomb, was responsible for the sinking of the USS *Arizona* at Pearl Harbor.[386]

After the war, programs were started to manufacture both *Little Boy* and *Fat Man* bombs. As Gunnar Thornton recalled:

> The assumption was that there was not going to be another gun-bomb, so there was a big book burning campaign right after the war. One of the things it did was keep a lot of people busy...it just broke my heart to burn all that stuff...I couldn't even find a set of drawings for *Little Boy...* the people at Sandia managed to get a hold of a set of drawings and they made six units.[387]

As Thornton indicated, because it was such an inefficient weapon, only a relative handful of *Little Boy* gun-bombs were made as backup for the meager US postwar implosion weapons stockpile. Harlow Russ became Group Leader (9/46-3/48) of the Z-11 Special Weapons Division at Sandia National Laboratory (SNL) in Albuquerque, which was charged with manufacturing and stockpiling *Little Boy.* Although bomb casings, barrels, and interior components were built and tested, the DOE claims no *Little Boy* HEU cores were ever actually stockpiled.

The wartime Y-1561 *Fat Man* was considered a "Rube Goldberg" affair. Sandia re-engineered it into something that could be manufactured and assembled on a production-line basis for stockpile and it became known as the Mark III. However, since Sandia kept modernizing components and systems, the Mark III underwent major redesign and eventually evolved into the Mark 4.

The color of the postwar *Little Boy* and *Fat Man* stockpile production units was a semi-matte dark olive/khaki green. The LB casing on display in the Air Force Museum at Wright-Patterson AFB in Dayton and The National Museum of Nuclear Science and History in Albuquerque, NM, are painted this color. The green color of the *Little Boy* casing on display in the Smithsonian Institution National Air and Space Museum in Washington corresponds to FS 24097.[388] The color of the actual L-11 *Little Boy* combat unit was most likely a semi-matte olive-drab primer.[389] Morris Jeppson stated later, "It was gray or dull green."[390] The *Little Boy* units on display at the Imperial War Museum in London and the Washington, DC Navy Yard are most likely painted the same as the L-11. The *Fat Man* casings on display in places like the USAF Armament Museum at Eglin AFB in Crestview, FL and the Pantex Company in Amarillo, TX are painted glossy white. This is because they were, at times, displayed outside in the hot sun. The *Fat Man* casings on display at the EAA Air Museum in Oshkosh, Wisconsin, Wright-Patterson AFB in Dayton, and at The National Museum of Nuclear Science and History in Albuquerque, NM, are painted a pumpkin color. The F-31 combat unit was painted with zinc chromate flat primer. These also have sealant coats and numbers so that they resemble test units dropped at Wendover.

Improvements in HE, tampers, fissile materials, and neutron sources (initiators) meant that experiments had to be undertaken to determine proper critical assembly configurations for postwar weapon designs. Shortly after the war ended, Los Alamos scientists used a Y-1561 Dural sphere in an assembly called the Bomb Mockup, to test near-critical implosion assemblies. The empty Dural sphere was bolted together, sliced in half through the waist sections, and filled with mock HE. It was bolted to an experimental stand, which was capable of separating the upper and lower halves mechanically. A near-critical core could be placed inside and the upper half of the sphere lowered as the scientists monitored the neutron count from a safe distance. "The process was repeated with increasing masses of fissile material until extrapolation to criticality was acceptable."[391] The Bomb Mockup was the first in a long series of remotely controlled critical-assembly machines produced by the scientists for neutron-multiplication experiments.

Because the *Little Boy* design was unique and never tested before it was used at Hiroshima, the bomb yield and neutron output were never measured. Several attempts have been made over the years to correct this problem. Los Alamos scientists created a spherical mockup of *Little Boy* in 1962. Known as *Ichiban*, it failed to adequately answer important health physics questions about the output of the Hiroshima bomb.

In a further attempt to clear up some of these problems, scientists at Los Alamos replicated a *Little Boy* in 1982. They used many original stockpiled non-nuclear components from three *Little Boy* training units uncovered earlier at Los Alamos in May 1981. The nuclear components were manufactured using original bomb drawings and specifications. Installed vertically in the Comet Assembly Machine at Los Alamos, this mockup was run as a delayed-critical reactor in an effort to study the neutron output of the original *Little Boy* design. Only the forward portion of the original device was utilized. This included a shortened barrel, target case adapter, target case, tamper, dummy initiators, and U-235 fissile material. The amount of uranium "was reduced to a point where the critical system could be safely operated as a low-power steady-state reactor."[392] Instead of using a cordite charge, the projectile was carefully inserted upward into the target by means of a linear actuator comprised of both a hydraulic lift and precision screw mechanism. Safety devices in place made it absolutely impossible for a nuclear explosion to occur. Health physics scientists from all over the US came to Los Alamos to run experiments with the mockup. Data from these experiments was used in an effort to help resolve questions of both the *Little Boy* yield and the neutron exposure to the residents of Hiroshima when the bomb exploded over their city in 1945.

The Y-1561 design was employed at Trinity, Nagasaki, the two CROSSROADS tests, and then never utilized again. The *Little Boy* design was used only one time at Hiroshima. At least six of these were manufactured and stockpiled as a postwar backup to the more complex MK III *Fat Man*. However, because it ultimately proved to be the better design, approximately 120 of the MK III bombs were manufactured and stockpiled between 1947 and 1949.[393] These, along with all of the *Little Boy* units, were withdrawn from the stockpile by the end of 1950. Of the two types of weapons, the implosion fission bomb design prevailed until the development of the hydrogen bomb almost a decade after the end of World War II.

Appendices

Project Alberta Tinian Team Members[394]

Officer-in-Charge	Captain William S. Parsons USN
Scientific and Technical Deputy	Norman F. Ramsey
Operations Officer and Military Alternate	Cdr. Frederick L. Ashworth USN
Fat Man Assembly Team	Roger S. Warner
Little Boy Assembly Team	Lt. Cdr. A. Francis Birch USN
Fuzing Team	Edward B. Doll
Electrical Detonator/Firing Team	Lt. Cdr. Edward Stevenson USNR
Pit Team	Philip Morrison Charles P. Baker
Yield Measurement Team	Luis W. Alvarez
Aircraft Ordnance Team	Sheldon Dike
Special Consultants	Robert Serber William G. Penney Capt. James F. Nolan

Team Members: Harold Agnew, Ensign David L. Anderson USNR, T/Sgt. Benjamin B. Bederson, Thomas H. Bolsatd, T/Sgt. Ray Brin, T/Sgt. Vincent Caleca, Morton Camac, T/Sgt. Edward G. Carlson, Tech Arthur W. Collins, T/Sgt. Robert W. Dawson, T/Sgt. Frank J. Fortine, Tech Walter Goodman, Tech Donald C. Harms, Lt. John D. Hopper, Lawrence H. Johnston, T/Sgt. Jesse Kupferburg, Lawrence Langer, T/Sgt. William J. Larkin, Henry Linschitz, Arthur B. Machen, Ensign Donald Mastick USNR, Tech Robert P. Matthews, Lt. Victor A. Miller USNR, Tech Leonard Motichko, T/Sgt. William L. Murphy, T/Sgt. Eugene L. Nooker, Thomas H. Olmstead, Ensign Bernard J. O'Keefe USNR, Theodore Perlman, Ensign W.R. Prohs USNR, Ensign George T. Reynolds USNR, Harlow W. Russ, Raemer E. Schreiber, T/Sgt. Gunnar Thornton, Ensign John L. Tucker USNR, Bernard Waldman, Tech Frederick H. Zimmerli.

Assigned Aircraft
393rd Bombardment Squadron (VH)
509th Composite Group
313th Bombardment Wing
Twentieth Air Force
United States Army Air Forces
Tinian Island North Field-July/August, 1945[395]

B-29 Aircraft Serial Number	Victor No.	Aircraft Name	Crew. No.	Aircraft Commander
35-MO-44-27296	84	*Some Punkins*	B-7	James N. Price
35-MO-44-27297	77	*Bockscar*	C-13	Frederick C. Bock
35-MO-44-27298	83	*Full House*	A-1	Ralph R. Taylor
35-MO-44-27299	86	*Next Objective*	A-3	Ralph N. Devore
35-MO-44-27300	73	*Strange Cargo*	A-4	Joseph E. Westover
35-MO-44-27301	85	*Straight Flush*	C-11	Claude R. Eatherly
35-MO-44-27302	72	*Top Secret*	B-8	Charles F. McKnight
35-MO-44-27303	71	*Jabit III*	B-6	John A. Wilson
35-MO-44-27304	88	*Up an' Atom*	B-10	George W. Marquardt
40-MO-44-27353	89	*The Great Artiste*	C-15	Charles D. Albury
40-MO-44-27354	90	*Big Stink*	C-12	Herman S. Zahn
45-MO-44-86291	91	*Necessary Evil*	C-14	Norman W. Ray
45-MO-44-86292	82	*Enola Gay*	B-9	Robert A. Lewis
50-MO-44-86346	94	*Spook*	A-5	Elbert B. Smith
50-MO-44-86347	95	*Laggin' Dragon*	A-2	Edward M. Costello

1. The crew/aircraft combination shown above was the standard arrangement. Variations often occurred.
2. V-82 (*Enola Gay*) is in the Smithsonian Institution National Air and Space Museum.
3. V-77 (*Bockscar*) is in the United States Air Force Museum, Wright-Patterson Air Force Base, near Dayton, Ohio.
4. V-90 was renamed *Dave's Dream* after the war.
5. V-94 was given the name *Spook* after the war.
6. Thomas J. Classen, the 509th Deputy CO, was the original aircraft Cdr. on V-94.

Special Bombing Missions to Japan
509th Composite Group
July-August, 1945[396]

Mission Number	Date	Number of Aircraft	Target	Bombs
1	July 20	3	Koriyama	Pumpkins
2	July 20	2	Fukushima	Pumpkins
3	July 20	2	Nagaoka	Pumpkins
4	July 20	3	Toyama	Pumpkins
5	July 24	3	Sumitomo	Pumpkins
6	July 24	4	Kobe	Pumpkins
7	July 24	3	Yokkaichi	Pumpkins
8	July 26	4	Nagaoka	Pumpkins
9	July 26	6	Toyama	Pumpkins
10	July 29	3	Ube	Pumpkins
11	July 29	3	Koriyama	Pumpkins
12	July 29	2	Yokkaichi	Pumpkins
13	Aug 6	7	Hiroshima	*Little Boy*
14	Aug 8	3	Osaka	Pumpkins
15	Aug 8	3	Yokkaichi	Pumpkins
16	Aug 9	6	Nagasaki	*Fat Man*
17	Aug 14	4	Nagoya	Pumpkins
18	Aug 14	3	Koroma	Pumpkins

B-29 Planes and Crews
Hiroshima
August 6, 1945
Mission #13
Operation CENTERBOARD I[397]

Enola Gay, 45-MO-44-86292, V-82, Strike Aircraft

Commander	Col. Paul W. Tibbets
Co-Pilot	Capt. Robert A. Lewis
Navigator	Capt. Theodore J. Van Kirk
Bombardier	Maj. Thomas W. Ferebee
Weaponeer	Capt. William S. Parsons USN
Electronics Test Ofc.	2nd Lt. Morris R. Jeppson
ECM	1st Lt. Jacob Beser
Flight Engineer	S/Sgt. Wyatt E. Duzenbury
Ast. Flight Engineer	Sgt. Robert H. Shumard
Radar	Sgt. Joseph A. Stiborik
Radio	Pfc. Richard H. Nelson
Tail Gunner	S/Sgt. George R. Caron

The Great Artiste, 40-MO-44-27353, V-89, Instrument Aircraft

Commander	Maj. Charles W. Sweeney
Co-Pilot	1st Lt. Charles D. Albury
Navigator	Capt. James F. Van Pelt, Jr.
Bombardier	Capt. Kermit K. Beahan
Flight Engineer	M/Sgt. John D. Kuharek
Ast. Flight Engineer	Sgt. Raymond G. Gallagher
Radio	Sgt. Abe M. Spitzer
Radar	S/Sgt. Edward R. Buckley
Tail Gunner	Sgt. Albert T. DeHart
Yield Measurement	Luis W. Alvarez
	Harold M. Agnew
	Lawrence H. Johnston

Necessary Evil, 45-MO-44-86291, V-91, Photo Aircraft

Commander	Capt. George W. Marquardt
Co-Pilot	2nd Lt. James M. Anderson
Navigator	2nd Lt. Russell Gackenbach
Bombardier	Capt. James W. Strudwick
Flight Engineer	T/Sgt. James R. Corliss
Ast. Flight Engineer	Sgt. Anthony D. Capua
Radio	Sgt. Warren Coble
Radar	Sgt. Joseph M. DiJulio
Tail Gunner	Sgt. Melvin H. Bierman
Scientists/Observers	Bernard Waldman

Straight Flush, 35-MO-44-27301, V-85, Hiroshima Weather Plane

Commander	Maj. Claude R. Eatherly
Co-Pilot	2nd Lt. Ira J. Weatherly
Navigator	Capt. Francis D. Thornhill
Bombardier	Lt. Franklin K. Wey
Flight Engineer	2nd Lt. Thomas Grennan
Ast. Flight Engineer	Sgt. Jack Bivans
Radio	S/Sgt. Pasquale Baldasaro
Radar	Sgt. Albert Barsumian
Tail Gunner	Sgt. Gillon T. Niceley

Full House, 35-MO-44-27298, V-83, Nagasaki Weather Plane

Commander	Maj. Ralph R. Taylor, Jr.
Co-Pilot	2nd Lt. Raymond P. Biel
Navigator	1st Lt. Fred A. Hoey
Bombardier	1st Lt. Michael Angelich
Flight Engineer	M/Sgt. Frank M. Briese
Ast. Flight Engineer	Cpl. Richard B. Anselme
Radio	S/Sgt. Theodore M. Slife
Radar	Cpl. Natheniel T.R. Burgwyn
Tail Gunner	T/Sgt. Robert J. Valley

Jabit III, 35-MO-44-27303, V-71, Kokura Weather Plane

Commander	Maj. John A. Wilson
Co-Pilot	2nd Lt. Ellsworth T. Carrington
Navigator	2nd Lt. James S. Duva
Bombardier	2nd Lt. Paul W. Gruning
Flight Engineer	M/Sgt. James W. Davis
Ast. Flight Engineer	Cpl. Donald L. Rowe
Radio	S/Sgt. Glen H. Floweree
Radar	Sgt. Vernon J. Rowley
Tail Gunner	Cpl. Chester A. Rogalski

Big Stink, 40-MO-44-27354, V-90, Standby Plane to Iwo Jima

Commander	Capt. Charles F. McKnight
Co-Pilot	2nd Lt. Jacob Y. Bontekoe
Navigator	2nd Lt. Jack Widowsky
Bombardier	2nd Lt. Franklin MacGregor
Flight Engineer	1st Lt. George H. Cohen
Ast. Flight Engineer	Cpl. Donald O. Cole
Radio	Sgt. Lloyd J. Reeder
Radar	T/Sgt. William F. Orren, Jr.
Tail Gunner	Sgt. Roderick E. Legg

B-29 Planes and Crews
Nagasaki
August 9, 1945
Mission #16
Operation CENTERBOARD II

Bockscar, 35-MO-44-27297, V-77, Strike Aircraft

Commander	Maj. Charles W. Sweeney
Co-Pilot	1st Lt. Charles D. Albury
3rd Pilot	2nd Lt. Fred J. Olivi
Navigator	Capt. James F. Van Pelt, Jr.
Bombardier	Capt. Kermit K. Beahan
Weaponeer	Cdr. Frederick L. Ashworth USN
Electronics Test Ofc.	Lt. Philip M. Barnes
ECM	Lt. Jacob Beser
Flight Engineer	M/Sgt. John D. Kuharek
Ast. Flight Engineer	Sgt. Raymond G. Gallagher
Radio	Sgt. Abe M. Spitzer
Radar	S/Sgt. Edward R. Buckley
Tail Gunner	Sgt. Albert T. DeHart

The Great Artiste, 40-MO-44-27353, V-89, Instrument Aircraft

Commander	Capt. Frederick C. Bock
Co-Pilot	2nd Lt. Hugh C. Ferguson
Navigator	2nd Lt. Leonard A. Godfrey
Bombardier	1st Lt. Charles Levy
Flight Engineer	M/Sgt. Roderick F. Arnold
Ast. Flight Engineer	Sgt. Ralph D. Belanger
Radio	Sgt. Ralph D. Curry
Radar	Sgt. William C. Barney
Tail Gunner	Sgt. Robert J. Stock
Yield Measurement	Walter Goodman
	Lawrence Johnston
Journalist	William Laurence

Big Stink, 40-MO-44-27254, V-90, Photo Aircraft

Commander	Maj. James I. Hopkins, Jr.
Co-Pilot	2nd Lt. John E. Cantlon
Navigator	2nd Lt. Stanley G. Steinke
Bombardier	2nd Lt. Myron Faryna
Flight Engineer	M/Sgt. George L. Brabenec
Ast. Flight Engineer	Sgt. Thomas A. Bunting
Radio	Sgt. Francis X. Dolan
Radar	Cpl. Richard F, Cannon
Tail Gunner	Sgt. Martin G. Murray
Scientists/Observers	William G. Penney
	Group Capt. G. Leonard Cheshire RAF

Enola Gay, 45-MO-44-86292, V-82, Kokura Weather Plane

Commander	Capt. George W. Marquardt
Co-Pilot	2nd Lt. James M. Anderson
Navigator	2nd Lt. Russell Gackenbach
Bombardier	Capt. James R. Strudwick
Flight Engineer	T/Sgt. James R. Corliss
Ast. Flight Engineer	Sgt. Anthony D. Capua
Radio	Sgt. Warren Coble
Radar	Sgt. Joseph M. DiJulio
Tail Gunner	Sgt. Melvin H. Bierman

Laggin' Dragon, 50-MO-44-86347, V-95, Nagasaki Weather Plane

Commander	Capt. Charles F. McKnight
Co-Pilot	2nd Lt. Jacob Y. Bontekoe
Navigator	2nd Lt. Jack Widowsky
Bombardier	2nd Lt. Franklin MacGregor
Flight Engineer	1st Lt. George H. Cohen
Ast. Flight Engineer	Cpl. Donald O. Cole
Radio	Sgt. Lloyd J. Reeder
Radar	T/Sgt. William F. Orren, Jr.
Tail Gunner	Sgt. Roderick E. Legg

Full House, 35-MO-44-27298, V-83, Standby Plane to Iwo Jima

Commander	Maj. Ralph R. Taylor, Jr.
Co-Pilot	2nd Lt. Raymond P. Biel
Navigator	1st Lt. Fred A. Hoey
Bombardier	1st Lt. Michael Angelich
Flight Engineer	M/Sgt. Frank M. Briese
Ast. Flight Engineer	Cpl. Richard B. Anselme
Radio	S/Sgt. Theodore M. Slife
Radar	Cpl. Nathaniel T.R. Burgwyn
Tail Gunner	T/Sgt. Robert J. Valley
Yield Measurement	Jesse Kupferberg

B-29 Plane and Crew
Bikini Atoll
July 1, 1946
ABLE Test
Operation CROSSROADS

Dave's Dream, 40-MO-44-27354, V-7354, Strike Aircraft

Commander	Maj. Woodrow P. Swancutt
Co-Pilot	Capt. William C. Harrison, Jr.
Bombardier	Maj. Harold H. Wood
Bomb Commander	Col. Jack R. Sutherland
Weaponeer	Ensign David L. Anderson USNR
Weaponeer	Leon D. Smith
Flight Engineer	1st Lt. Robert M. Glenn
Radio	T/Sgt. Jack W. Cothran
Radar	Capt. Paul Chenchar, Jr.
Left Scanner	Cpl. Herbert B. Lyons
Right Scanner	Cpl. Roland M. Medlin
Observers	Gen. Roger M. Ramey
	Col. William J. Blanchard

Little Boy and Fat Man
Test and Combat Units[398]

<u>L-1</u> - 1 each – LB Assembly Y-1792, less Projectile, Brode's equipment, powder and detonators
1 each – Projectile for LB Y-1792 Assembly
4 each – Archies, No.s 5329, 9763, 5622, and 6550
1 Box – Contents of box as follows:

- 1 each Clock Box
- 1 each Informer battery box
- 4 each Archies battery box
- 4 each Archie Antenna
- 6 each Baro(metric) switches
- 1 each Cable kit
- 1 each Junction box for 9L2
- 1 Hardware kit
- 1 each Safety kit
- 1 each Hardware kit (spare)
- 4 each Informers

1 Box – Contents as follows:

- 25 NT-6 Batteries
- 10 BA-51 Batteries
- 9 Bottles of electrolyte

1 each – BuOrd M7 Powder Can (8 charges)
1 each – BuOrd Mk15, Mod 1 primers (24 each)

<u>L-2</u> - Same as L-1 except with Clock wiring material and no powder or Primers

<u>L-3</u> - LB Assembly Y-1491, complete with tail. (Note: Brode's equipment, Projectiles, primers, and powder not required for this assembly)

<u>L-4</u> - Same as L-3

<u>L-5</u> - LB Assembly Y-1792, less projectile, Brode's equipment, etc. Case, Anvil, Plug, Pad Assembly, Container Assembly, Plate, Cover, Anchor Ring, Spacer Rod, Tail Assembly, Top Door, Side Door, Bulkhead Assembly, 6.5" Dummy Gun consisting of:

- 1 Barrel
- 1 Breech
- 1 Breech Plug Assembly containing 1 Primer Housing, 1 Contact Pin Assembly, 1 AN-3102-20AN receptacle and cap

1 – 150 pound Projectile, 4 Archies, 1 Clock Box, 4 Battery racks, 4 Baro switches, 4 Informers, 1 Informer battery box, 1 cable kit, 1 hardware kit, 1 safety kit, 1 battery kit, 24 batteries, 1 powder can with 4 – 2 pound charges of Cordite, 2 safety kits

L-6 - Same as L-5

This was a "live" unit. It contained everything except the fissile material. It was used to check the assembly, loading, flight, and drop test. It was flown to Iwo Jima on July 29, unloaded and reloaded on the same B-29 and then flown back to Tinian where it was unloaded and inspected. This was repeated on July 31, except it was reloaded into a different B-29 and flown back to Tinian where it was drop tested. The test was considered a success and the OK was given to prepare the L-11 unit for its use in combat

L-7 - Same as L-5. "Live" unit

L-8 - Same as L-7

L-11- This was the combat unit that was dropped on Hiroshima.

F-1 – Assembly of Ellipsoids and Spheres as follows:

1 each – Polar Cap, 72 hole system, front, drilled for impact fuses
1 each – Polar Cap, rear, undrilled for impact fuses
1 each – Top Zone Segment, Sphere for 72 hole booster sphere
1 each - Middle Segment, Sphere for 72 hole booster sphere
1 each – Middle Segment, Sphere for 72 hole booster sphere
1 each – Lower Segment, Sphere for 72 hole booster sphere
1 each – Lower Segment, Sphere for 72 hole booster sphere
1 each – Ellipsoid, rear, mild steel, modified for manifolds
1 each – Ellipsoid, front, mild steel, modified for impact fuses
1 each – Nose Piece, mild steel with ring, nose mounting part No. Y-1291-28
1 each – Cone, mounting, 8 hole, Aluminum
1 each – "C" plate, modified with center hole and "A" frame less Brode's equipment
1 each – Lug, steel, 4340
    1 set – Tubing, Manifold, above equipped with necessary hardware. No spacer rings included or required for Nose Piece and Forward Mounting plate
1 each – Raytheon unit, dummy
1 each – Lug, bronze insert, alternate
1 each – Tail Assembly, composed of the following:
- "D" plate
- "E" plate and necessary hardware

1 each – Pit (male), 24.5" dia. C.I. (Cast Iron) with following
- 1 set spacers, cork, ½" MK No. 1, for 72 hole boosters

1 each – Pit (female) 24.5" dia. C.I.
1 set - Blocks, Mk I, concrete, for 72 hole booster system. Set composed of 12 regular Pentagonal and 60 irregular

Pentagonal as follows: Box 65/65 – 8 Irregular Pentagonal blocks
Boxes 1 to 12 – 1 Regular per box
Boxes 13 to 64 – Irregular per box

1 box – 4 each Archies, No.s 5673, 5637, 5675 and 5676

1 box – Contents of box:

- 1 each Clock Box
- 1 each Informer battery box
- 1 each Archie battery box
- 4 each Informers
- 6 each Baro(metric) switches
- 4 each Archie antenna
- 1 each Hardware kit
- 1 each Safety kit
- 1 each Hardware kit (spare)
- 2x1 Roll safety wire
- 1 Cable kit
- 1 box, contents of box:
    - 35 batteries
    - 10 batteries
    - 12 bottles of electrolyte

<u>F-2</u> - Same as above except "E" plate had Puff tubes

<u>F-3</u> - Same as above, but rear Ellipsoid was not modified for manifolds

<u>F-4</u> - Same as F-3

<u>F-5</u> - Assembly of Ellipsoids and Spheres as follows:

1 each – Polar Cap, front, 32 hole, 2", drilled for impact fuses with coaxial cable retainer clips

1 each – Polar Cap, rear, 32 hole, 2", undrilled for impact fuses with coaxial cable clips

1 each – Top Zone Segment, 32 hole, 2", with coaxial cable retainer clips

1 each – Middle Segment, 32 hole, 2", with coaxial cable retainer clips

1 each – Middle Segment, 32 hole, 2", with coaxial cable retainer clips

1 each – Lower Segment, 32 hole, 2", with coaxial cable retainer clips

1 each - Lower Segment, 32 hole, 2", with coaxial cable retainer clips

1 each – Ellipsoid, rear, mild steel, completely modified for spray sealing with ring, nose mounting, Part No. Y-1291-28

1 each – Ellipsoid, front, mild steel, completely modified for spray sealing and tubes for impact fuses

1 each – Nose Piece, mild steel with spacer rings, Part No. Y-1910

2 each – Cone, Mounting (1-10-hole front and 1-8 hole rear),
1 each – "C" plate, modified with center hole and "A" frame less Brode's equipment, with spacer ring, Part No. Y-1560-
140

1 each – Lug steel, 4340
1 each – Lug, bronze, insert, as alternate
1 each – Ring, manifold
1 set - Tubing, manifold
1 set - Channel guides, above unit equipped with necessary hardware
3x1 each - Pit (male) 18.5" dia. C.I.
3x1 each - Pit (female) 18.5" dia. C.I.
(Felt, Mk No.3 ¼" for each 32 holes booster system complete with each pit)
1 box – 4 each Archies, No.s 5620, 9716, 5639
1 box – Contents of box:

- 1 each Clock Box
- 1 each Archie battery box
- 1 each Informer box
- 4 Archie Antenna
- 4 each Informers
- 6 Baro(metric) switches
- 1 each Hardware kit
- 1 each Hardware kit
- 2 Delay relay

1 box – Contents as follows:

- 35 each NT-6 Batteries
- 10 each BA-51 Batteries
- 12 each bottles of electrolyte

1 each – "X-unit" with following included:

- 69 Coaxial cables and connectors

1 each – "A" plate with following included:

- cables and connectors

16 each – Castings, H.E., Irregular Pentagons, 72 booster hole type for use in a 32 booster hole type Sphere. (No 32 hole HE castings available)
16 each – Castings, HE. , Irregular Pentagons, 72 booster hole type for use in 32 hole type Sphere. (No 32 hole HE castings available)
16 each – as follows:

- 14 each castings, HE, Regular Pentagons, 72 hole type for use in a 32 booster hole type Sphere. (No 32 hole HE castings available)

- 2 each Castings, HE, Irregular Pentagons, 72 hole type for use in a 32 booster hole type Sphere. (No 32 hole HE castings available)

16 each – Castings, HE, Irregular Pentagons, 72 booster hole type for use in a 32 booster hole type Sphere. (No 32 hole HE castings available)

16 each – Castings, HE, Irregular Pentagons, 72 booster hole type for use in a 32 booster hole type Sphere. (No 32 hole HE castings available)

F-6 - Same as F-3 and also included the following:

16 each – Castings, concrete, Inner Pentagons, for 32 booster hole Sphere

2 each – Castings, concrete, Inner Hexagons, for 32 booster hole Sphere

16 each – Castings, concrete, Outer Pentagons, for 32 booster hole Sphere

2 each – Castings, concrete, Outer Pentagons, for 32 booster hole Sphere

F-7 - Same as F-5, except that Tail Assembly was modified to 59" overall width with rubbing strip, concrete regular and irregular charges and 24.5" steel Pit

F-8 - Same as F-5, except with the Mk III version of HE castings in concrete

F-9 - Same as F-8

F-10- Same as F-8, except with Comp "B" charges

F11- Same as F-10

F-12- Same as F-10, except with the coaxial cable retainers on Sphere case, lifting lugs clevis attached to "C" plate, 18.5" dia., 2 Pits, one of steel and one of aluminum, "A" plate with attached pump, inverter, and battery box, Blake switches, Blake cables, Mk II CF cables, Pumps, Zenith Mk 24 Inverter, etc.

F-13- Same as F-12, except with dummy concrete ballast on "A" plate This contained an inert plaster HE mockup, steel pit, eight live detonators, a full set of fuzing components, an X-unit Mod 2, inert A.N. 219-2 nose fuzes, informers to test the simultaneity of the detonators, and a pyrotechnic smoke device to show if the fuzes worked. This was also the first test of the sealant coating procedure. The drop test was considered a success.

F-18- This was identical to the F-13 unit, except for a different adjustment to the barometric (baro) switches. This drop test was unsuccessful.

F-31- Y-1561 with 0-3 fuses and 0-3 informers, puff tubes on "E" plate, X-unit accessories, provided with MK III m-1, H.E. and aluminum pit sent by a trap door assembly loaded at Y. Armor ellipsoids and armor nose piece.

This was the combat unit that was dropped on Nagasaki.

F-32- Y-1560 similar to F-31 except that the H.E. will be shipped in boxes.

F-33- Y-1561 provided with McAlester H.E., dummy "A", "C" and "E" plates for impact fusing only. Unit will have steel pit and armor ellipsoids. This was a full-function "live" unit. It contained an inert pit with mockup components, live HE, live detonators, live nose fuzes, complete fuzing, firing and radio informer systems. It was used in a full-function dry run to check the assembly, loading, flight, and drop test. It was the final practice before the combat mission. This test was also used to check if one person could handle both fuzing and firing circuits. This drop was a success.

F-34- Y-1561 with McAlester H.E., 0-3 fusing and 0-3 informers, steel pit and X-unit accessories.

F-35 thru F-39- Y-1561's with MK III plaster blocks plus steel pits assembled into spheres at W-47. Each unit will have 32 Blake switches, X-unit accessories, 0-3 fuses, Blake/Brode informers and smoke puffs

F-40- A complete set of structural parts as spare equipment of modifications on units previously sent.

Many of the items on this list were spares shipped to Tinian as part of the so-called "Bowery Shipments" and specially earmarked for each individual test unit.

1945 Timetable

March 9	325 B-29's drop 4,500,000 lbs. of incendiaries on Tokyo, destroy 267,171 buildings, kill somewhere between 83,000 and 200,000. Highest single day death toll of W.W.II.
July 1	554 B-29's drop incendiaries and mines on Ube, Kure, Shimonoseki, and Kumamoto.
July 3	L-11 projectile completed at Los Alamos; 586 B-29's drop incendiaries and mines on Kochi, Himeji, Takamatsu, and Tokushima.
July 6	F-31 tamper machined; 576 B-29's drop HE and incendiaries on Chiba, Akashi, Shimizu/Kofu, and Osaka.
July 9	567 B-29's drop incendiaries, HE, and mines on Sendai, Sakai, Gifu, Wakayama, and Yokkaichi.
July 12	506 B-29's drop incendiaries and HE on Kawasaki, Utsonomiya, Ichinomiya, Tsuruga, and Uwajima.
July 14	L-11 leaves Santa Fe-Albuquerque-San Francisco.
July 16	Trinity test; *Indianapolis* leaves San Francisco [0836 Pacific War Time] with major L-11 components; 466 B-29's drop incendiaries on Numazu, Oita, Kuwana, and Hiratsuka.
July 19	Pumpkin raids over Empire begin; 13 raids made covered by Operational Orders #1-12, and 14; 580 B-29's drop incendiaries, HE, and mines Fukui, Hitachi, Chosi, Okazaki, and Amagasaki.
July 23	Test unit L-1 dropped; F-31 plutonium hemispheres cast at Los Alamos; implosion bomb materials arrive at Tinian.
July 24	Test unit L-2 dropped; L-11 target inserts casting completed at Los Alamos; 570 B-29's drop incendiaries and HE on Handa and Nagoya.
July 25	Test unit L-5 dropped; L-11 targets tested at Los Alamos.
July 26	F-31 plutonium, initiator, and L-11 target inserts leave Albuquerque for Tinian on five ATC C-54 cargo planes; *Indianapolis* delivers L-11 bomb parts and projectile to Tinian; *Indianapolis* departs Tinian; 350 B-29's drop incendiaries on Matsuyama, Tokuyama, and Omuta.
July 28	F-31 plutonium and 1st L-11 target insert arrives at Tinian; three *Fat Man* pre-assembly units (F-31, F-32, F-33) leave Albuquerque for Tinian on three separate B-29's; 471 B-29's drop incendiaries and HE on Tsu, Aomoro, Ichinomiya, Ujiyamada, Uwajima, and Shimotsu.
July 29	2nd and 3rd L-11 target inserts arrive at Tinian; last pumpkin raid.
July 30	*Indianapolis* sunk; L-11 projectile, inserts, and initiators installed in combat unit.
July 31	Test unit L-6 dropped; L-11 completed; test unit F-13 completed.
Aug 1	Test unit F-13 dropped; start assembly of test unit F-18; news of the *Indianapolis* sinking reaches Tinian; 784 B-29's drop incendiaries

			on Hachioji, Toyama, Nagaoka, and Mito.
Aug	2		Three *Fat Man* units arrive at Tinian on three B-29's; start assembly of test unit F-33.
Aug	3		*Indianapolis* survivors spotted.
Aug	3		*Indianapolis* survivors rescued.
Aug	4		Test units F-18 and F-33 completed.
Aug	5		Test unit F-18 dropped; weather forecasters give OK for bombing on August 6.
		1400	Gen. LeMay issues Special Bomb Operational Order #13, authorizing the Hiroshima mission. L-11 loaded onto transport trailer.
		1430	L-11 arrived at loading pit.
		1500	Install Flight Test Box in *Enola Gay* (Leon Smith, Philip Barnes, Morris Jeppson, Bruce Corrigan); *Enola Gay* backed over loading pit; 1st crew briefing.
		1530	Start loading L-11 into *Enola Gay.*
		1545	L-11 secured in plane.
		1615	Group photo taken outside 509th headquarters.
		1800	L-11 unit "all ready."
		1917	Gen. Farrell sends Groves a message informing him that Parsons would arm the bomb in-flight.
		2330	Final briefing for three weather plane crews; 597 B-29's drop incendiaries, HE, and mines on Saga, Mae, Bashi, Imbari, Nishinomiya-Mikage, and Ube.
Aug	6	0000	Final briefing by Tibbets, Parsons, and Ramsey.
		0137	Weather planes takeoff.
		0220	Final group photo taken.
		0227	Start engines.
		0230	Preflight completed.
		0245	Take Off* (*Enola Gay* runway A).
		0246	*The Great Artiste* takeoff runway B.
		0249	*Necessary Evil* takeoff runway C.
		0251	*Big Stink* takeoff runway D.
		0300	Started final loading of gun* (Parsons & Jeppson). Check list for loading charge in plane with special breech plug (after all 0-3 tests are complete). 1: Check that green plugs are installed. 2: Remove rear plate. 3: Remove armor plate. 4: Insert breech wrench in breech plug. 5: Unscrew breech plug (about sixteen turns), place on rubber pad.
		0310	6: Insert charge, 4 sections, red ends to breech. 7: Insert breech plug and tighten home. 8: Connect firing line. 9: Install armor plate.

10: Install rear plate.
11: Remove and secure catwalk and tools.

		0315	Finished loading.*
		0320	Climb out of bomb bay.
		0552	Approach Iwo. Begin climb to 9,300 feet.
		0605	Headed for Empire from Iwo.*
		0730	Red plugs in.* (Jeppson)
		0741	Started climb. Weather report received that weather over primary and tertiary targets was good but not over secondary target.*
		0825	Weather plane-Cloud cover less than 3/10ths at all altitudes. Advice: Bomb Primary.
		0838	Leveled off at 32,700 feet.*
		0847	All Archies tested to be OK.*
		0904	Course west.*
		0909	Hiroshima in sight.
		0912	Initial Point (IP).
		0914	Glasses on. Tone started.
		0915	Dropped bomb*. Fell for 44.4 seconds.
		0915	Bomb explodes. Blast followed by two slaps on plane. Huge cloud.*
		1000	Still in sight of cloud which must be over 40,000 feet high.*
		1003	Fighter reported.*
		1041	Lost sight of cloud 363 miles from Hiroshima with the aircraft being 26,000 feet high.*
		1458	Landed at Tinian.
Aug	7		Start final assembly of combat unit F-31.
Aug	8	0300	Take off of *Bockscar* to drop Test unit F-33
		1000	F-33 dropped (0930-1030) near Iwo Jima piloted by Maj. Sweeney
		1130	*Bockscar* returns to Tinian
		2000	Combat unit F-31 assembly completed and loaded in *Bockscar*; 211 B-29's drop incendiaries and HE on Yahata, Fukuyama, and Tokyo.
Aug	9	0000	Final briefing.
		0215	Plane crews arrive at North Field.
		0347	Take off.** (0348)
		0400	Changed green safe plugs to red arm plugs prior to pressurizing airplane.**
		0500	Charged detonator condensers to test leakage. Satisfactory.**
		0700	Black Box lights begin to flash wildly.
		0710	Problem corrected.
		0900	Arrived rendezvous point at Yaku-Shima and circled awaiting accompanying aircraft.** (0910)
		0920	One B-29 sighted and joined in formation.**
		0950	Departed from Yaku-Shima proceeding to primary target Kokura, having failed to rendezvous with second B-29. The weather reports received by radio indicated good weather at Kokura (3/10ths low clouds, no intermediate or high clouds, and

			forecast of improving conditions). The weather reports for Nagasaki were good, but increasing cloudiness was forecast. For this reason the primary target was selected.**
		1044	Arrived IP (Initial Point) at Kokura and started bombing runs on target. Target was obscured by heavy ground haze and smoke. Two additional runs were made hoping that the target might be picked up after closer observations. However, at no time was the aiming point seen. It was then decided to proceed to Nagasaki after about 45 minutes had been spent in the target area.**
		1130	Depart for Nagasaki.
		1150	Arrived in Nagasaki target area. Approach to target was entirely by radar.**
		1202	The bomb was dropped after a 20-second visual bombing run.** Bomb explodes [1202]. The bomb functioned normally in all respects.**
		1205	Departed for Okinawa after having circled smoke column. Lack of available gasoline caused by an inoperative bomb bay tank booster pump forced decision to land at Okinawa before returning to Tinian.** (1206)
		1330	Landed at Yontan Field, Okinawa.** (1330)
		1730	Departed Okinawa for Tinian.** (1730)
		2230	Landed at Tinian** (2330); 95 B-29's drop incendiaries, HE, and mines on Hikari, Osaka, Marifu, Kumagaya, Isezaki, and Tsuchizakiminato. 7 509th B-29's drop pumpkins on Koromo and Nagoya.
Aug	15	1300	Japan broadcasts surrender.

All times listed are Marianas Time. Standard military 24-hr time nomenclature is used for all times shown. B-29 raids listed were launched at night on these dates. They reached their targets on the following day.

* Parsons' log entries. (0300 entry includes Parsons' loading procedure checklist which was not in original log). The original checklist is on permanent display in the Navy Museum.

** Ashworth's log entries. Times listed in parenthesis are from Olivi's log. Tibbets wrote later they departed at 0415.

Bomb Display Locations

Little Boy

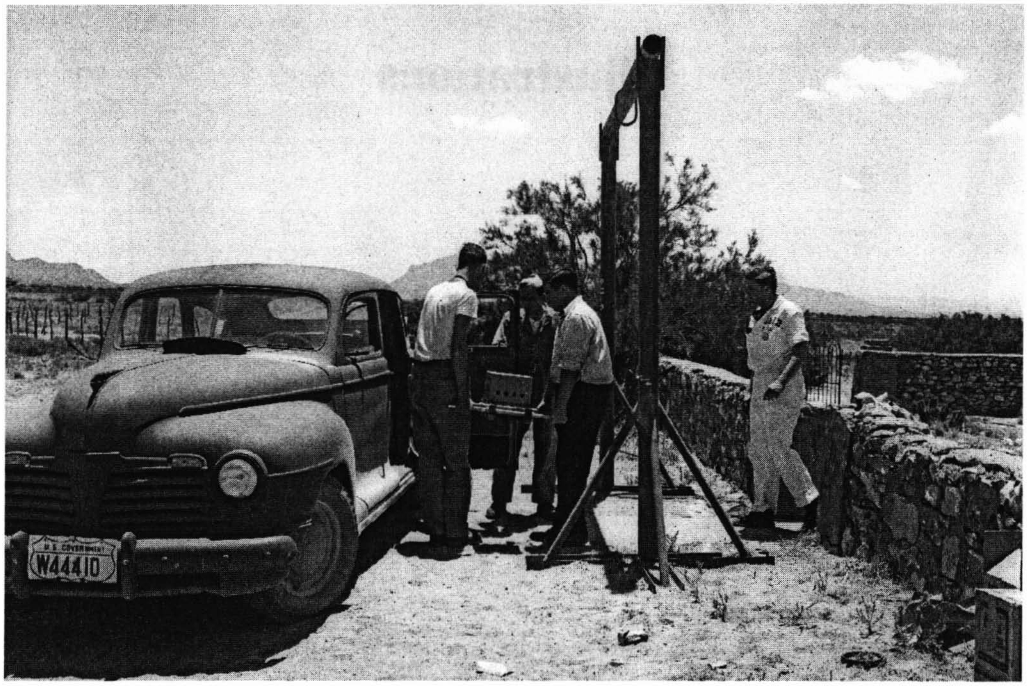
American Airpower Heritage Museum, Midland, TX *
American Museum of Science and Energy, Oak Ridge, TN *
Defense Nuclear Weapons School, Albuquerque, NM
Historic Wendover Airfield, Wendover, UT *
Hiroshima Peace Memorial Museum, Hiroshima, Japan *
Imperial War Museum, London, England
Military Branch Museum, Nashville, TN *
Musée de l'Armée, Paris, France *
National Museum of Nuclear Science and History, Albuquerque, NM
Norris Bradbury Science Museum, Los Alamos, NM *
Smithsonian Institution National Air and Space Museum, Washington, DC (AAA 491)
USAF Museum, Wright-Patterson AFB, Dayton, OH
U.S. Army Engineer Museum (Walker Museum), Fort Leonard Wood, MO *
U.S. Navy Museum, Washington, DC

Fat Man

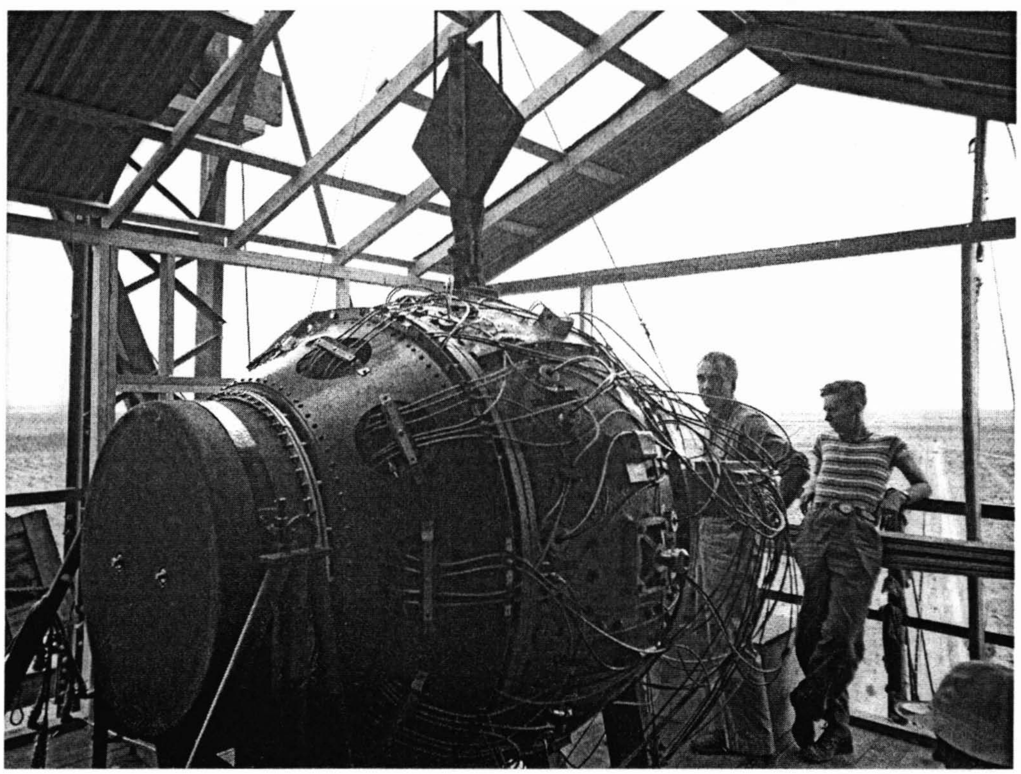
American Airpower Heritage Museum, Midland, TX *
Defense Nuclear Weapons School, Albuquerque, NM
Experimental Aircraft Museum, Oshkosh, WI
Nagasaki Atomic Bomb Museum, Nagasaki, Japan *
National Museum of Nuclear Science and History, Albuquerque, NM **
National Museum of the Pacific War, Fredericksburg, TX **
National Naval Aviation Museum, Pensacola, FL
Norris Bradbury Science Museum, Los Alamos, NM *
Smithsonian Institution National Museum of American History, Washington, DC
Travis Air Force Museum, Travis AFB, Fairfield, CA **
USAF Armament Museum, Eglin AFB, Crestview, FL **
USAF Museum, Wright-Patterson AFB, Dayton, OH **
U.S. Navy Museum, Washington, DC
U.S. Army Museum, West Point, NY **
White Sands Missile Range, White Sands, NM

* Replica
** Exterior ballistic case only

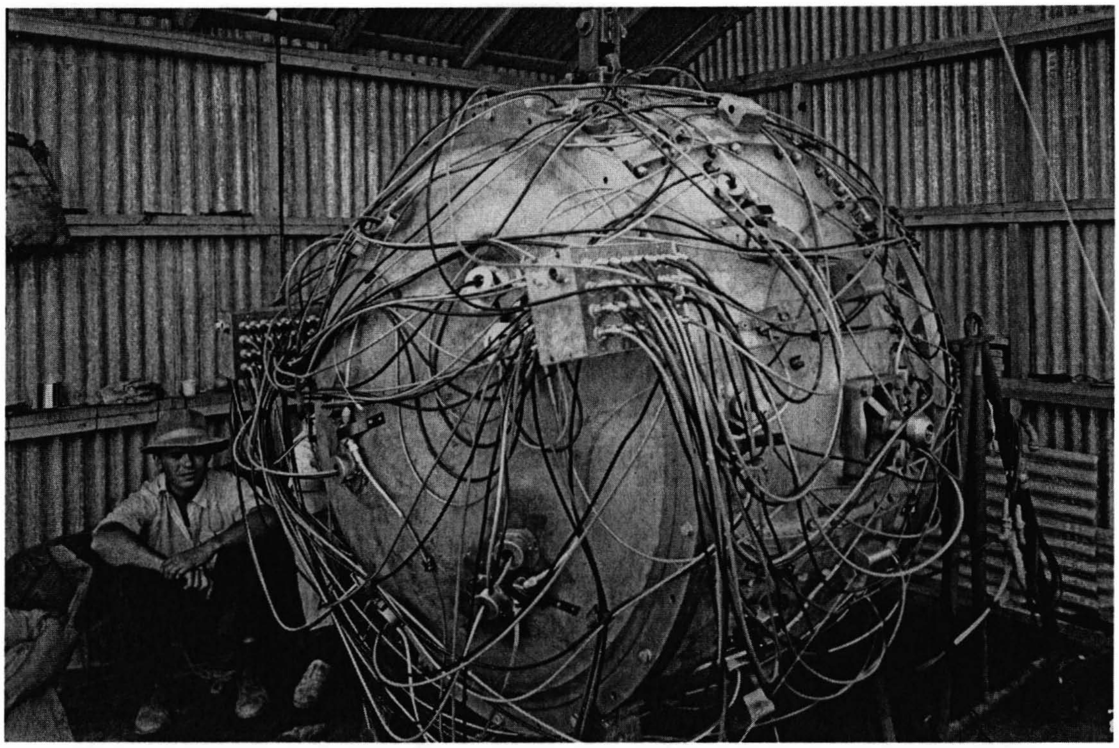
Illustrations



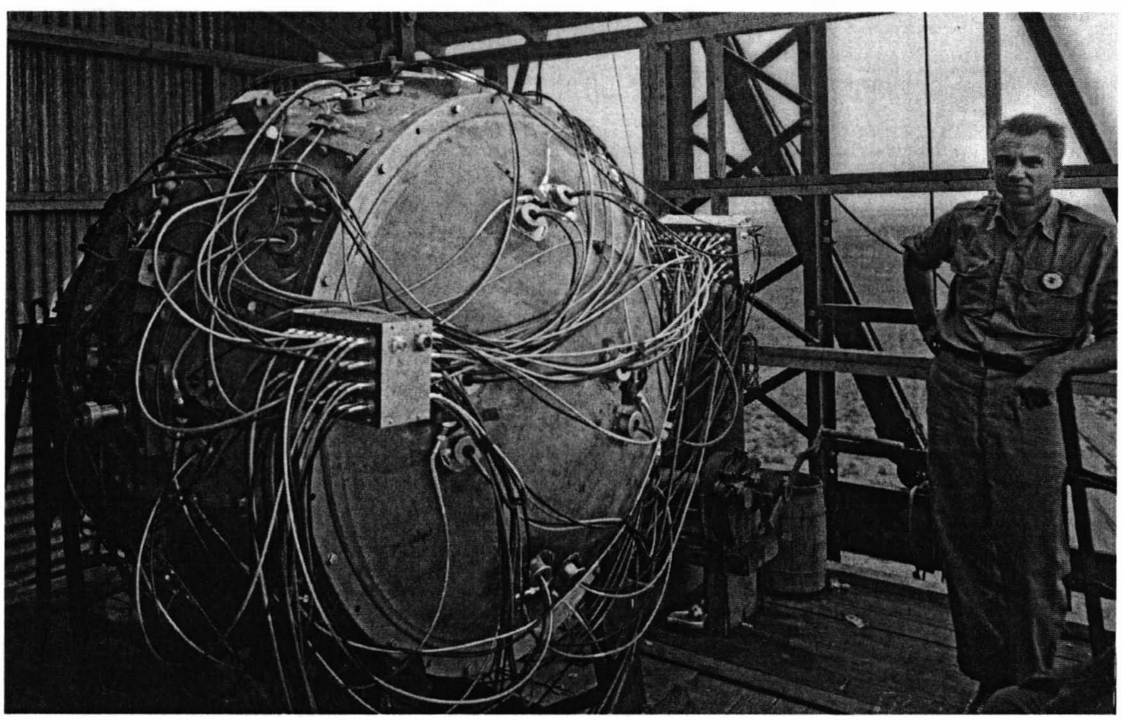
Herb Lehr (l) and Harry Daghlian (r) loading the ventilated wood box containing the assembled nuclear capsule into the 1942 Plymouth outside the McDonald Ranch house. (LANL)



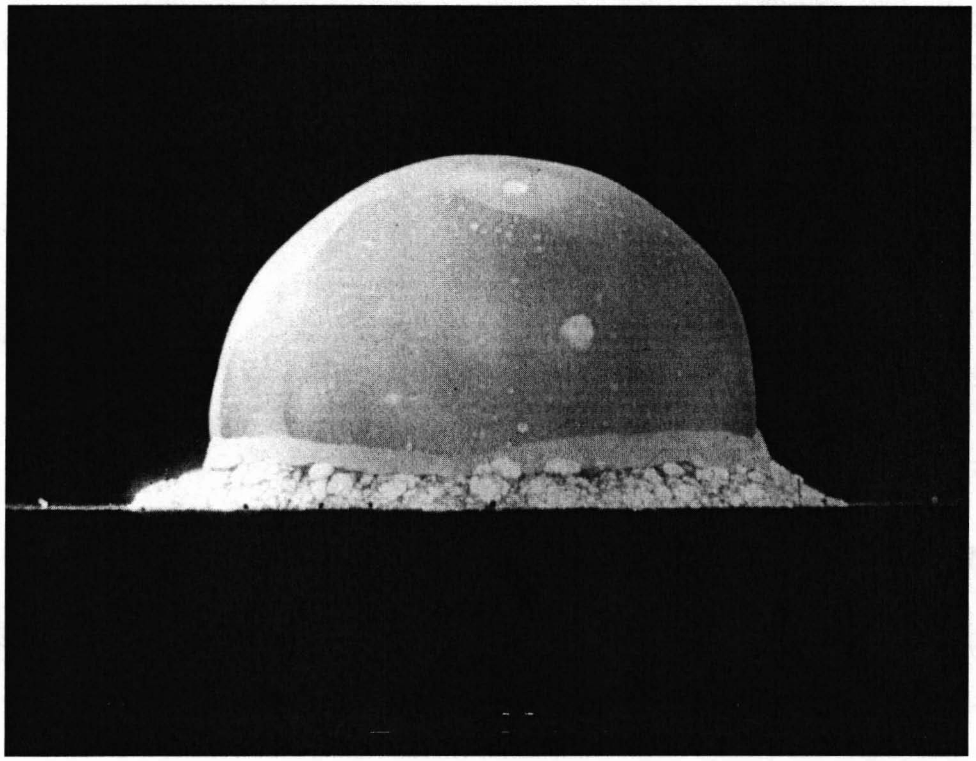
Norris Bradbury (l) and SED Boyce McDaniel standing next to the Trinity device. (LANL)



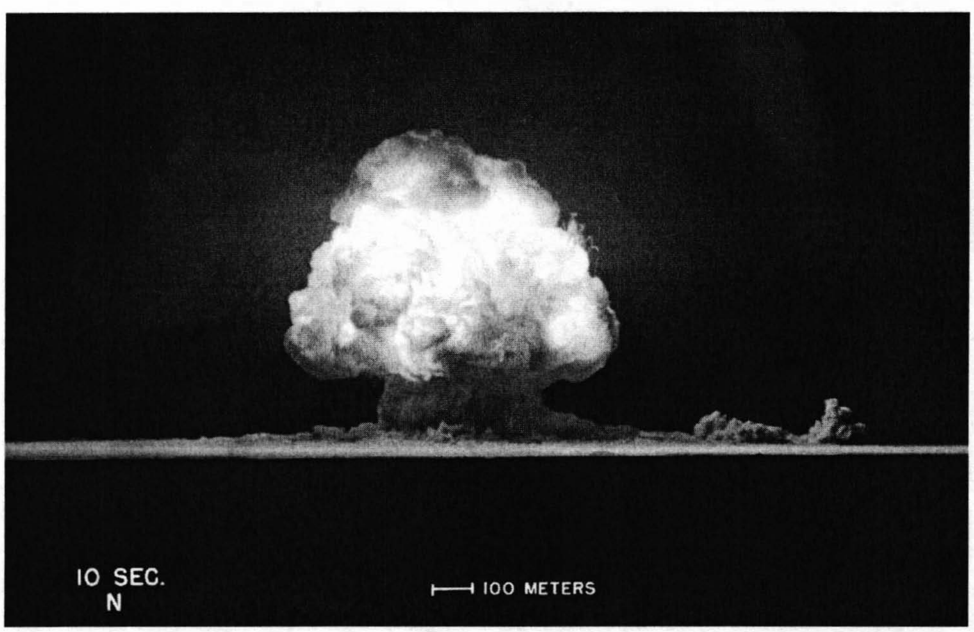
Another view of the "Gadget" atop the test tower. Donald Hornig shown sitting with hat. (LANL)



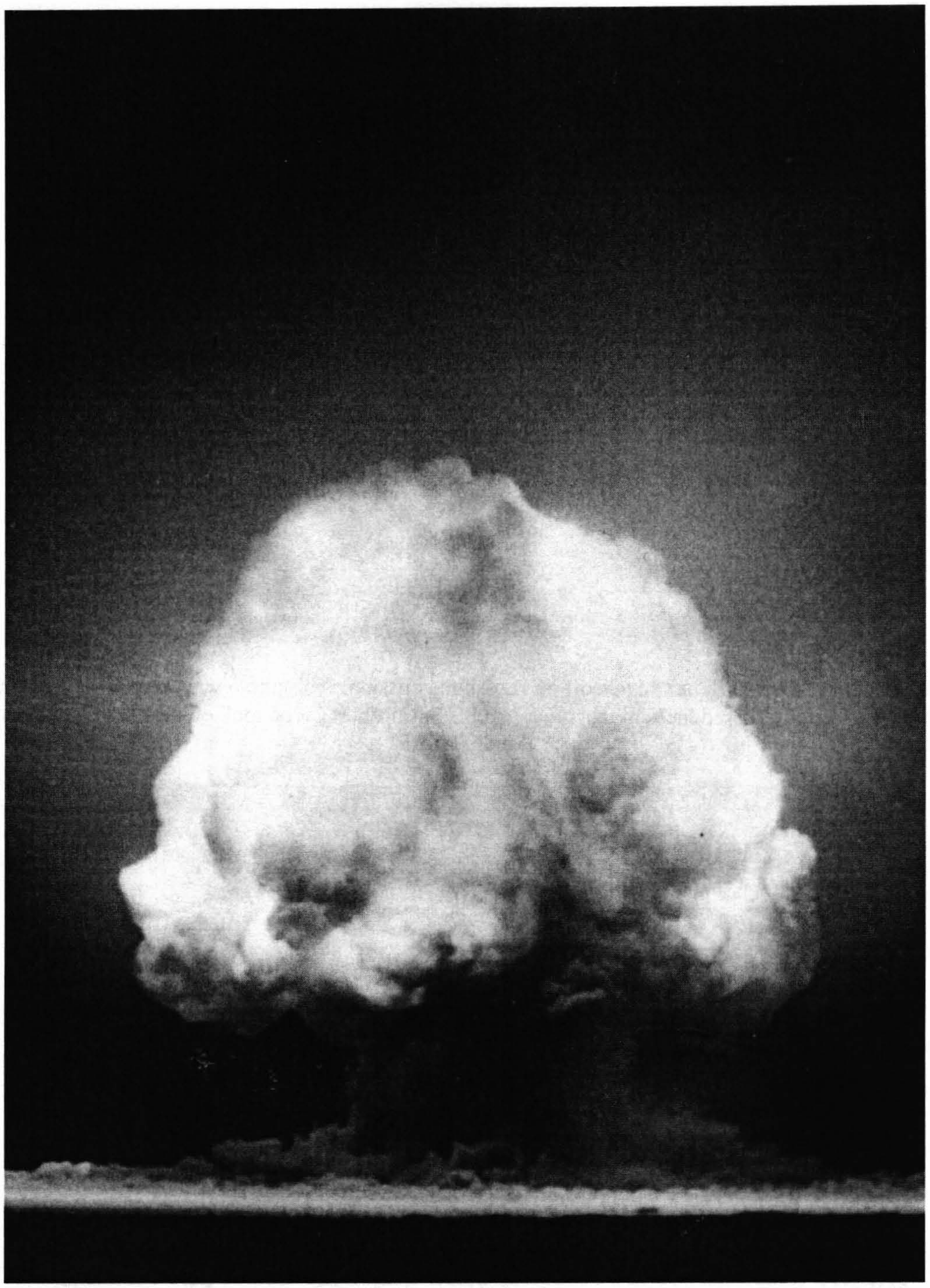
Bradbury shown standing next to the device. The two circular parts next to each of the 32 bridgewire detonators on the sphere were informers to indicate if each detonator worked properly. (LANL)



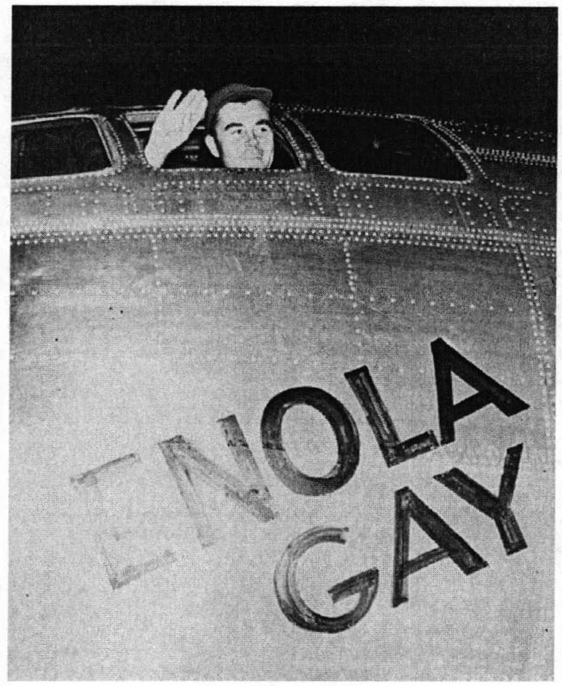
Trinity test a few microseconds after detonation. This series of photos was taken by Berlyn Brixner. (LANL)



Trinity mushroom cloud 10 seconds after detonation. (LANL)



Trinity explosion + 12 sec. (LANL)

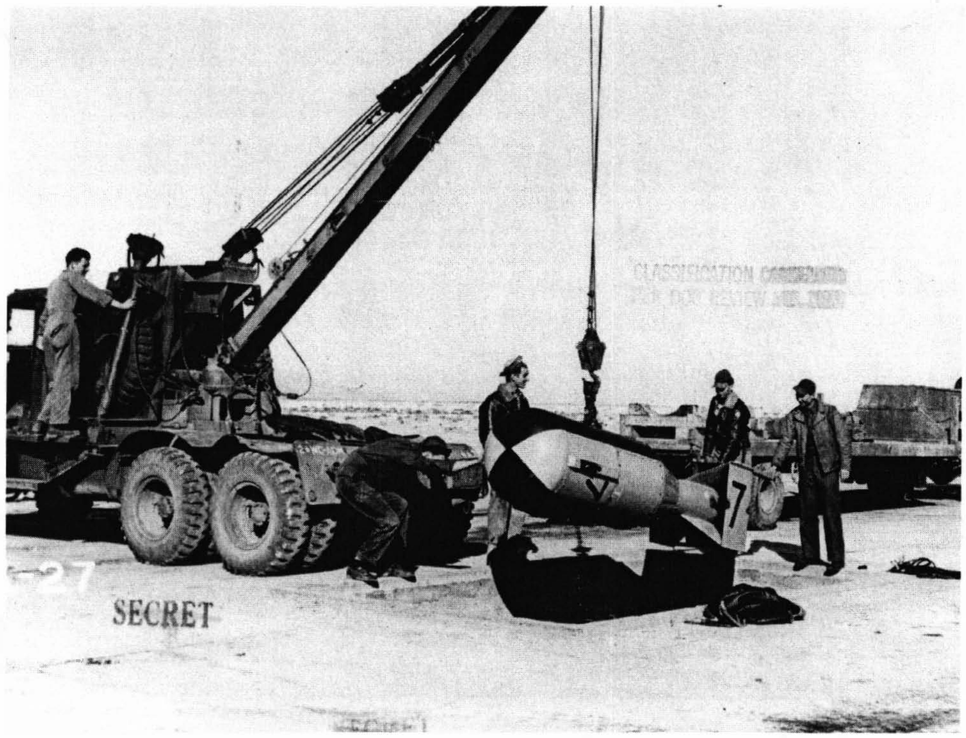


Col. Paul W. Tibbets just before takeoff on Hiroshima mission. This photo was taken by Pfc. Armen Shamlian who also processed the film that tail gunner S/Sgt. Robert Caron took of the Hiroshima mushroom cloud. (USAF)

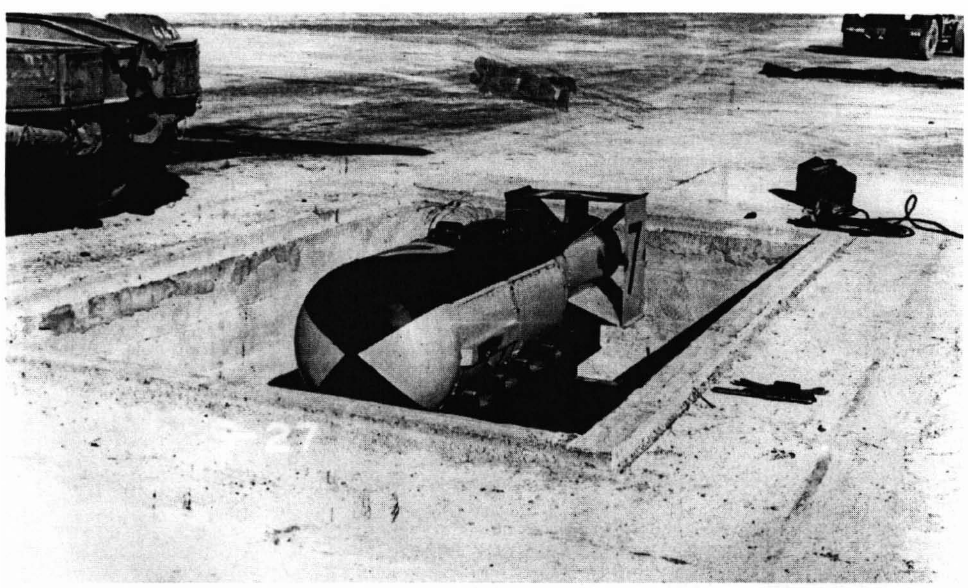
Last surviving members of the *Enola Gay* crew with the author at their 2004 509th Composite Group reunion in Kansas City. L-R Jeppson, Tibbets, Author, and Van Kirk. (Author)

1st Ordnance Capt. Charles F. H. Begg at his desk on Tinian. (USAF)

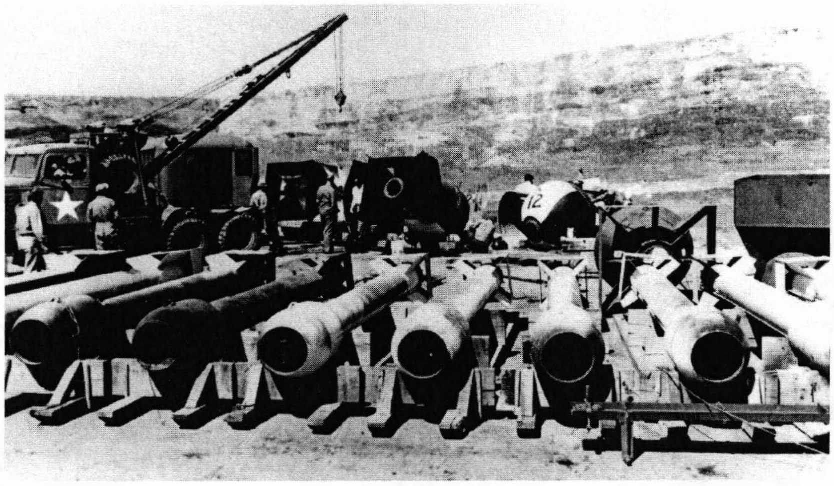
Rear Adm. Purnell, General Farrell, Colonel Tibbets, and Capt. Parsons on Tinian. (USAF/Armen Shamlian)



Early *Little Boy* test model being lowered into loading pit at Wendover. (LANL)

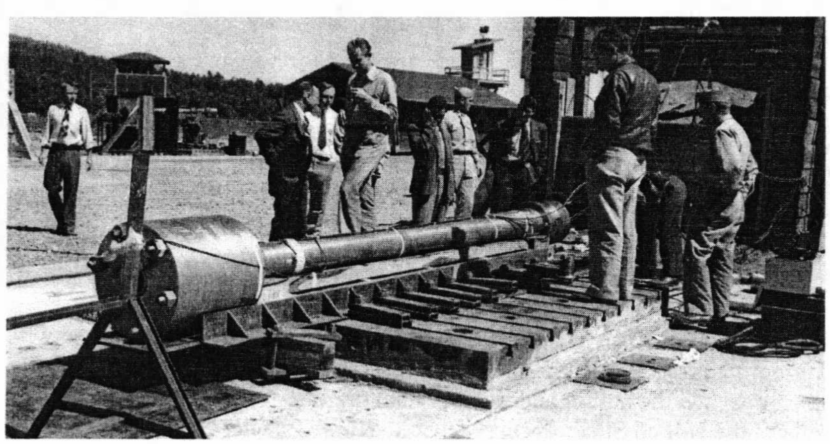


Early *Little Boy* test unit in Wendover loading pit. Final dimensions for the Tinian loading pits were 127" wide X 240" long with a depth of 80" to the bottom of the baseplate. The centerline of the hoist piston was 108" from the front of the pit. (LANL)

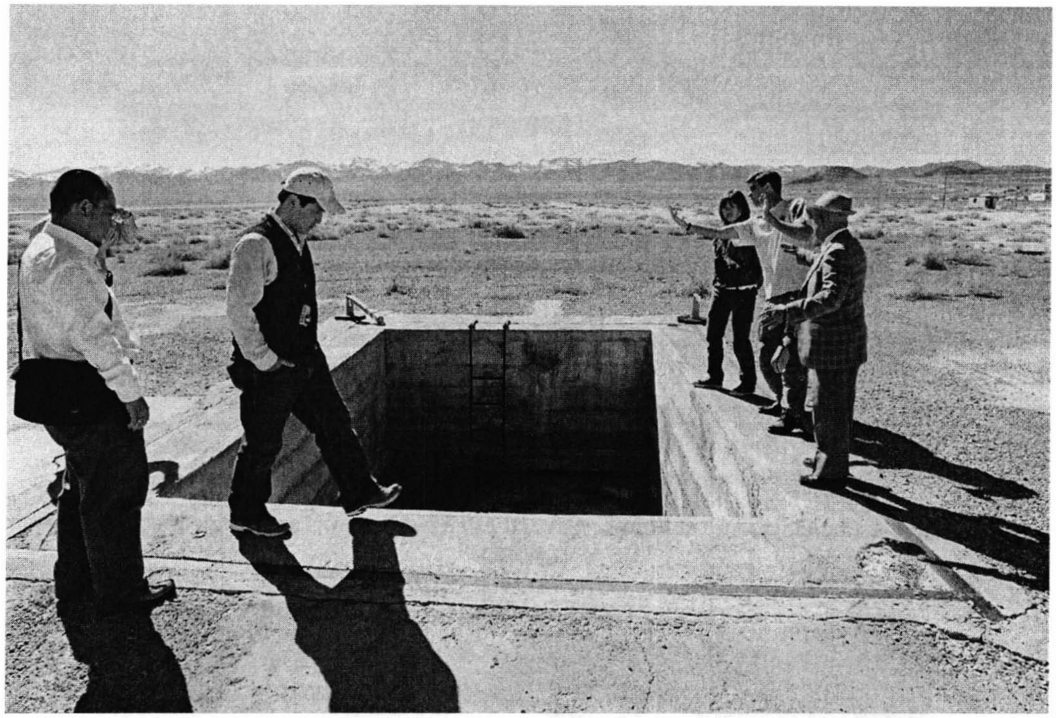


Early *Thin Man* test units lined up at Muroc. Several *Fat Man* test units are visible in the background. (LANL)

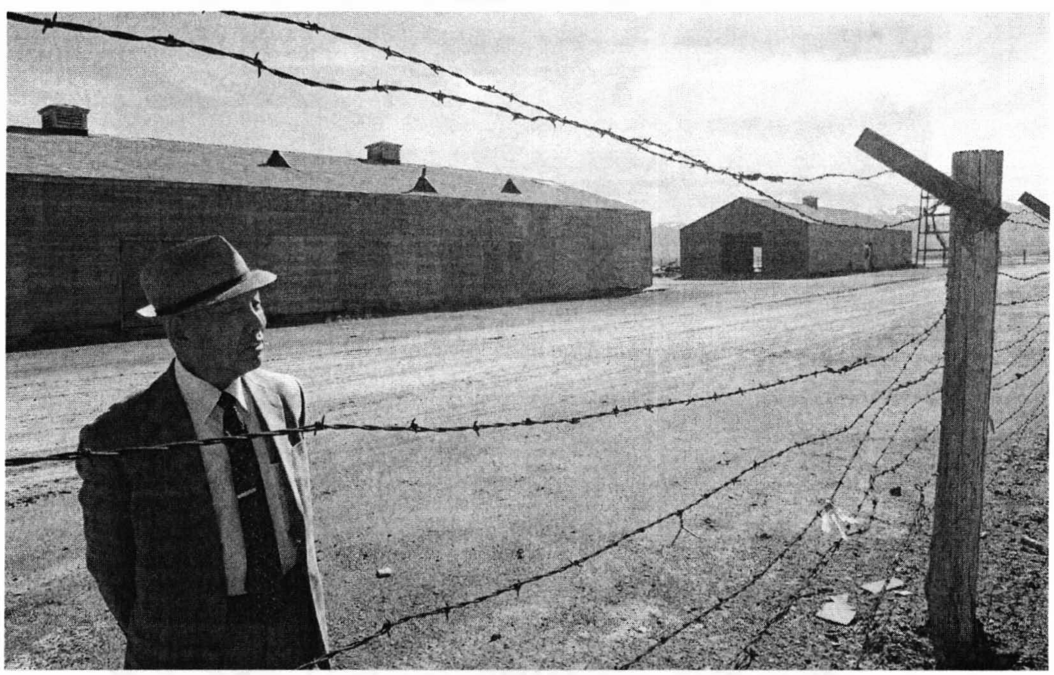
Side view showing the *Thin Man* units lined up before testing. (LANL)



Thin Man Pu gun undergoing testing at Anchor Ranch in Los Alamos. (LANL)



Members of the Hiroshima World Peace Mission are shown here on April 6, 2005 examining one of three surviving Wendover loading pits. (Author)

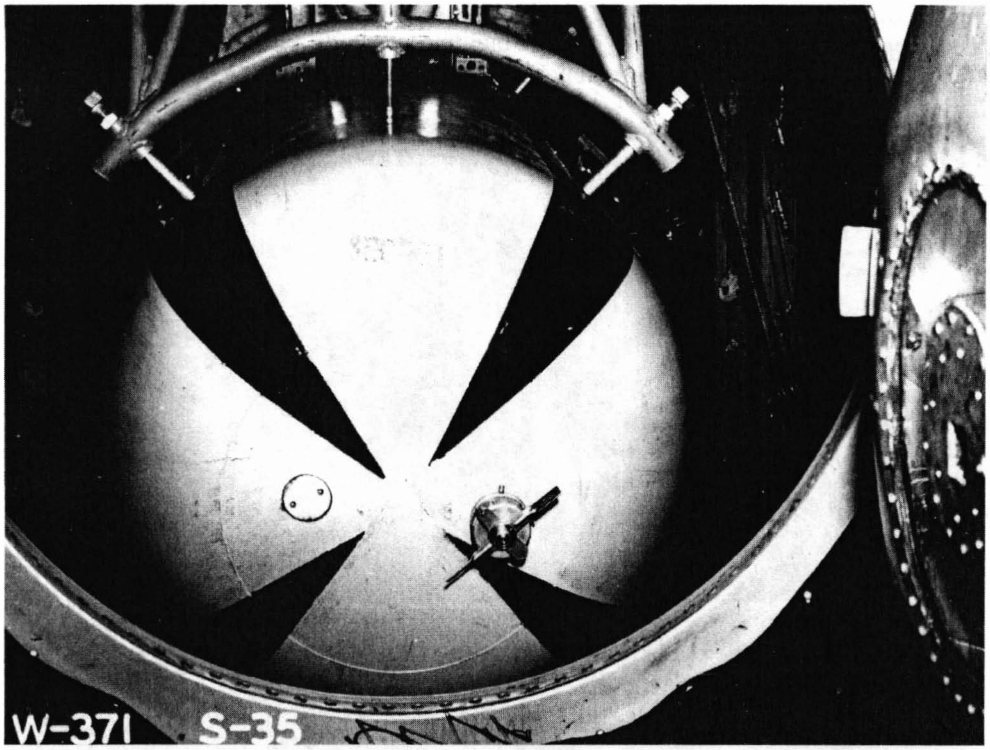


Hiroshima bombing survivor (Hibakusha) Keijiro Matsushima gazes into the barbed wire enclosure that surrounds the formerly secret atomic bomb test unit assembly areas at Wendover. Shortly after this photo was taken, he approached the author and stated, "I am grateful for the protection of my country by the nuclear umbrella of the United States during the Cold War." Exactly four months later, he met with the author on Tinian and in 2010 he gave the author a personal tour of Hiroshima and Miyajima. (Author)

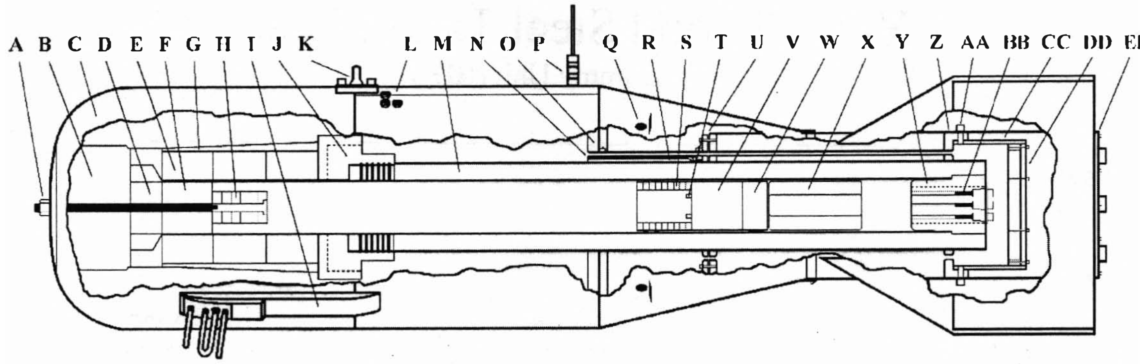
This is all that is left of the *Fat Man* test unit final assembly building at Wendover. The building itself, like the *Little Boy* assembly building, was disassembled at the end of WWII, shipped to Sandia Base in Albuquerque, and re-assembled. Historic Wendover Airport Director Jim Peterson is shown here examining one of the corner footings for the building. The area directly behind him was the sub-floor with a grounded copper wire grid embedded in it. Both buildings were 20' across and prototypes of the Tinian assembly buildings. (Author)

Here is a close-up of the corner steel girder with a 4 gauge copper wire embedded in the concrete footing. The whitish object on the left is believed to be part of the wood frame building exterior. (Author)

All that remains in 2005 of the *Fat Man* final assembly building are the footings and crumbling concrete floor on a cinder block pad spread over the Wendover desert. (Author)



This photo taken from inside the forward crew compartment shows the sway bracing and nose fuze on a Wendover *Little Boy* test unit loaded inside a B-29 bomb bay. The open bomb bay pressure door can be seen on the right. Although the 15.0" diameter nose nut is clearly visible, the cadmium-plated draw bolt was not used on this test unit. The spin-off fuse shown in the right-side nose nut handling bolt hole was not used in the L-11 combat unit. (LANL)

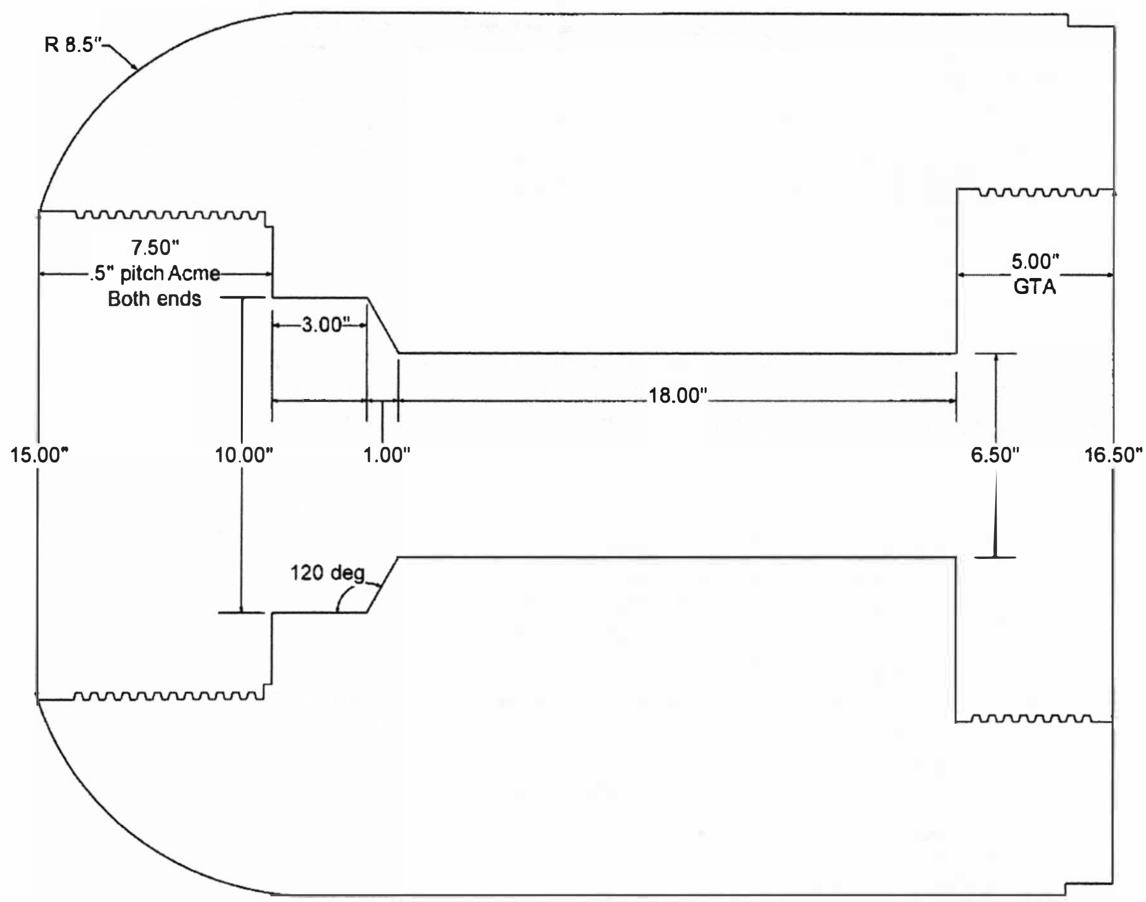


Cross-section drawing of Y-1852 *Little Boy* showing major mechanical component placement. Not shown are the APS-13 radar units, clock box with pullout wires, baro switches and tubing, batteries, and electrical wiring. Numbers in ( ) indicate quantity of identical components. Drawing is shown to scale. (Author)

A) Front nose elastic locknut attached to 1.0" diameter cadmium-plated draw bolt
B) 15.0" diameter forged steel nose nut w/14" diameter back end
C) 28.0" diameter forged steel target case
D) Impact absorbing anvil surrounded by cavity ring
E) 13" diameter 3-piece WC tamper liner assembly w/6.5" bore
F) 6.5" diameter WC tamper insert base
G) 18" long K-46 steel WC tapered tamper liner sleeve w/15" diameter back end
H) 4" diameter U-235 target insert discs with a 6.75" length (6)
I) Yagi antenna assemblies (4)
J) Target-case to gun-tube adapter with four vents slots and 6.5" hole
K) Lift lug
L) Safing/arming plugs (3)
M) 6.5" bore gun tube
N) 0.75" diameter armored tubes containing primer wiring (3)
O) 27.25" diameter bulkhead plate
P) Electrical plugs (3)
Q) Baro ports (8)
R) 1.0" diameter rear alignment rods (3)
S) 6.25" diameter U-235 projectile rings with a 6.75" length (9)
T) Polonium-Beryllium initiators (4)
U) Tail tube forward plate
V) Projectile WC filler plug
W) Projectile steel back
X) 2-pound WM slotted-tube Cordite powder bags (4)
Y) Gun breech with removable 4" diameter inner breech plug and stationary outer bushing
Z) Tail tube aft plate
AA) 2.25" long 5/8-18 socket-head tail tube bolts (4)
BB) Mark 15 Mod 1 electric gun primers w/AN-3102-20AN receptacles (3)
CC) 15" diameter armored inner tail tube
DD) Inner armor plate bolted to 15" diameter armored tube
EE) Rear plate (w/smoke puff tubes) bolted to 17" diameter tail tube

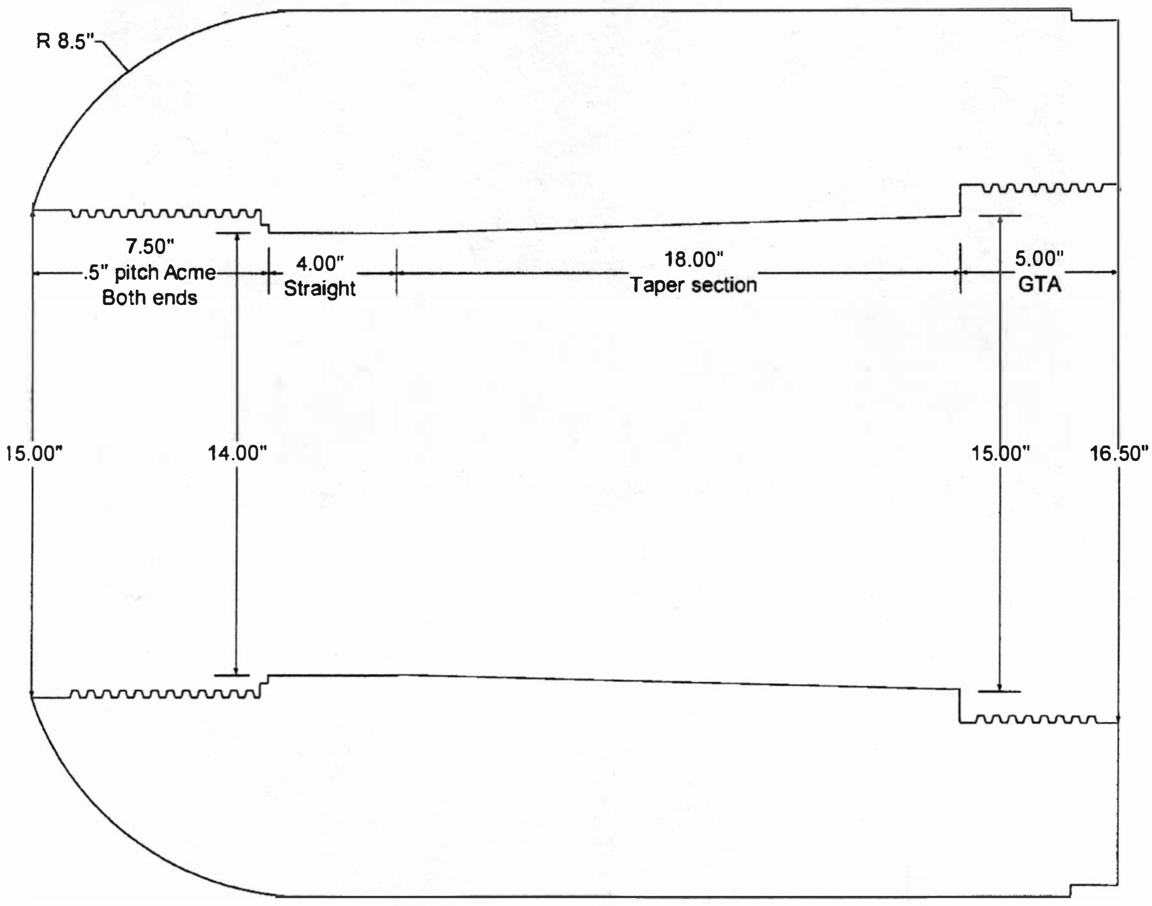
Y-1792 Solid Steel Target Case

Bomb, Dummy Unit (BDU)

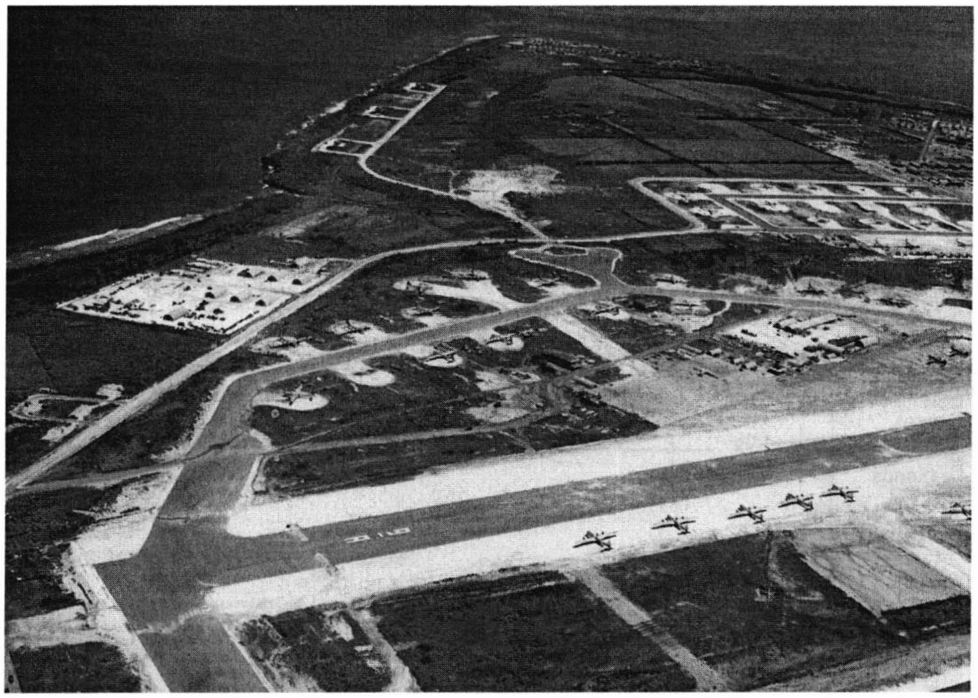


These two exclusive scale drawings represent over two decades of research by the author, including numerous "Nuclear Archeology" expeditions, and are fully revealed here for the first time. The exterior of both 28.0" diameter cases were identical. This drawing shows the one-piece machined heat-treated 4340 high-alloy steel LB dummy target case used during the 1945 drop testing period in the US and near Tinian. Los Alamos has never released any information whatsoever about this dummy case. However, a complete physical examination of this case (including photographing and measuring) by the author confirmed that the central section sides were 10.75" thick with a 6.5" gun bore. It did <u>not</u> contain the WC-filled K-46 liner sleeve and that 18" long area was simply machined as an integral part of the solid steel case. Both this dummy case and the Y-1852 used the same 9.25" thick, 15.0" diameter (14.0" diameter at the aft end) "Nose Nut" (B) and the 5.0" thick, 16.5" diameter "Gun Tube Adapter or GTA" (J) shown on the previous page. The angled area machined into the forward part of this case represents the "Cavity Ring" shown in the LB Cross-Section drawing on the previous page. This ring was a separate machined component in the Y-1852. It was 4" thick, with a 14.0" O.D. and 10.0" I.D. and surrounded the 4" thick, 6.5" diameter "Anvil" (D) that was added separately on both cases. During testing, both cases used the one-piece solid steel 01-350 dummy target "insert" (not shown) that represented both items "F" and "H" on the LB cross-section drawing. (CAD drawings by Tom Bower)

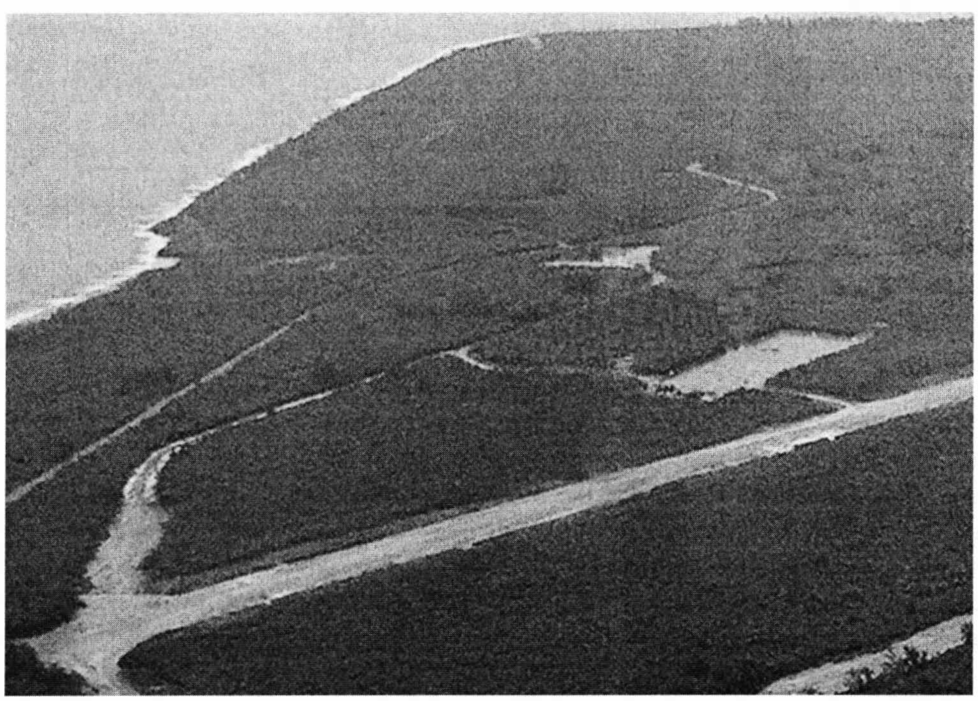
Y-1852 Combat Target Case



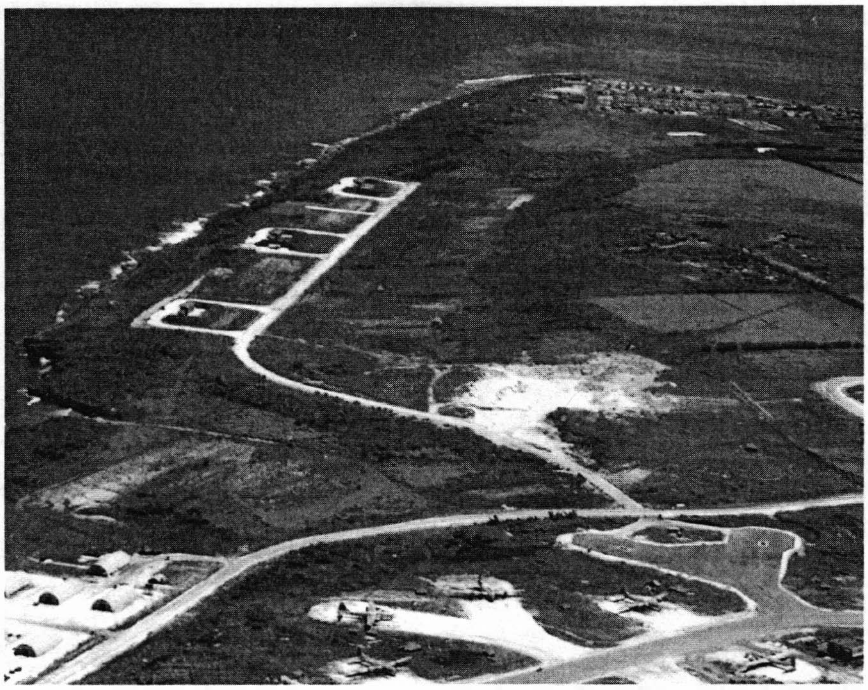
This is a drawing of the Y-1852 heat-treated 4340 high-alloy steel LB target case used in the 1945 drop testing period in the US and near Tinian along with the actual L-11 combat weapon. Compare this case with the dummy case to visualize where the 18" long WC-filled K-46 liner sleeve was added. You can also see the empty area in the forward portion directly behind the Nose Nut where the "Cavity Ring" and "Anvil" were added. This 22.0" long central machined area, starting at the aft end of the "Nose Nut", was 14.0" I.D. at the front for a distance of 4.0" then it tapered out at about 1.6° to a final 15.0" I.D. at the point where it touched the forward end of the 5.0" thick "Gun Tube Adapter" shown near the aft end of this drawing. This tapered area served to secure the WC-filled K-46 liner sleeve to the target case. This liner sleeve was pushed into the case through the aft end before the Gun Tube Adapter (GTA) was attached. The Acme threads (two per inch) at the forward and aft ends of both cases were identical. All interior/exterior measurements on both cases were made directly by the author using a variety of measuring instruments, including digital calipers. (CAD drawings by Tom Bower)



Tinian North Field area in 1945. Runway A is shown at the bottom. The large white rectangular area to the left is the Project Alberta and 1st Ordnance Squadron tech area with the 509th B-29 parking area located just to the right of it. The three bomb assembly buildings are shown at the top left of this photo facing the coast and the whitish coral transport road is visible running alongside these buildings. (Courtesy of Leon Smith)

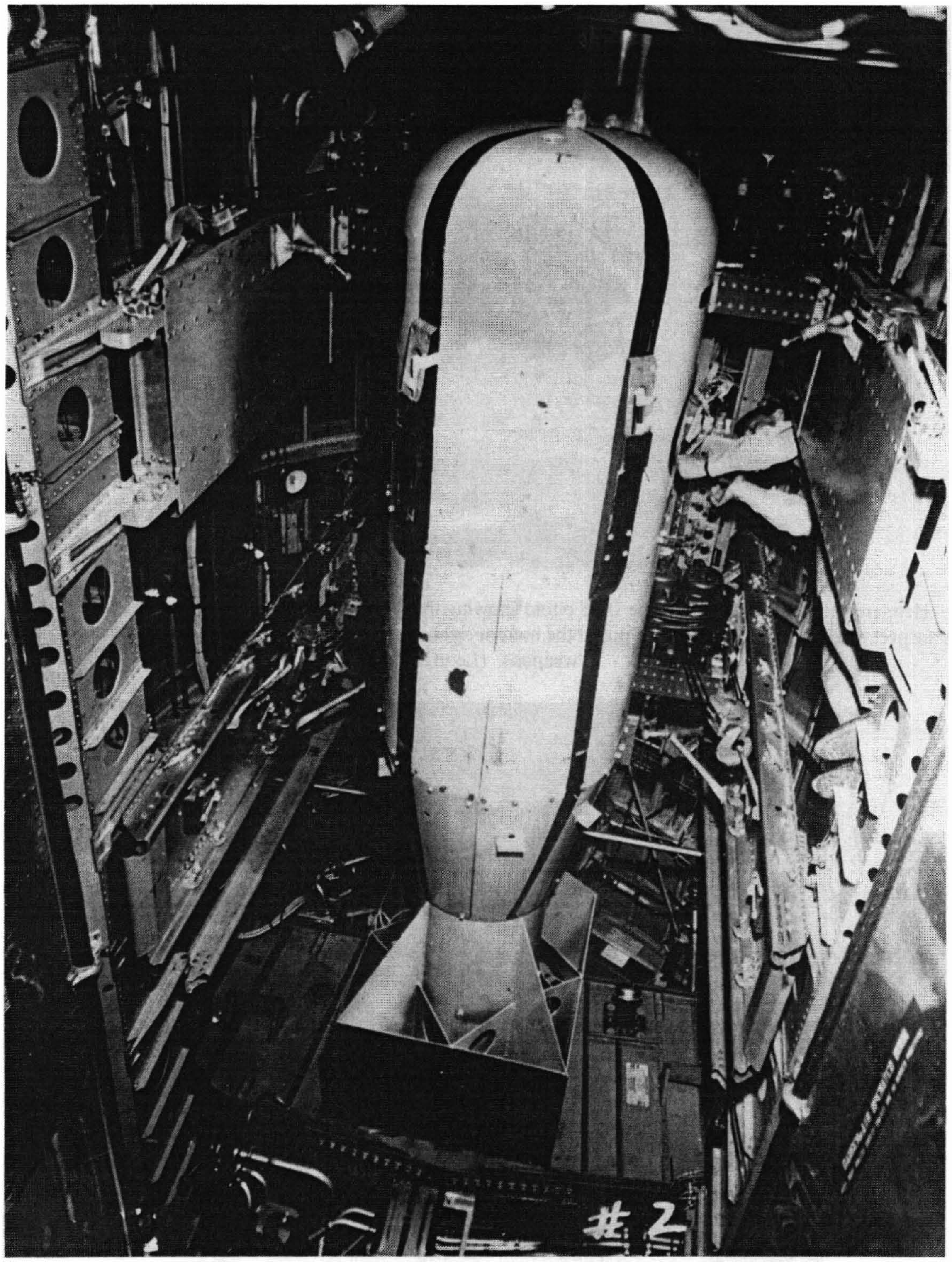


By comparison, this is how the same area as it looked in 2005. Runway A and part of B are at the bottom and the Y-shaped loading pit area is visible just to the right of the center of this photo. Except for some of the roadways, almost everything else is now covered by thick jungle growth. (Author)

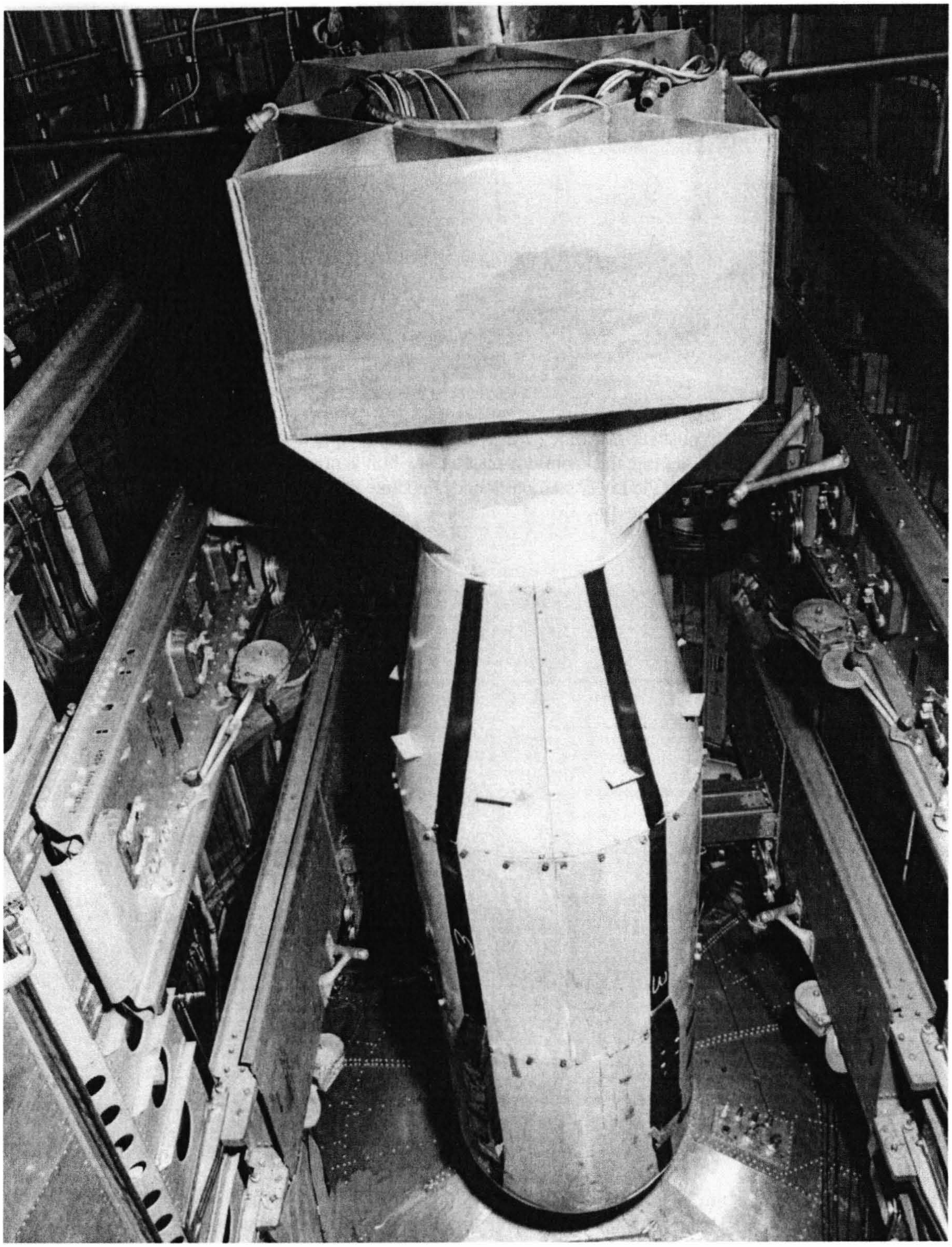


Here are enlargements of the same 1945 photo showing the three bomb assembly buildings and the coral transport road leading to the loading pits at the bottom right. The pit on the left was used to load both combat weapons. (Leon Smith)

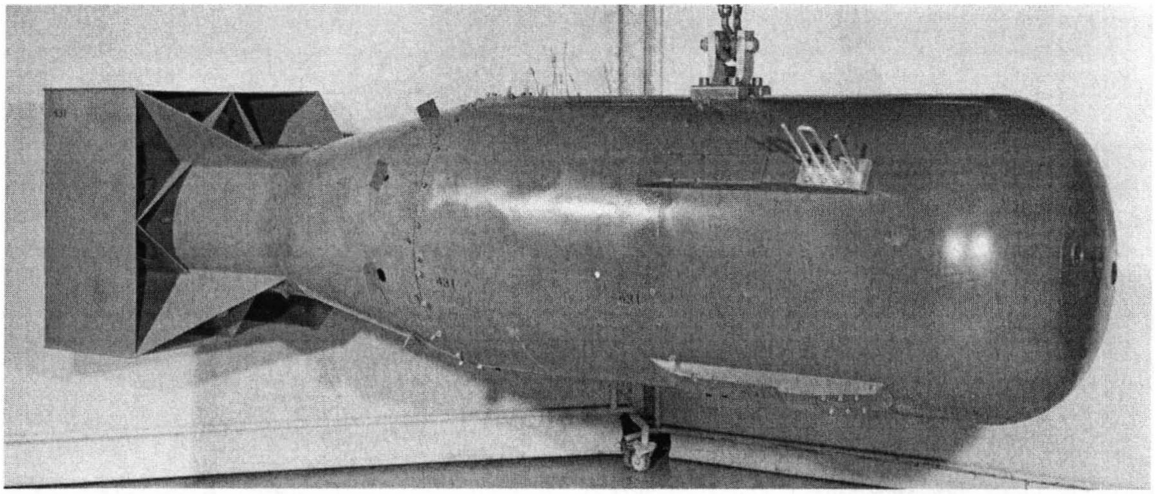
Here are the three bomb assembly buildings. The #1 building at the bottom is where *Little Boy* was assembled, #2 was used for assembly of the *Fat Man* test units, and building #3 shown at the top was used to assemble the F-31 combat *Fat Man*. The earthen berms are visible surrounding each building on three sides. (Leon Smith)



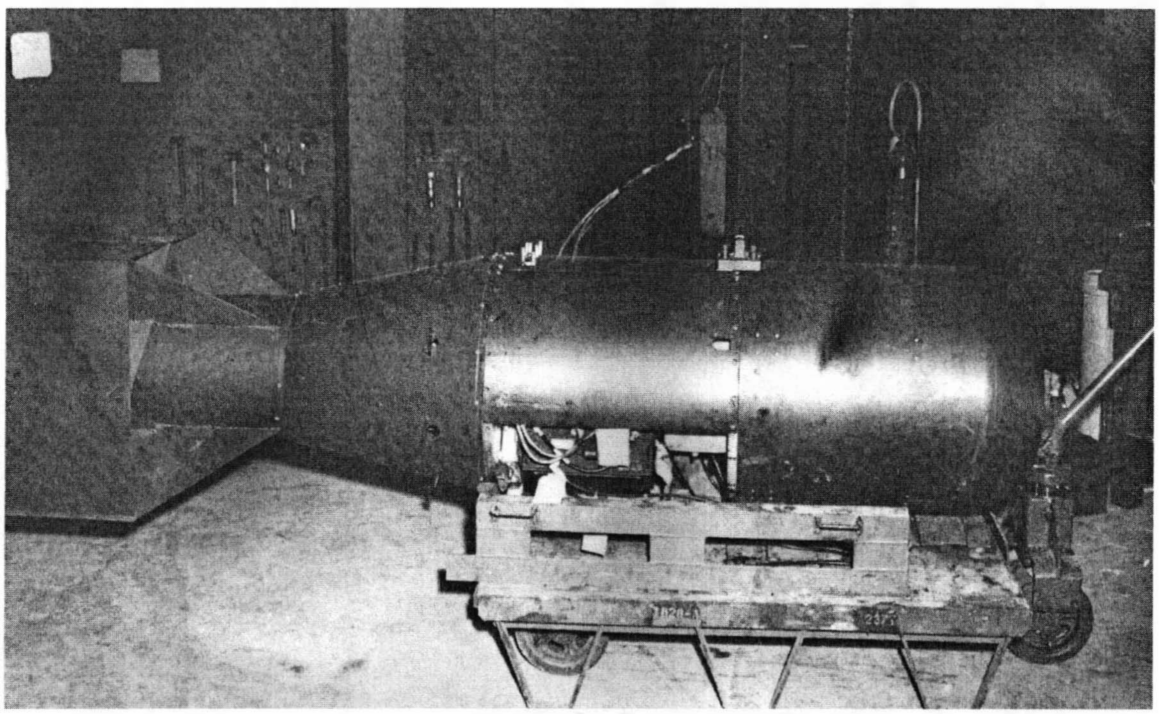
Little Boy test unit mounted inside a B-29 at Wendover. View from below looking up through the open bomb bay shows a technician on the right making final connections to the test unit. The antennas have not been attached. Note the sway braces installed for use when a *Fat Man* was being tested. (LANL/Armen Shamlian)



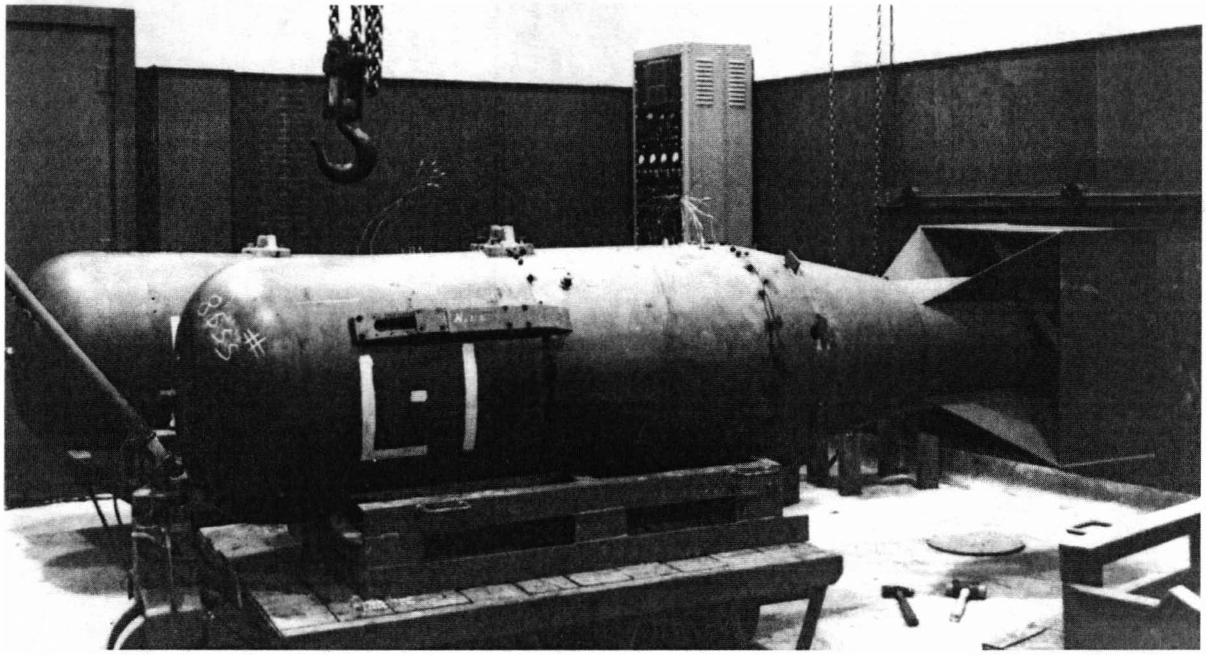
Here is another *Little Boy* test unit in B-29 bomb bay showing numerous cables protruding from the open tail. (LANL/Armen Shamlian)



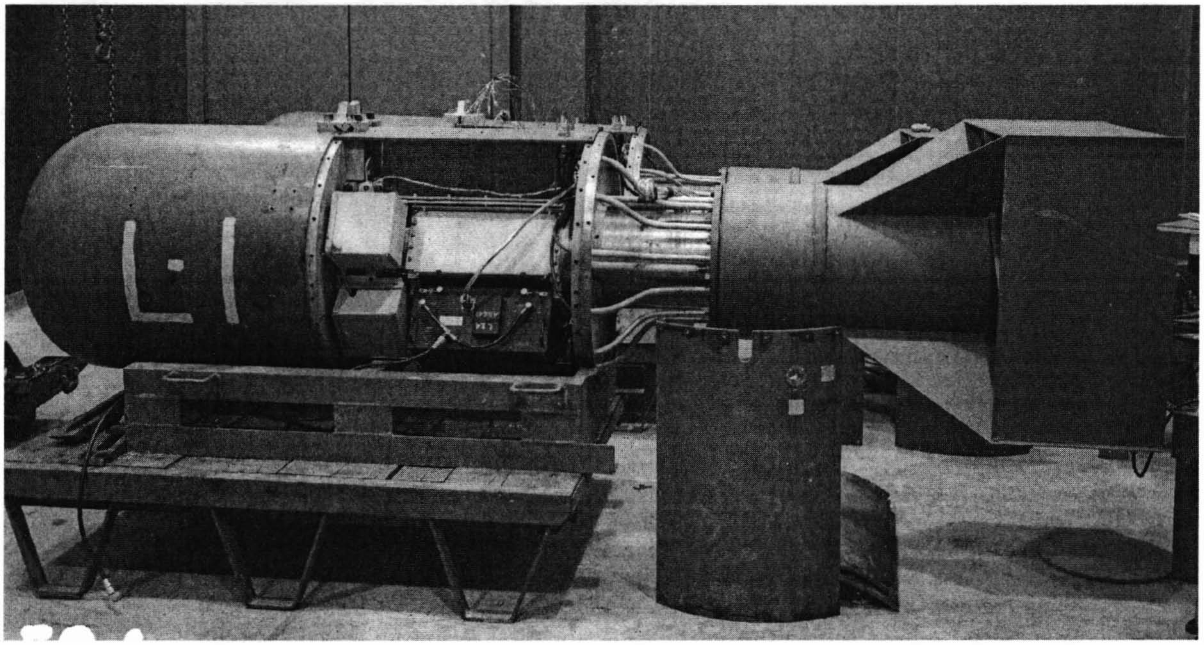
Little Boy unit AAA 431 postwar stockpile (War Reserve/WR) atomic bomb. Although the Clock Box pullout wires are visible on the top, the cadmium-plated draw bolt is missing on the nose of this unit along with the lower starboard-side Yagi antenna. (LANL)



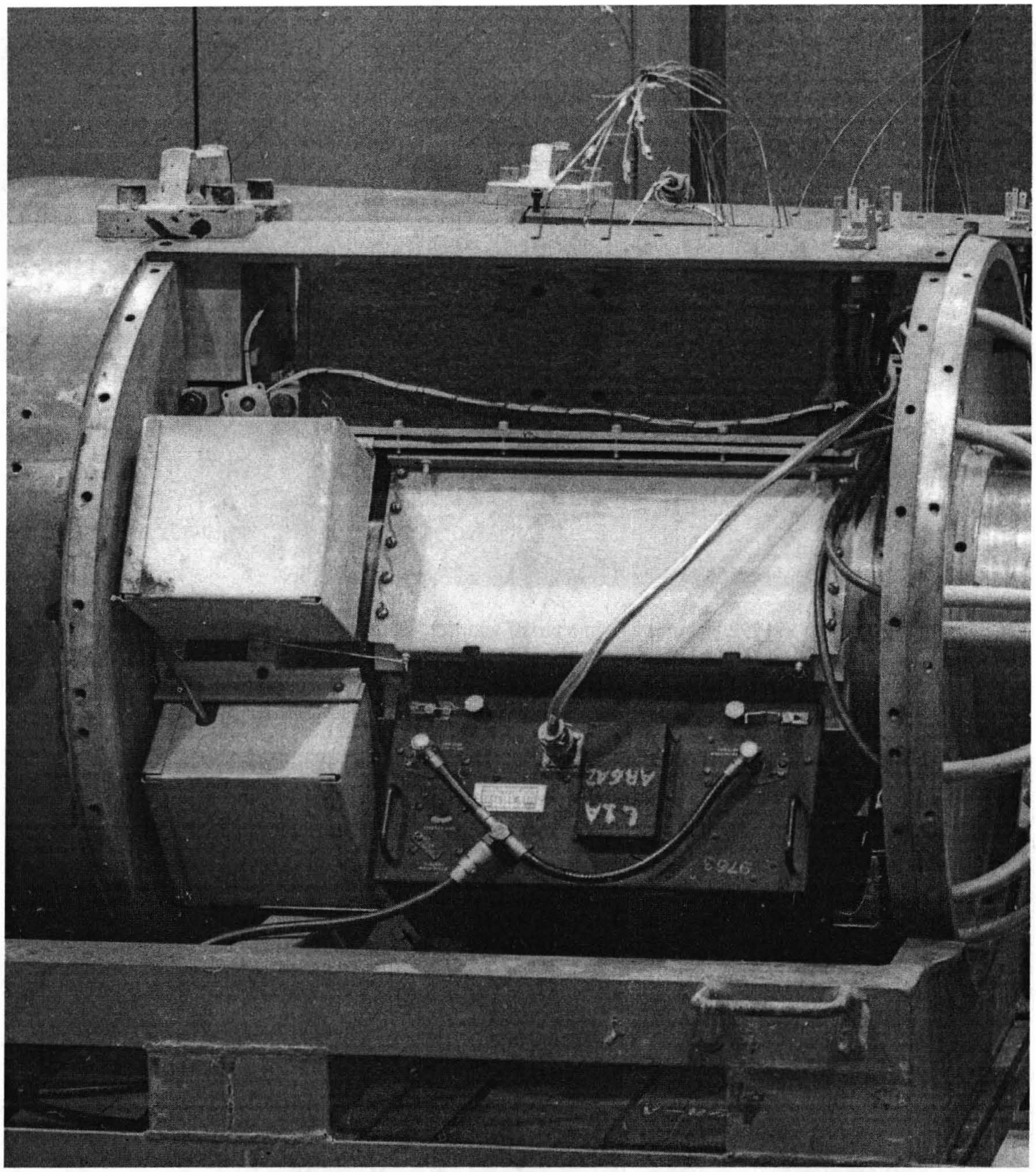
L-11 Hiroshima combat unit inside the Tinian assembly building the showing right side. (National Archives)



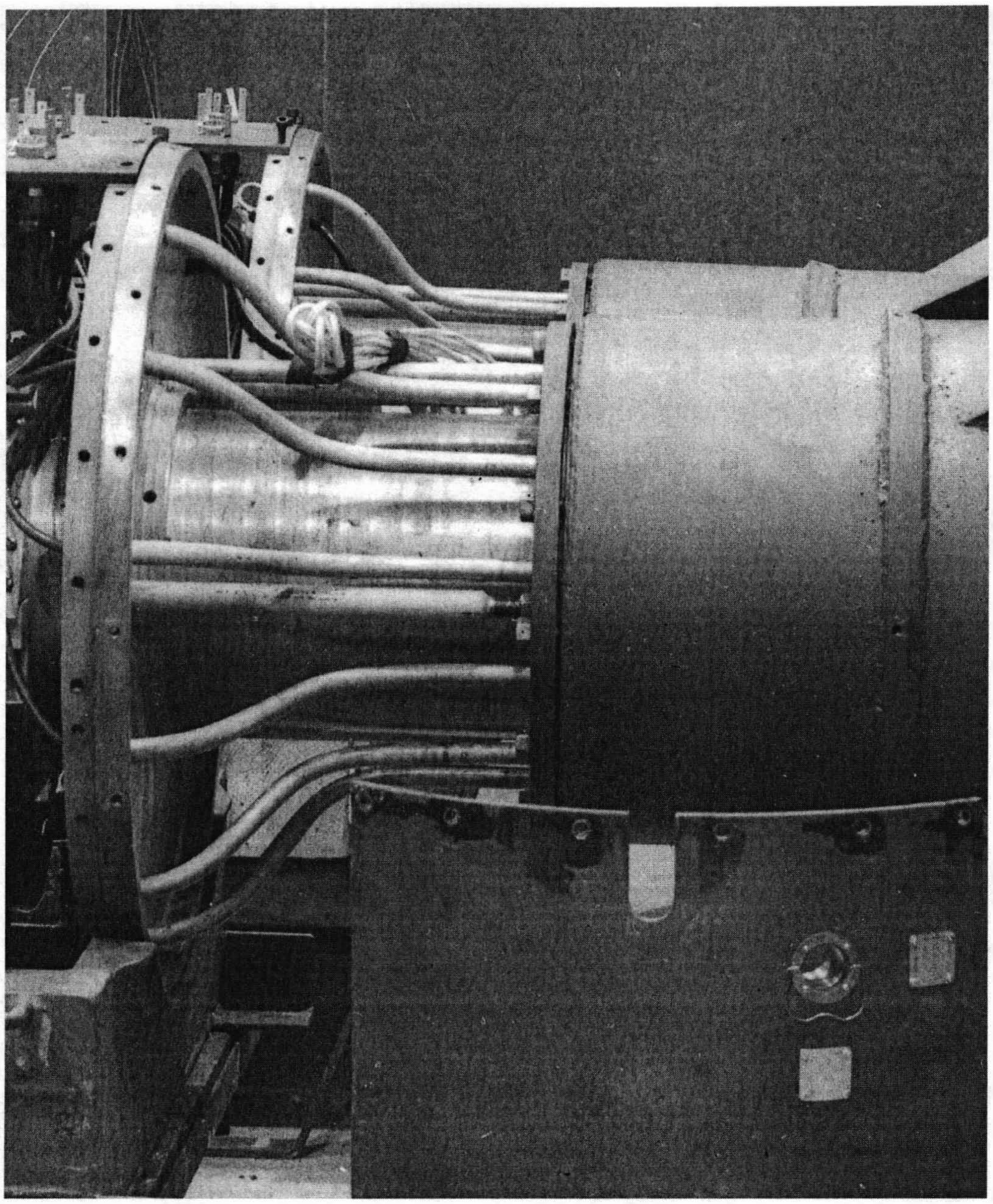
Completed *Little Boy* Y-1792 test unit L-1 in front of another test unit (L-2?) inside the Tinian assembly building. The 15" inner armor plate used inside the tail tube can be seen lying on the floor just below the tail of LB. The weight (8,555#) is painted on the nose. L-1 and L-2 were dropped over the Pacific on July 23 and 24. (LANL)



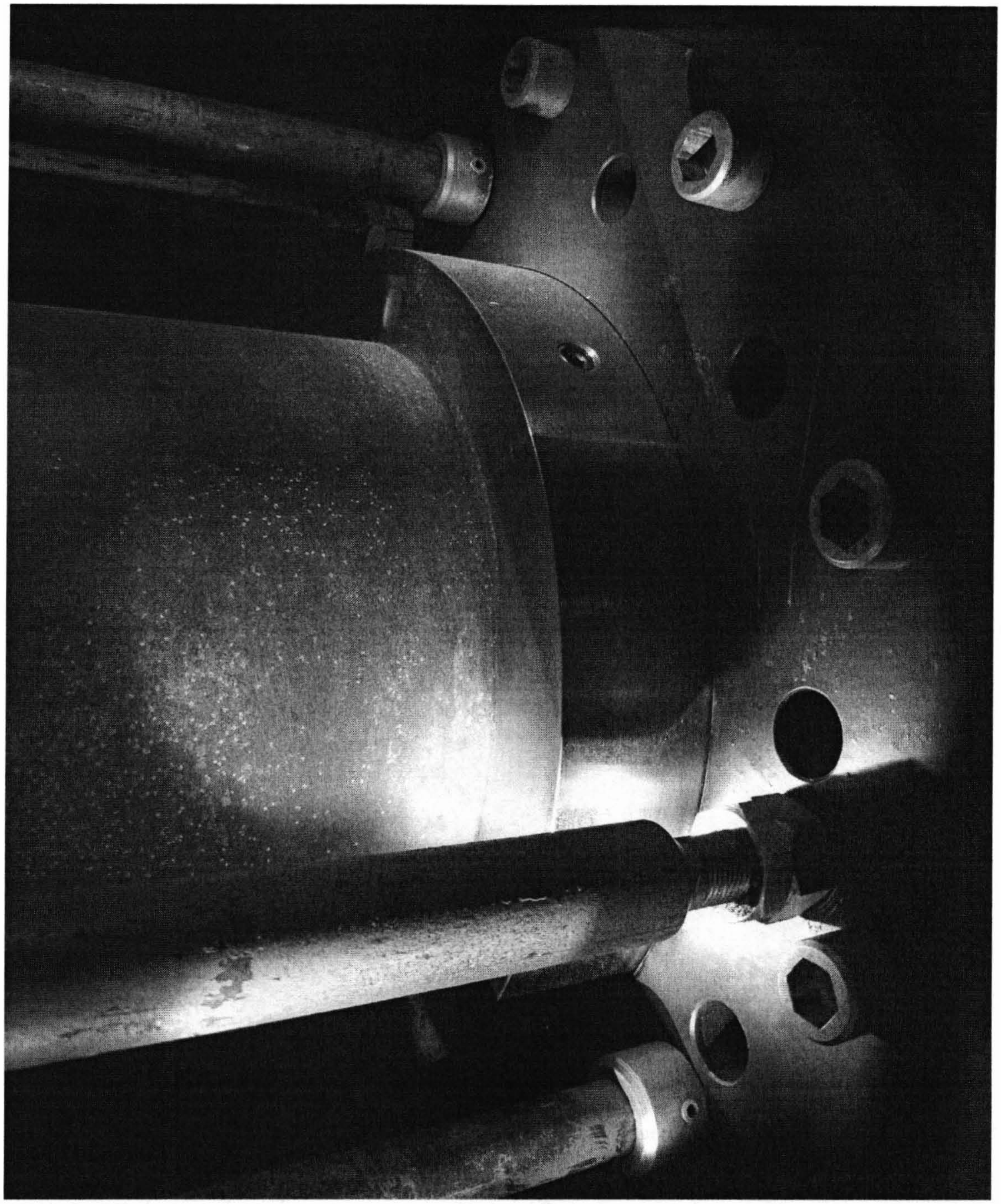
This is a photo taken earlier showing the partially-assembled test unit L-1 in front of the other test unit without the side panels and tail cone plates attached. Only the lower APS-13 radar unit has been installed at this point. This photo also gives a good view of some of the bent-metal conduit tubes encircling the gun tube that were used to run wires from the electrical equipment back into the tail tube. Some of the wires can be seen entering these tubes just to the left of the large bulkhead plate. The baro switches and tubing have also not been installed. The cast metal Yagi radar housings are lying on the wood platform just under the nose. (LANL)



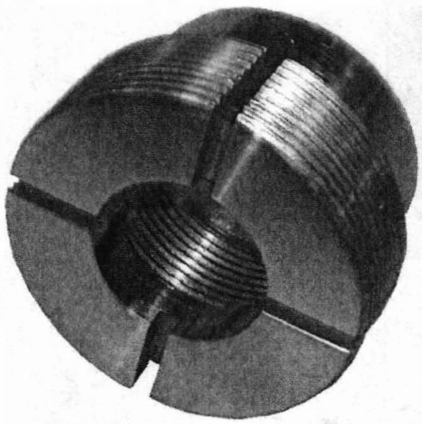
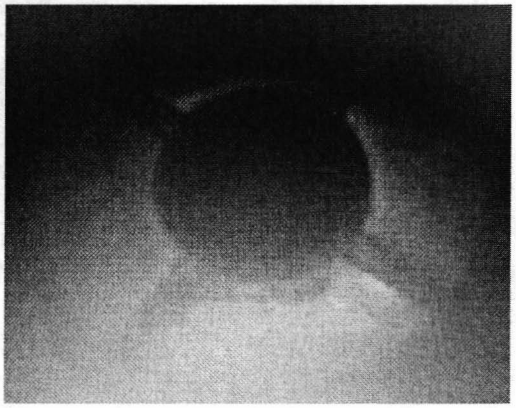
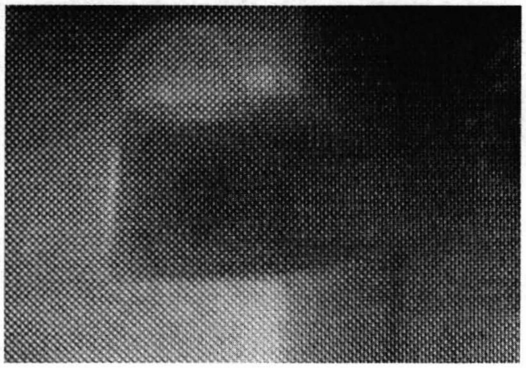
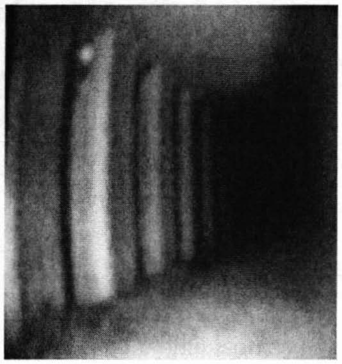
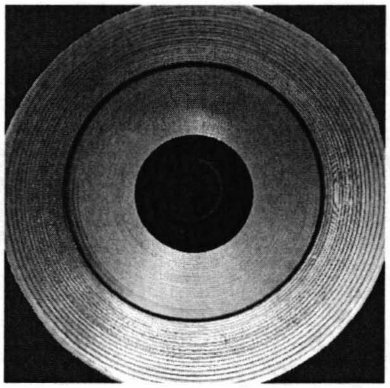
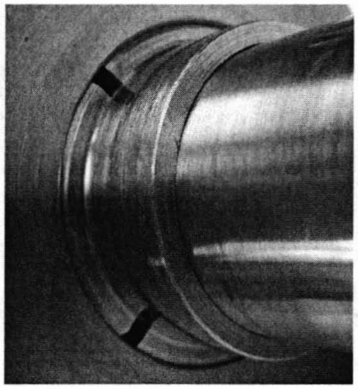
Here is a close-up view of the electronics section of the partially-assembled L-1 test unit. APS-13 unit #9763 has been installed and the white rectangular plate above it (note the safety wires) was where the next APS-13 radar unit was to be mounted. On the left are two of the four heated radar unit battery boxes. The two split-ring brackets that these boxes were mounted to can be seen just above the upper box and between the boxes along with the steel mounting block for the lift lug. In fact, with the exception of this steel mounting block, everything else shown here was mounted to brackets that were secured around both the gun tube and the target-case to gun-tube adapter. The dark felt-covered clock box is shown at the top and the pullout wires can also be seen just above the top plate along with the three electrical connectors. The metal tabs on these electrical connectors were attached to the plugs in the B-29 that fit into these connectors. The black cable that went to one of the four Yagi antennas is shown attached to the APS-13 unit. (LANL)



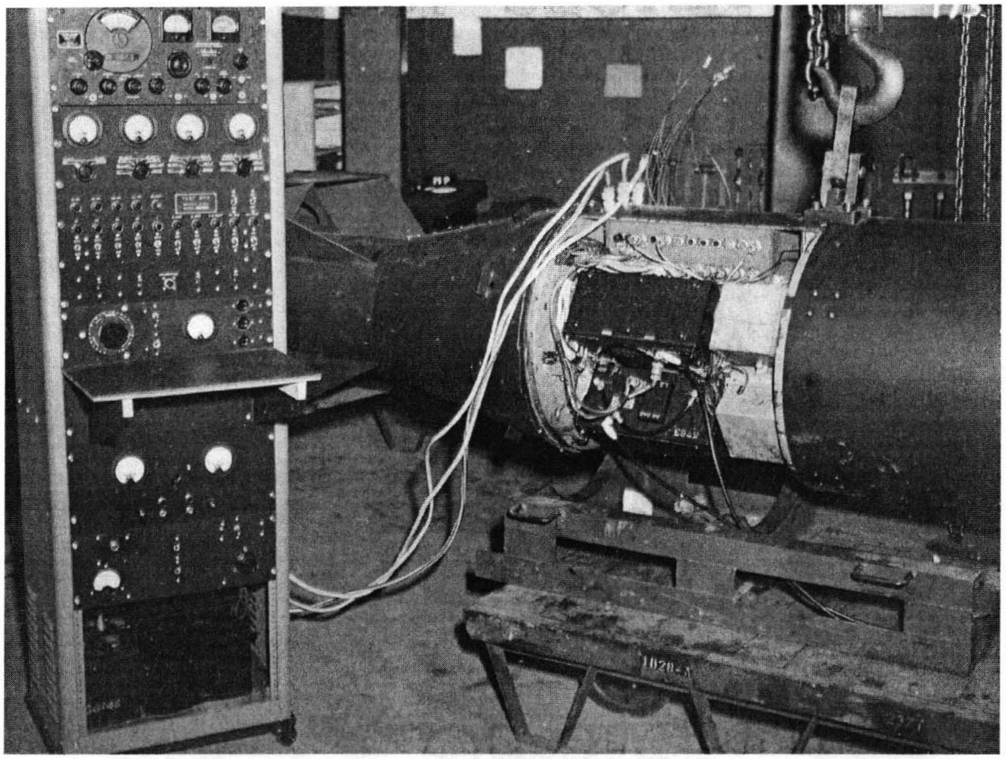
This close-up view shows the large bulkhead plate on the left. The cone-shaped metal covers (not shown) were later attached to both this bulkhead and the large tapered collar surrounding the tail tube on the right side. The 10.5" diameter gun tube is visible along with the collar that secured it to the bulkhead. This collar (w/setscrew) was, in turn, bolted to the bulkhead. The bent-metal conduit tubes are shown connected to both this bulkhead and the 16.5" diameter plate that was bolted to the forward plate welded on the end of the tail tube. In addition, one of the three straight rods is visible in the center that secured the tail to the bulkhead. It has a tapered end on the right side that is secured with two threaded nuts (only one visible) to the 16.5" plate. Only one breech wire conduit tube was needed on this test unit and it is visible at the very top of the gun tube collar. One of the large central exterior armored plates is standing on its end on the floor just in front of L-1. After it was attached, the cable from the APS-13 radar unit was snaked through the u-shaped hole on the upper end of that plate to the metal Yagi housing bolted to the nose of the weapon. Only one safing plug was used on this test unit and the metal clip for that plug is seen hanging down from the collar surrounding the plug hole while the two remaining holes are covered with metal plates. (LANL)



Here is a close-up view of the 16.5" plate on the publicly-displayed stockpile unit at the Wright-Patterson USAF Museum in 2008. For comparison purposes, this photo shows the same side as the previous L-1 photo. Two of the three threaded straight rods with the tapered ends and two nuts securing them to this plate are visible at the top and bottom along with two of the three breech wire conduit tubes with locking collars. Four of the twelve large bolts used to secure this plate to the welded plate on the front of the tail tube are visible along with four of the ten 0.75" holes for the bent-metal conduit tubes. For security purposes, the original gun tube had been replaced earlier by the DOE with a section of 8" pipe. The steel bushing surrounding it fills in the gap between the original 10.5" O.D. gun tube and the smaller 8" diameter pipe. (Author)

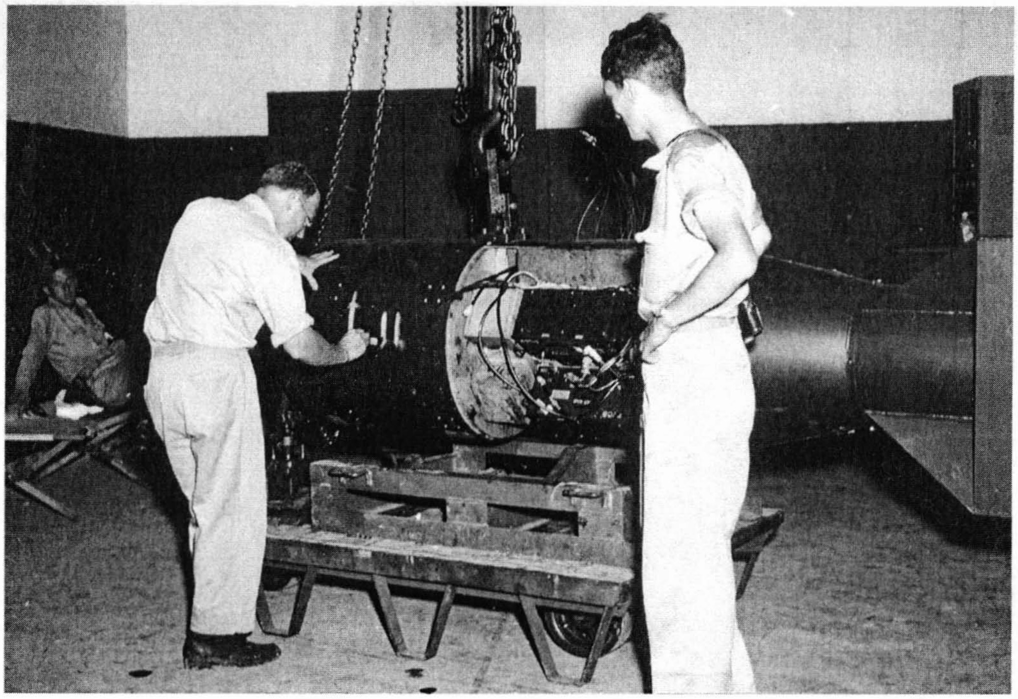







The top left photo shows a target-case to gun-tube adapter. The three exclusive screen-capture images taken inside the target case of the stockpile unit at the Imperial War Museum in 2008 using a Rigid SeeSnake® micro inspection TV camera show the adapter. The top right photo, looking rearward toward the aft end of the target case, shows the 14" wide front face of this adapter with the four vent slots machined into the surface at 90° intervals and the 6.5" opening for the projectile to pass through. Some of the air pushed forward by the projectile was vented into these slots as it entered the target case. The projectile passed out of the gun tube directly behind this adapter, through this hole, and into the WC tamper liner assembly (which had been previously removed prior to placing this unit on public display). The left middle photo, taken from inside the 6.5" hole, shows a 90° side-view close-up of a vent with the target case inner wall visible on the right while the right photo shows the inside of an end vent located at the outside end of one of these slots. Some of the Acme threads on the inside of the target case where the adapter was attached can be seen on the left side of this photo. The bottom left photo shows the LB nose with the nose nut removed and the WC tamper liner assembly installed in front of the adapter. The right photo shows the rear of the target case with the vent outlets on the adapter and the front of the gun tube. The battery boxes, split-ring brackets, and radars are missing. (Author)



L-11 Hiroshima combat unit in the Tinian assembly building shown connected to the electronic monitoring equipment. With the side panel off, the clock box (top), APS-13 radar units (dark) and battery boxes (white) are clearly visible inside the bomb. (National Archives)

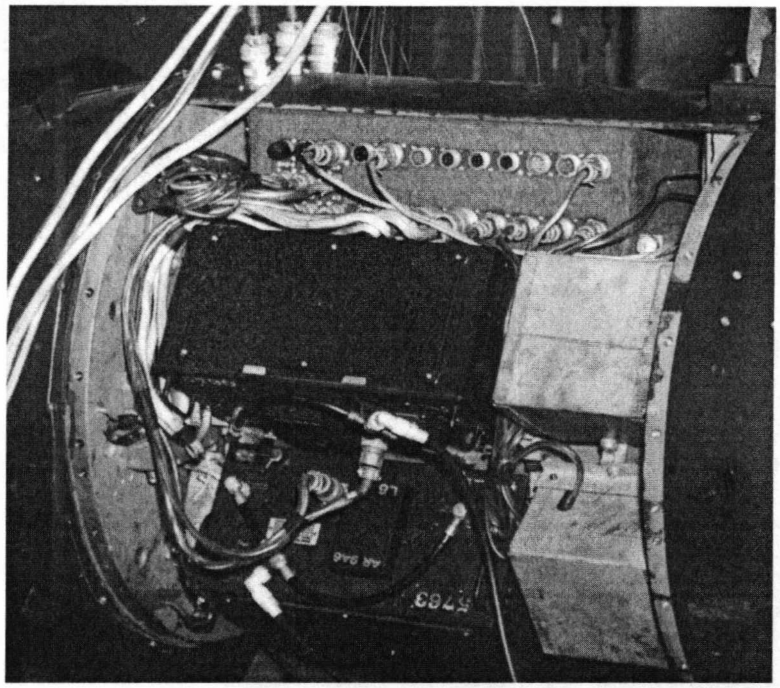
This is what the same Tinian assembly building looked like in August 2005. The structure itself was torn down by salvagers decades ago. What remains is the concrete floor and wall footings surrounded by dense jungle growth. The tape measure represents the placement of the LB unit in the 1945 photo. The area in the upper photo hidden behind the equipment cabinet is the double door leading to the outside concrete apron. The opening for that door is shown on the left side of this photo. (Author)



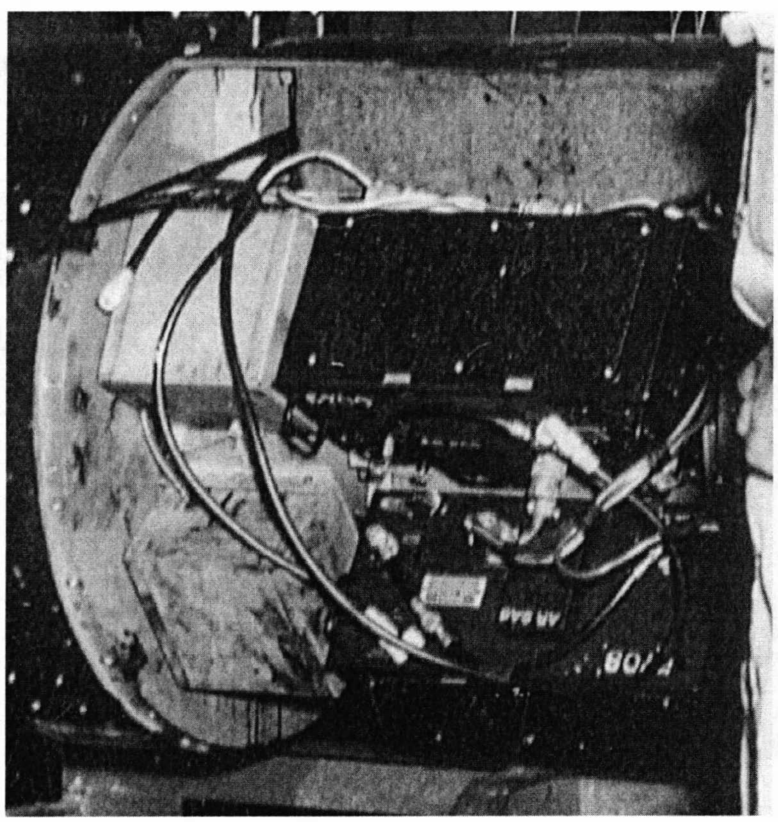
Hiroshima combat unit in Tinian assembly building. Navy Commander A. Francis Birch (l) is painting L-11 on target case while Norman Ramsey (r) looks on. Note the MP sitting on the cot in the background. (National Archives)

Here is the same area in 2005. The small concrete pad in the background is where the air conditioning structure was located. The tape on the floor represents the position of L-11 in the upper photo. (Author)

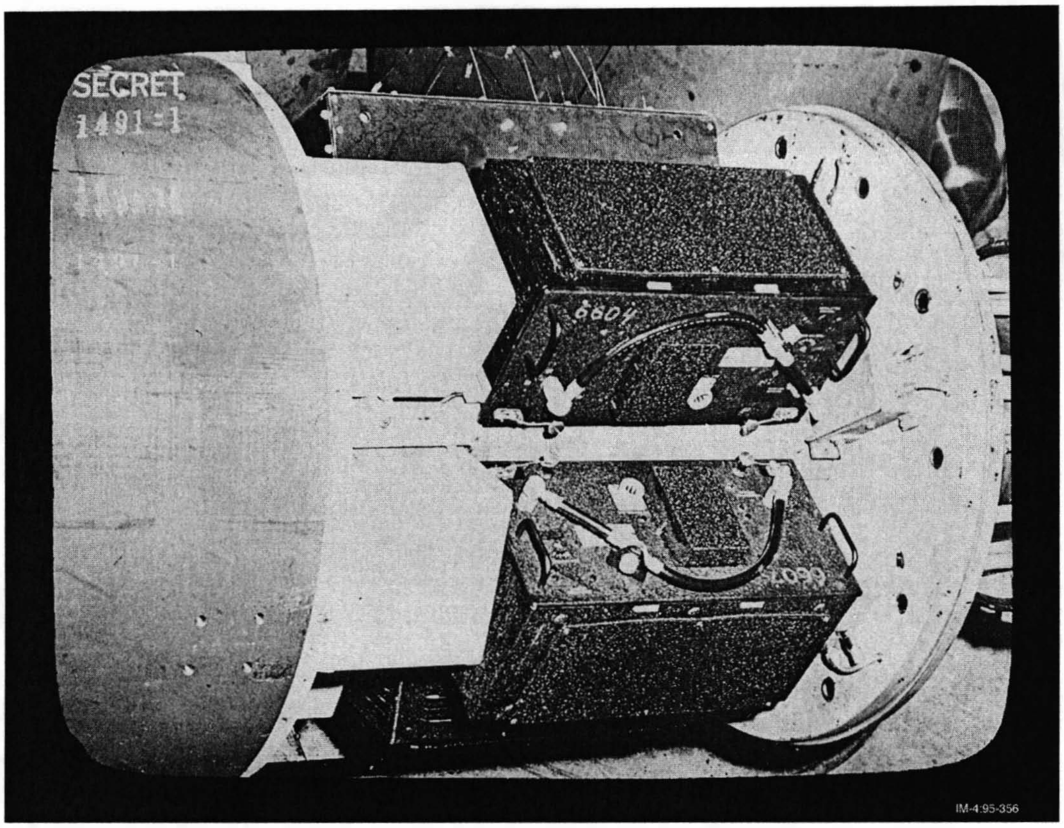
These photos taken in 2005 show the 14 gauge (below) and 15 gauge (above) copper grounding wires embedded in the concrete floor of the *Little Boy* Tinian assembly building. The mottled area on the floor in these photos is the result from the rusting of the iron filings cast into the concrete when it was poured back in 1945. (Author)



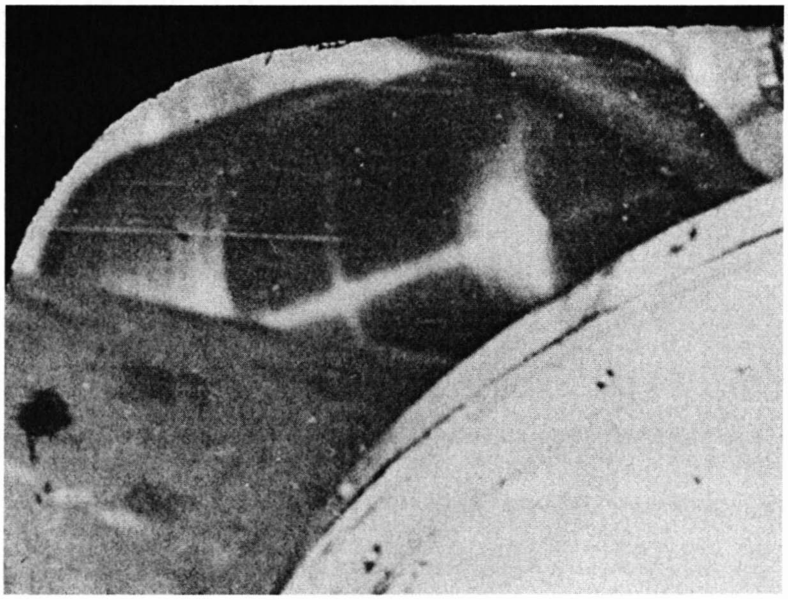
Close-up of L-11 Hiroshima combat unit with the starboard side panels off. (National Archives)

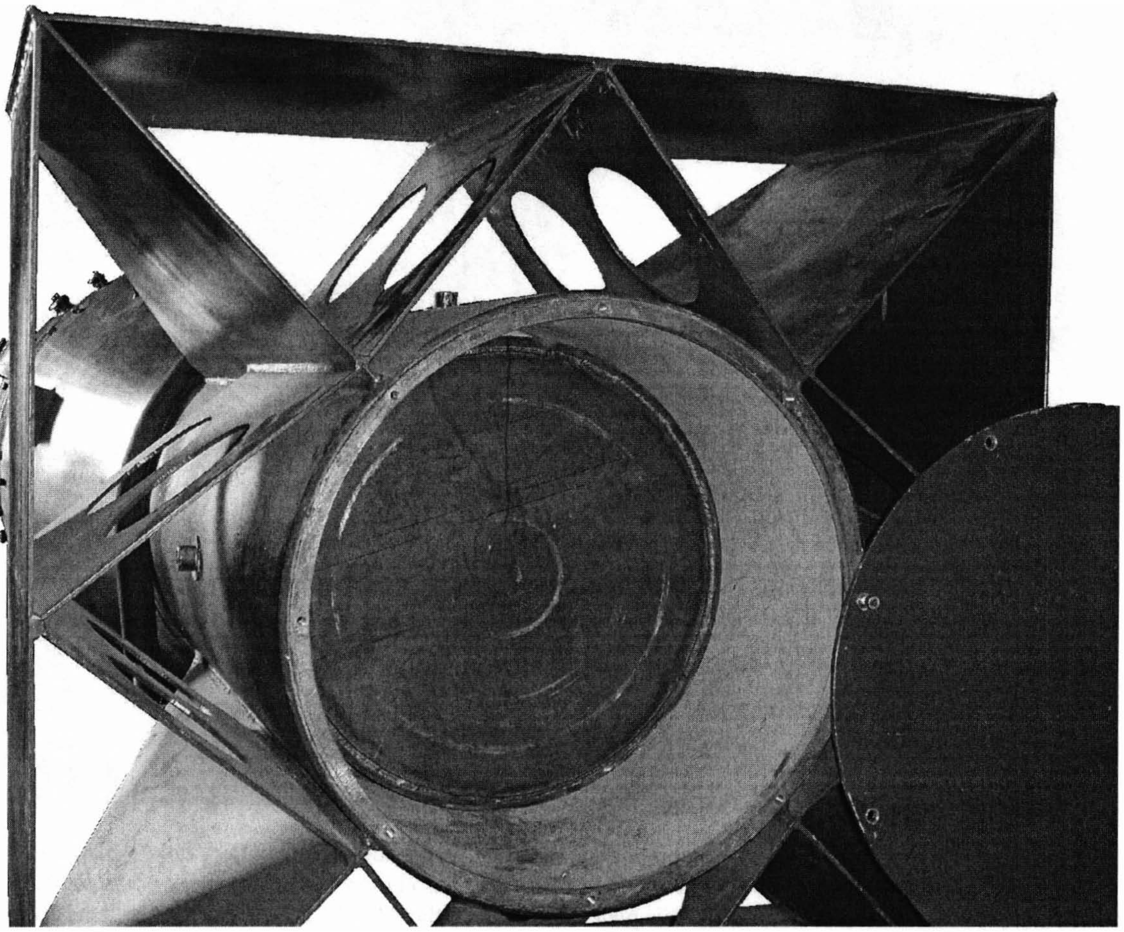


Close-up of L-11 with the port side panels off. (National Archives)

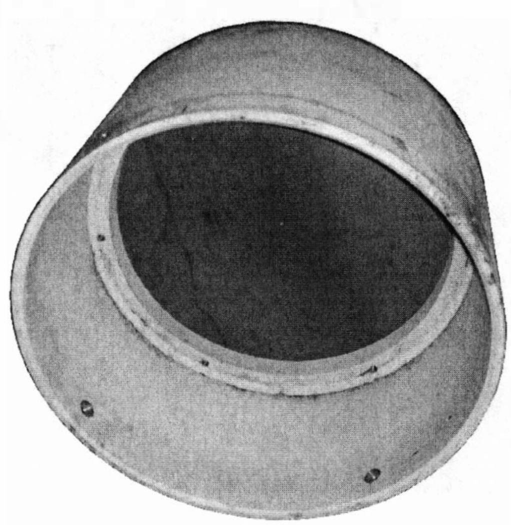


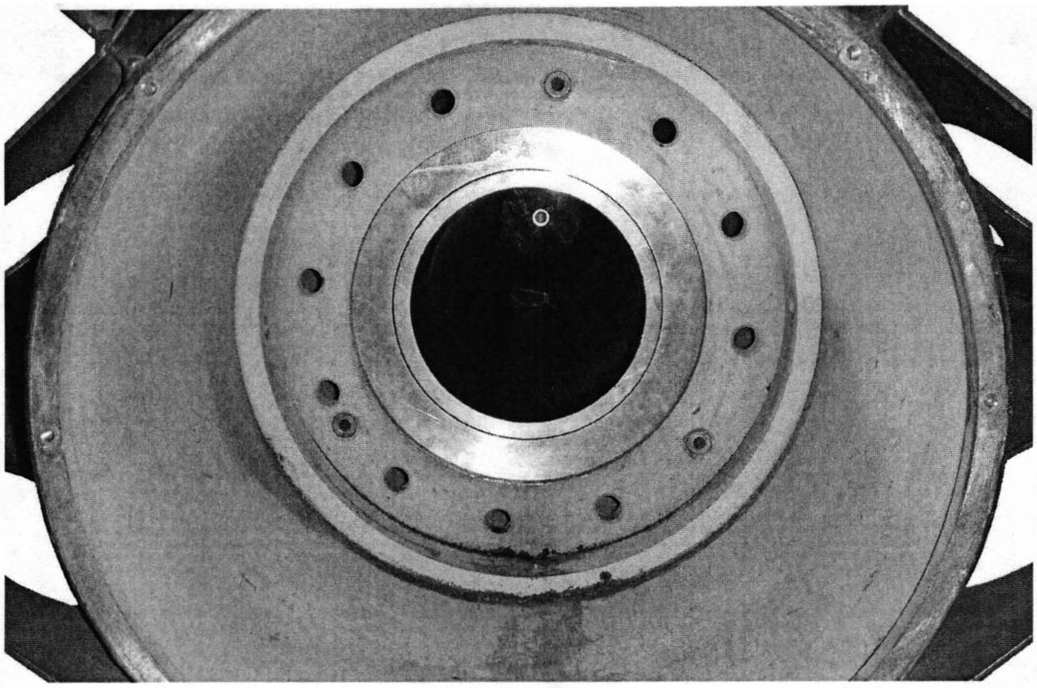
This close-up view inside a *Little Boy* test unit shows (l-r) the target case, white battery boxes, black APS-13 proximity radar units, and center-bulkhead plate with white baro boxes installed and six of the ten 0.75" diameter conduit holes also visible on this plate. Wires from the APS-13 radars and baro switches were passed through these holes and then out through to the tail during the testing phase. The Clock Box can be seen at the top with pullout wires. The silver-colored object in the upper right corner is the breech plug (detail below showing Acme threads and rounded nose). (LANL)



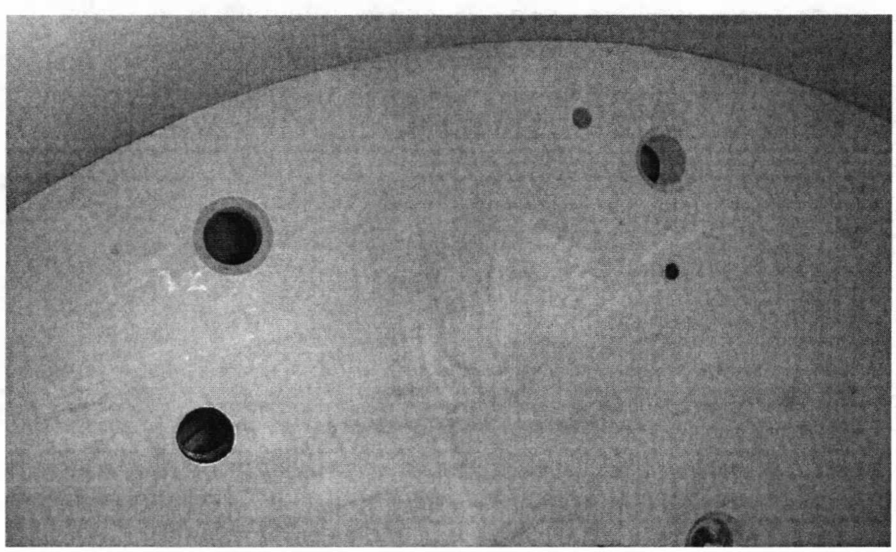


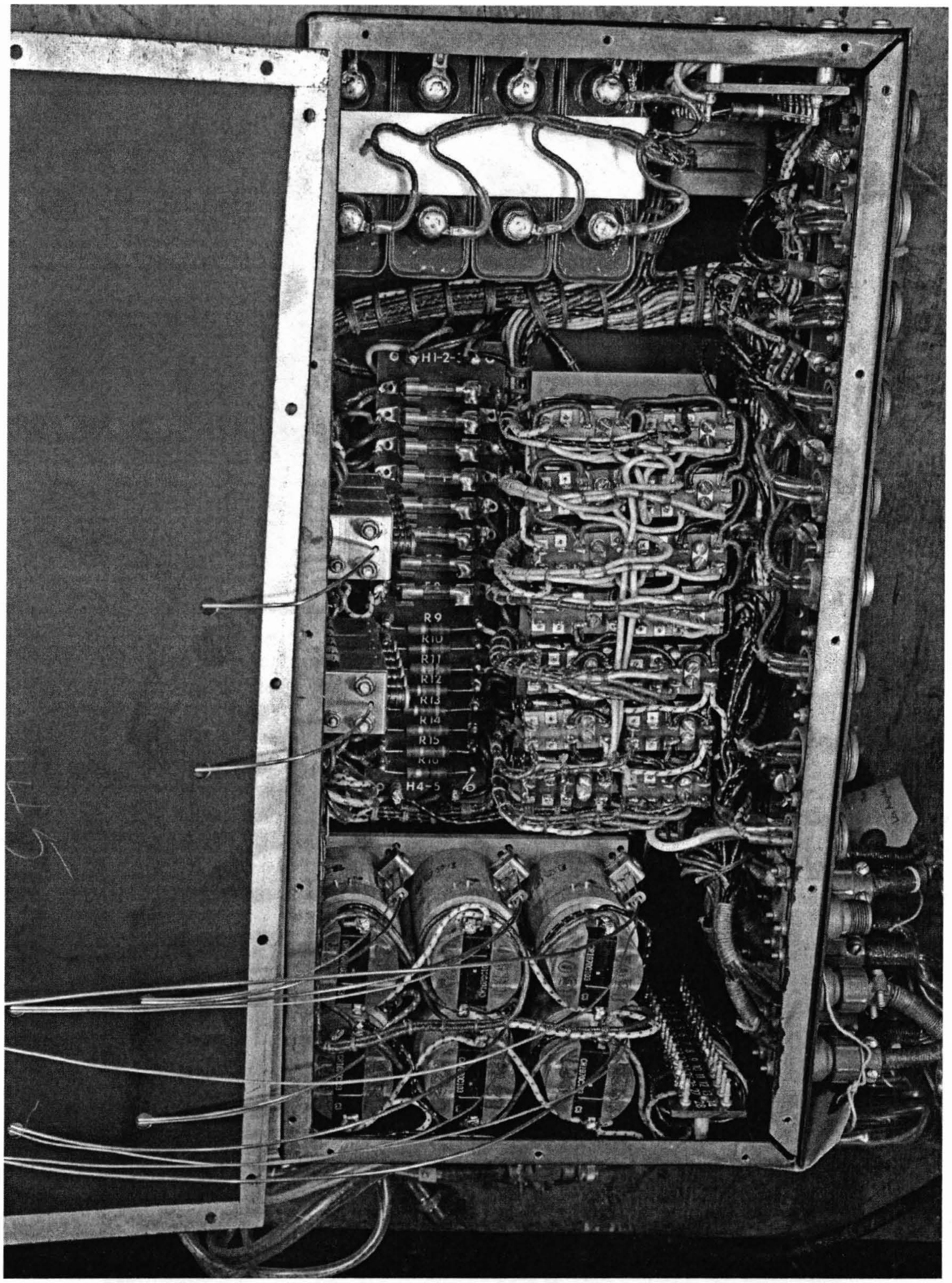
This is the view of a postwar stockpile LB showing the 17" diameter tail that Captain Parsons would have seen inside the *Enola Gay* bomb bay after he unbolted and moved the tail plate to expose the inner armor plate attached to the 15" diameter armor tube. The inside of this tube is shown below. The original armor plate itself was secured with six bolts to the inner flange in this tube, which in turn was attached with four 5/8" bolts to the aft tail plate. Two of those bolts are visible on the top and left side of the tail tube in the upper photo. (Author)



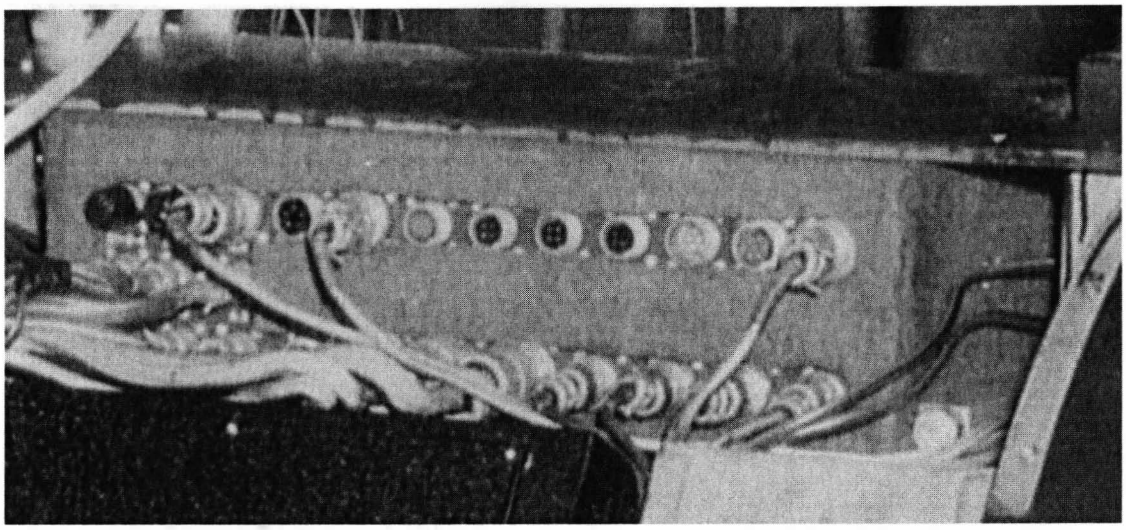


This is what the breech area looked like after the inner armor plate was removed by Parsons. The 15" armor tube it was attached to had been removed on this stockpile LB for the sake of clarity. The front end of this tube fit just inside the flange that is visible on the aft tail tube plate. During the testing phase, cables from the fusing instruments were passed through the ten 0.75" diameter holes shown here surrounding the gun tube on this plate and then hooked up to monitoring equipment in the bomb bay. The aft ends of the three 0.75" diameter armor tubes for the primer wires are located next to these ten holes. For security concerns, all classified material in this LB had been removed by the DOE before it was placed on public display. They removed the original 6.5" bore gun tube (with the two-piece breech plug) and replaced it with a length of standard 8" steel pipe. A steel bushing now fills in the gap between the gun tube and the 10.5" diameter hole in the aft plate where it had been originally positioned. The view below of the large bulkhead plate shows two of the ten 0.75" holes at the top and the forward end of one of the primer wire tubes at the lower right. The bent-metal conduit tubes are not installed on this unit and thus not attached to the upper 0.75" holes. (Author)

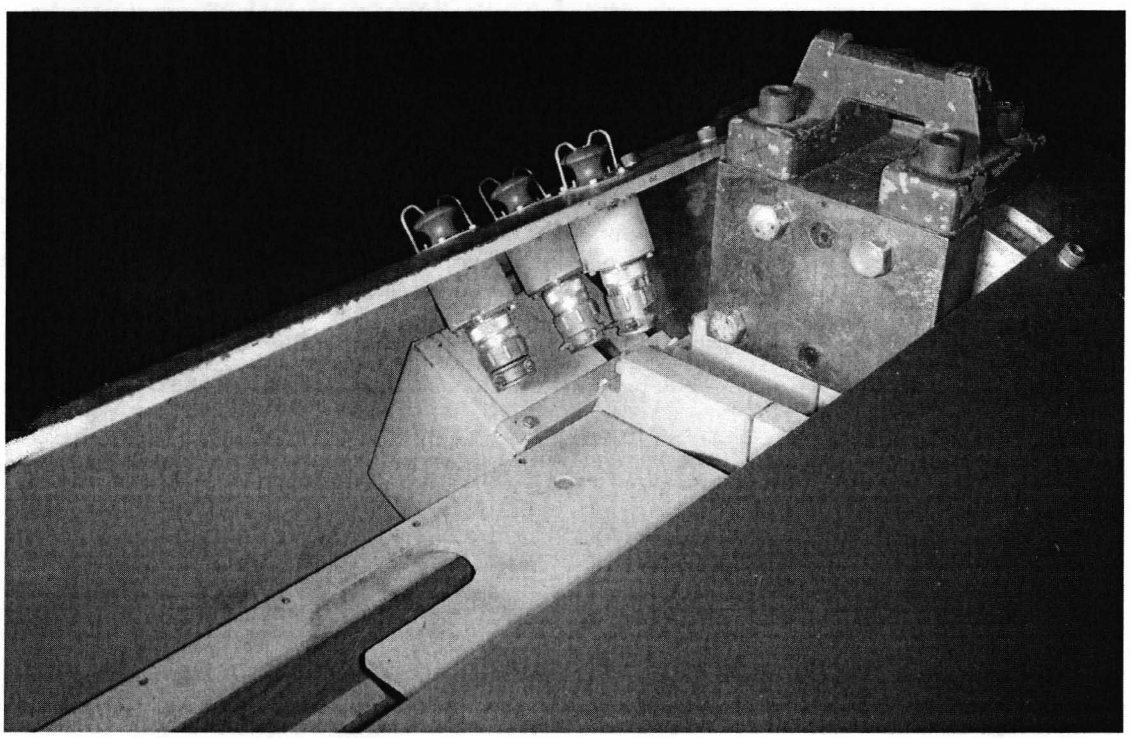




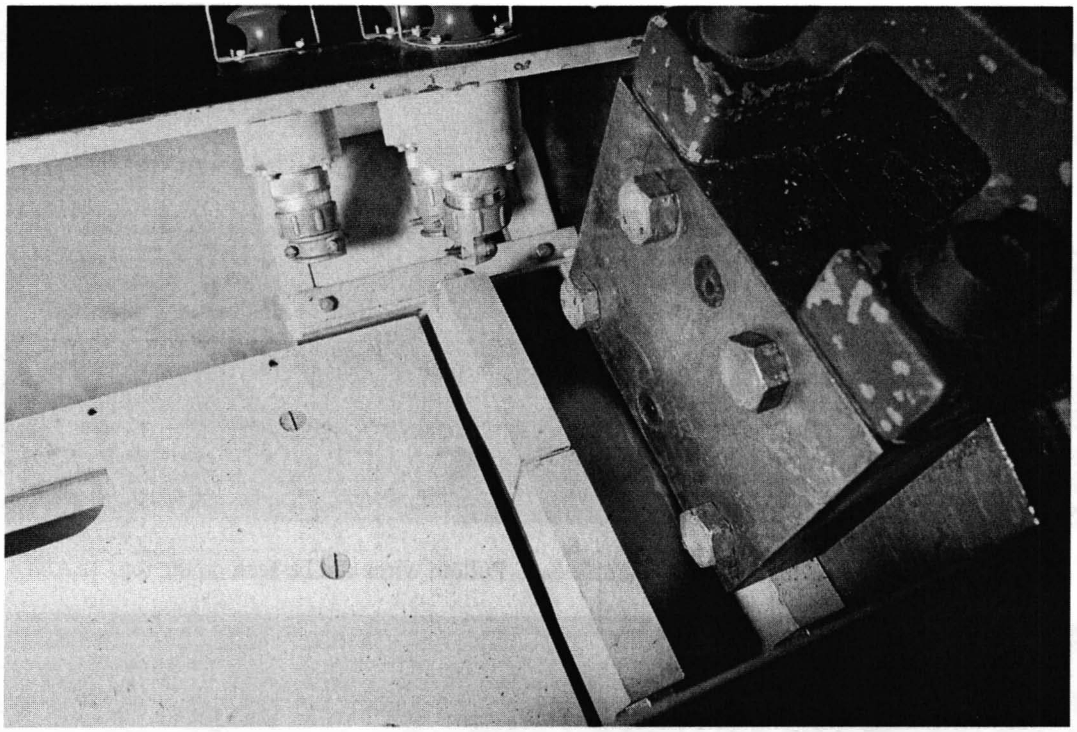
Clock Box showing the pullout wires extending though the holes on the underside of the lid. The six 15-sec clock delay timers are shown at the bottom, the relays just above them, the fuses on the left side, the capacitors at the top, and all the electrical sockets on the right side. (LANL)



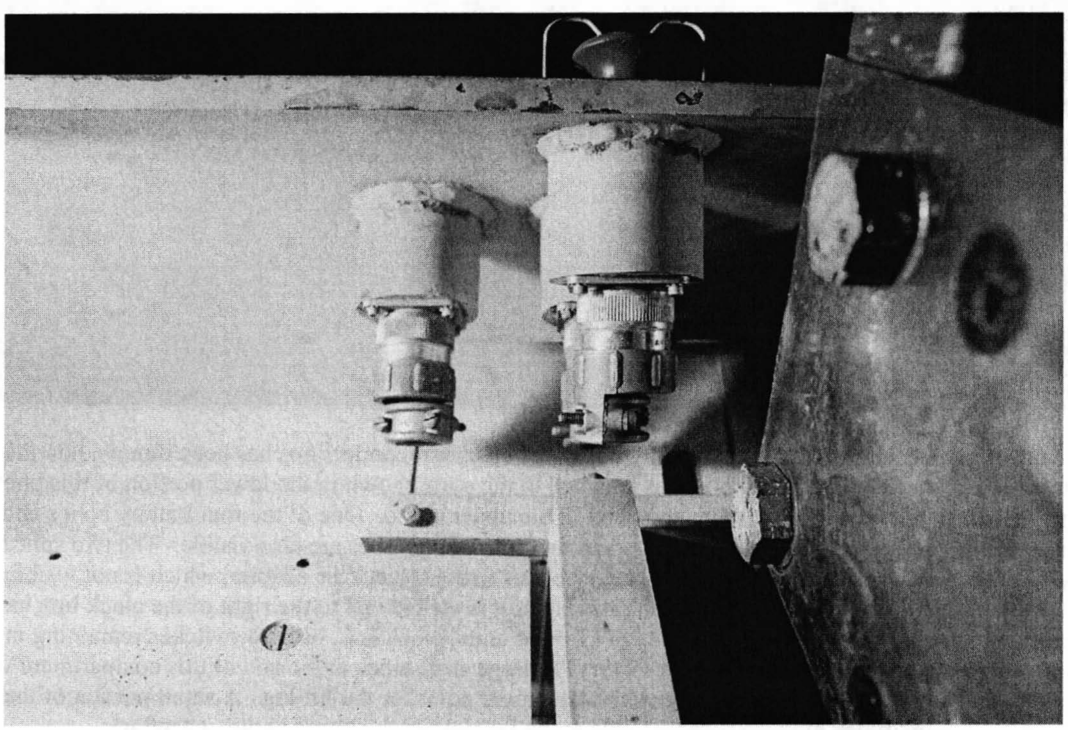
Felt-covered Clock Box inside the L-11 *Little Boy*. Pullout wires can be seen on the top. (LANL)

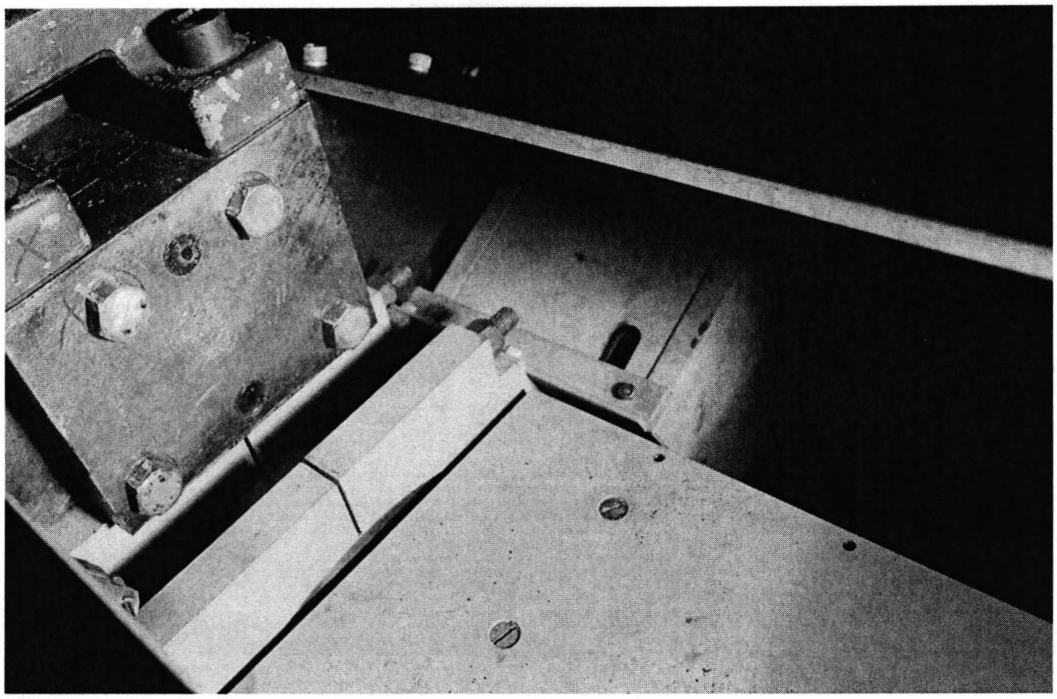


The upper plate containing the pullout wire holes and electrical connections has been removed on this LB to show the interior. The clock box was attached to the plate shown in the lower portion of this photo. This plate is barely visible under the clock box in the upper photo. One of the four battery boxes and the three safing/arming plugs electrical fittings and their mounting tubes are also visible. The two split-ring locking collars are visible that secured the battery boxes to the target case adapter, which is not visible here. The top of one of these collars with the tightening bolt is visible just to the right of the clock box in the upper 1945 photo. There are no longer APS-13 radar units, clock box, or baro switches remaining in this postwar stockpile unit manufactured in 1949. The large steel block at the end of this compartment was bolted to the target case and served as the aft attachment point for the lift lug. A small portion of the lug and block are also barely visible at the far right in the upper photo. (Author)

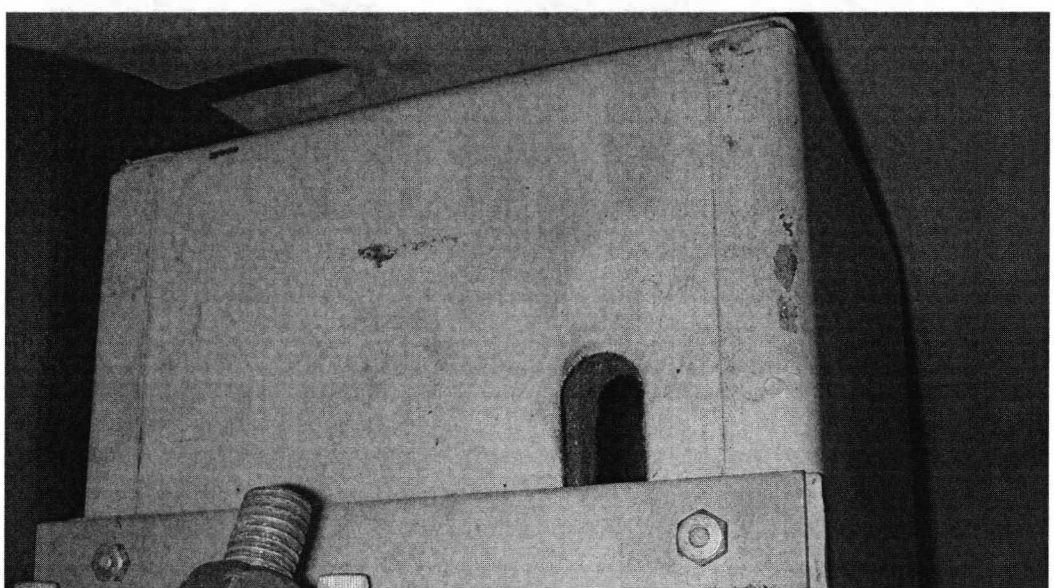


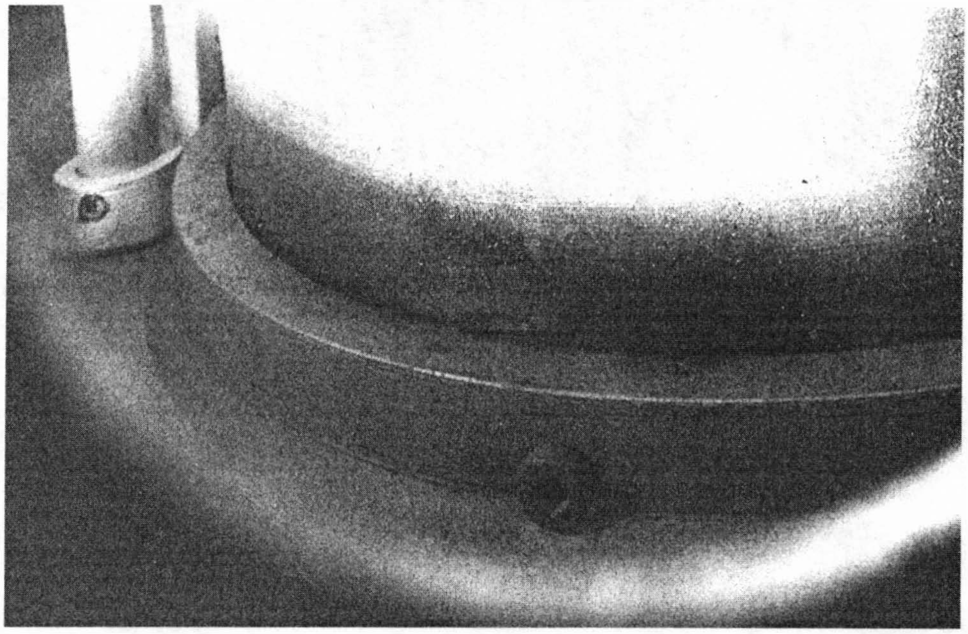
These photos show the rear surface of the target case, the steel block bolted to it that was used to attach the lift lug, the two split-ring brackets (one partially hidden under the lift lug mounting block) surrounding the target-case to gun-tube adapter (also visible between the brackets) that were used for attaching the battery boxes along with the clock box mounting plate, one of the four battery boxes, and the safing/arming plugs and their electrical socket connections. (Author)





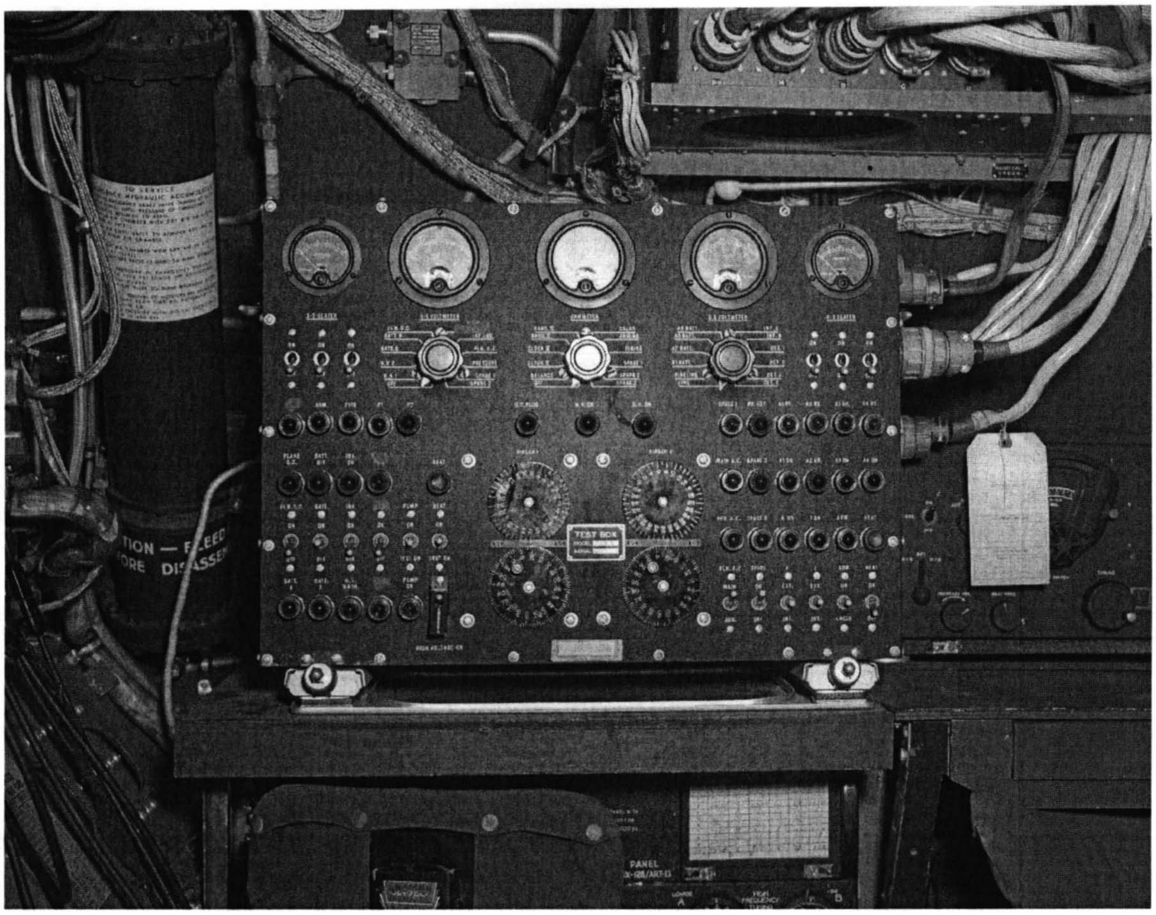
These two views show how the battery boxes were attached to the split-ring bracket by using a length of angle aluminum bolted to both the box and the bracket. Note the insulation that is visible inside the battery box. The long bolts are also visible that ran through a hole bored through the top of the split-ring brackets and the nuts that were then used to tighten down the brackets onto the gun tube adapter. (Author)



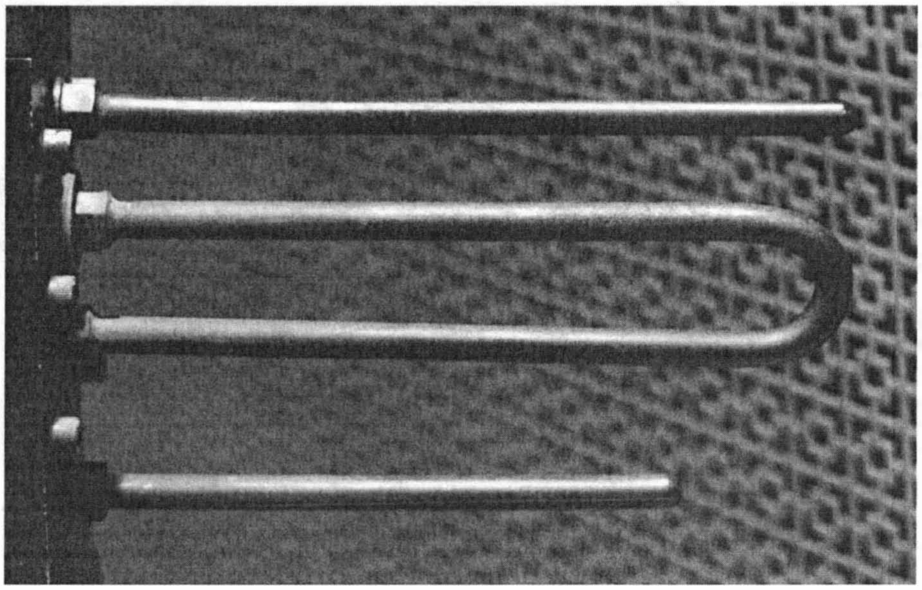


The original gun tube (top) and locking collar (below), with set screw at bottom, can be seen in this photo. The 0.75" diameter tube on the left with a locking collar was one of three tubes that contained the wires for the breech primers. Photo was taken in 1995 through one of the baro holes in the tapered tail section on the Wright-Patterson LB before it was "restored" in 2004. (Author)

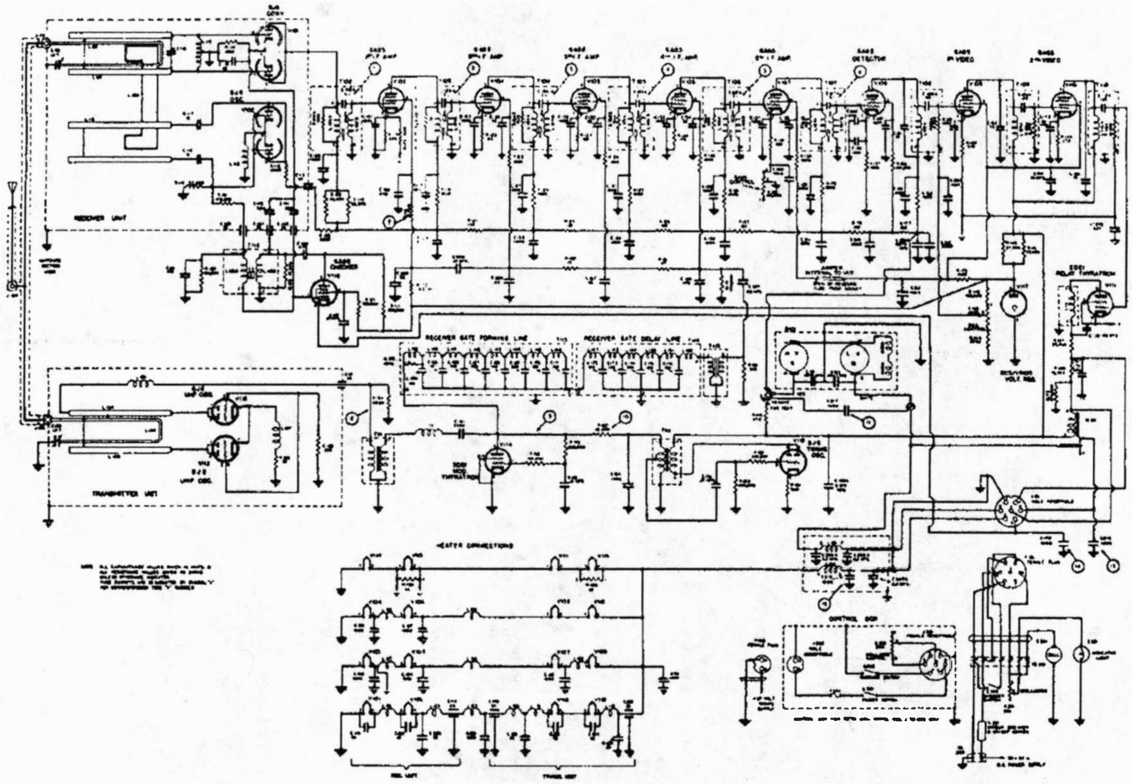
This photo shows the 8" steel pipe that the DOE later substituted for the original gun tube in this LB. The newly-manufactured steel filler bushing is visible between the pipe and the locking collar. The primer wire tube is shown on the far right and the 1.0" steel rod used to attach the tail section to the bulkhead plate is also visible in the foreground. (Author)



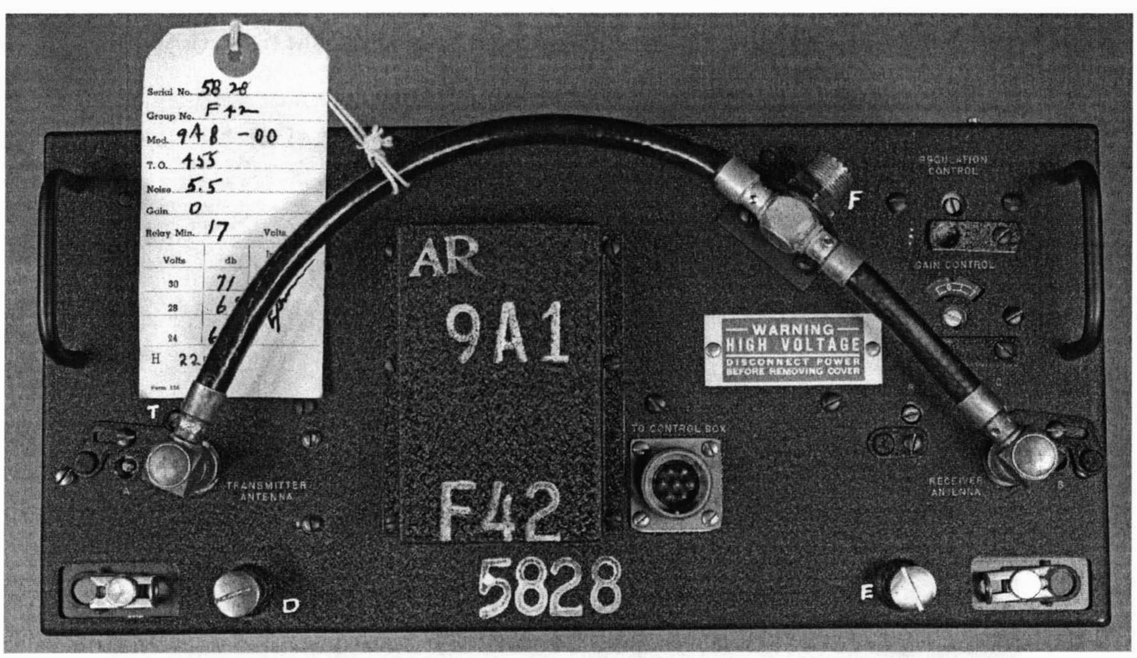
FTB mounted inside the B-29. The radio operators' station is to the right. (LANL)



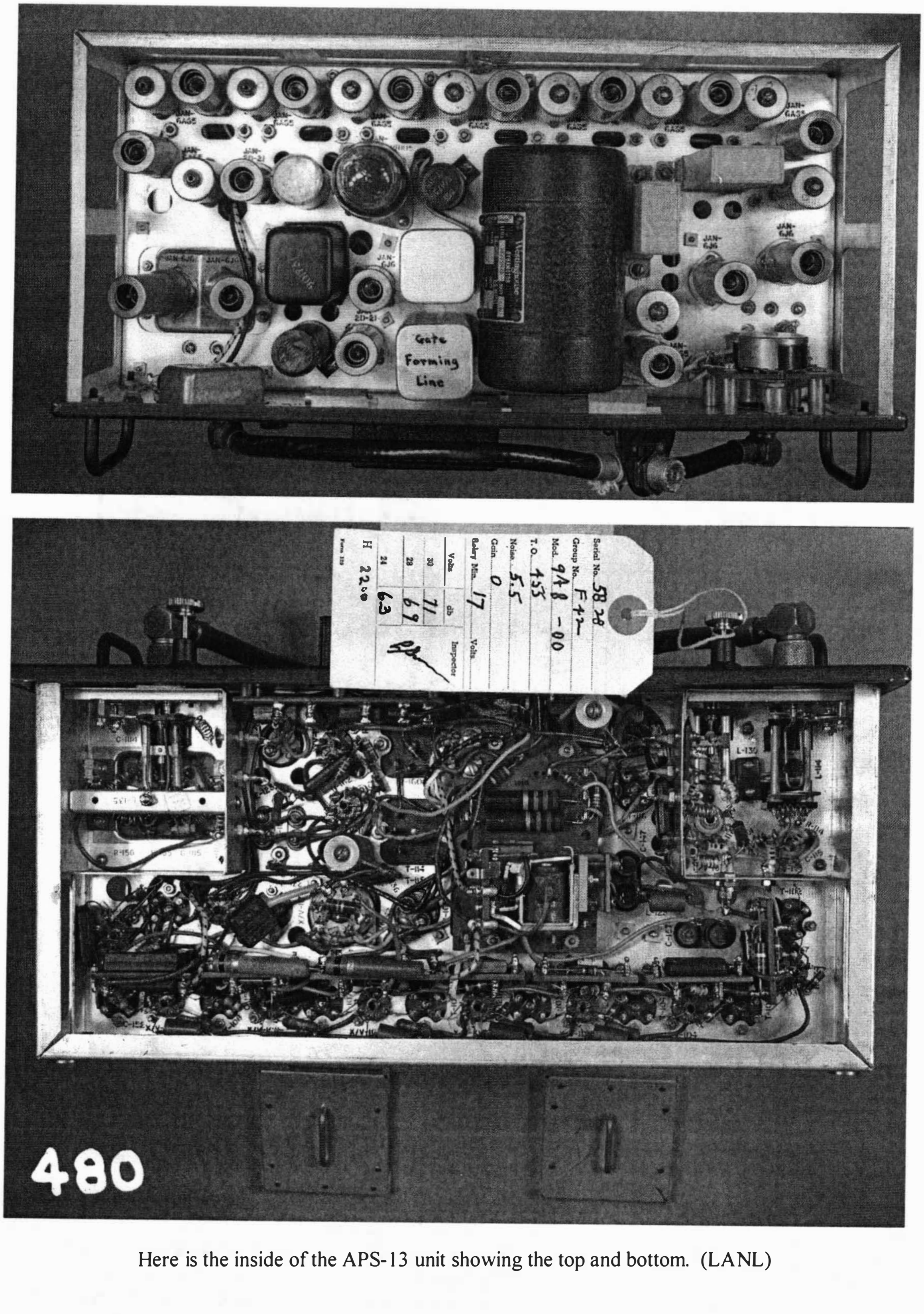
Yagi antenna as used on *Little Boy*. (Author)



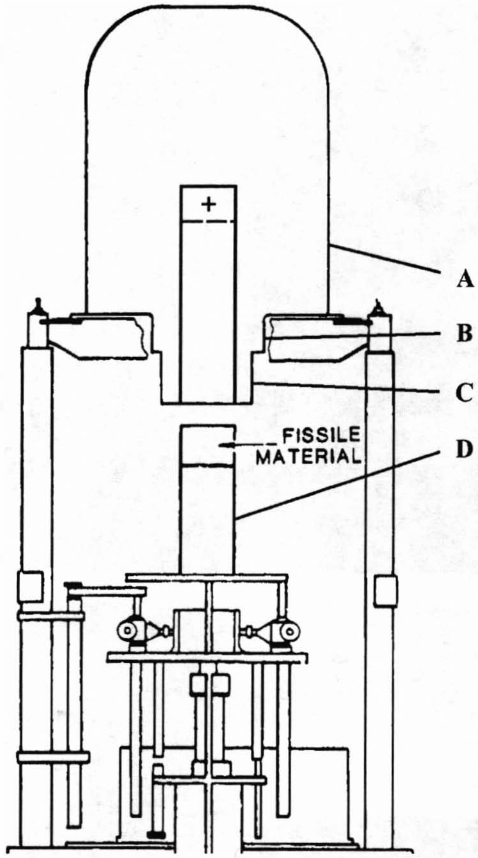
Wiring diagram for the standard APS-13 radar unit. The electrical circuit shown in this diagram was modified by Los Alamos for use in both bombs. (Courtesy of the Imperial War Museum)

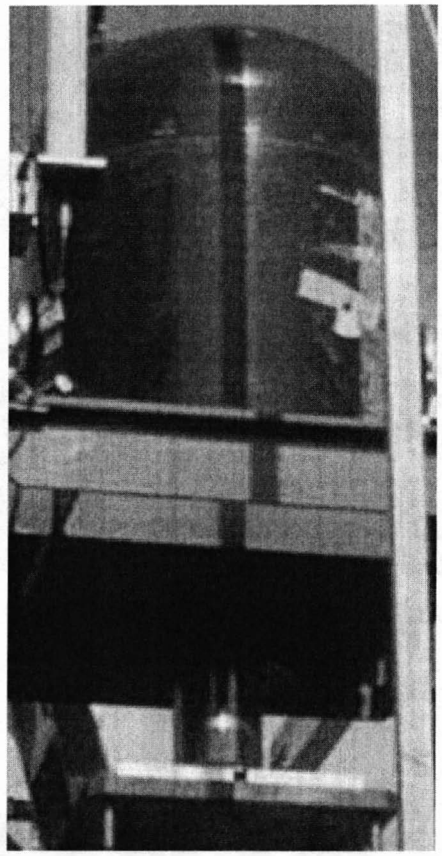


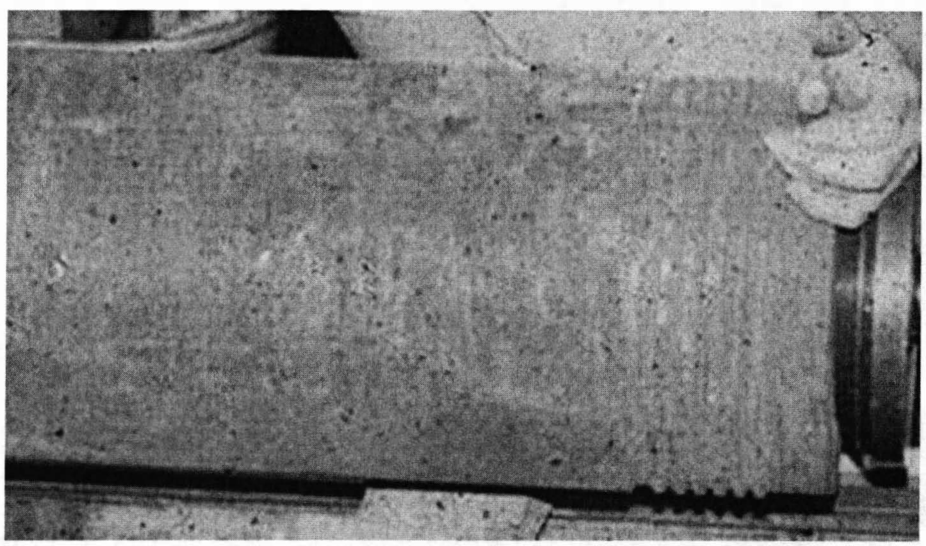
Front panel of the APS-13 unit used on both bombs. The antenna cable attached to the plug just above the "Warning High Voltage" label. The 7-pin electrical plug connected to the battery and clock box in both weapons. (LANL)



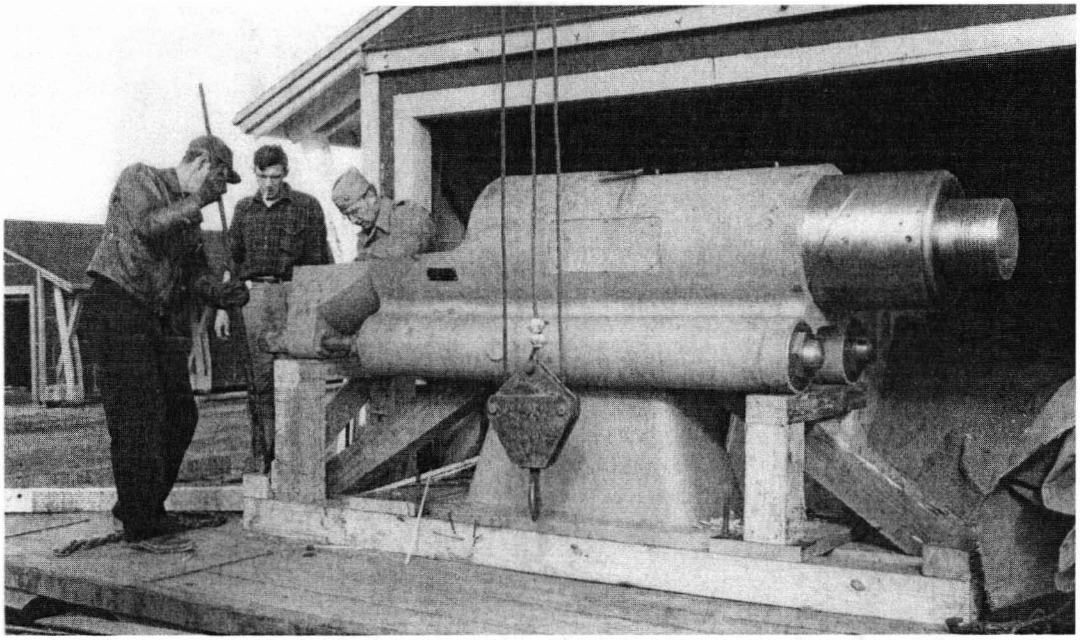
Here is the inside of the APS-13 unit showing the top and bottom. (LANL)



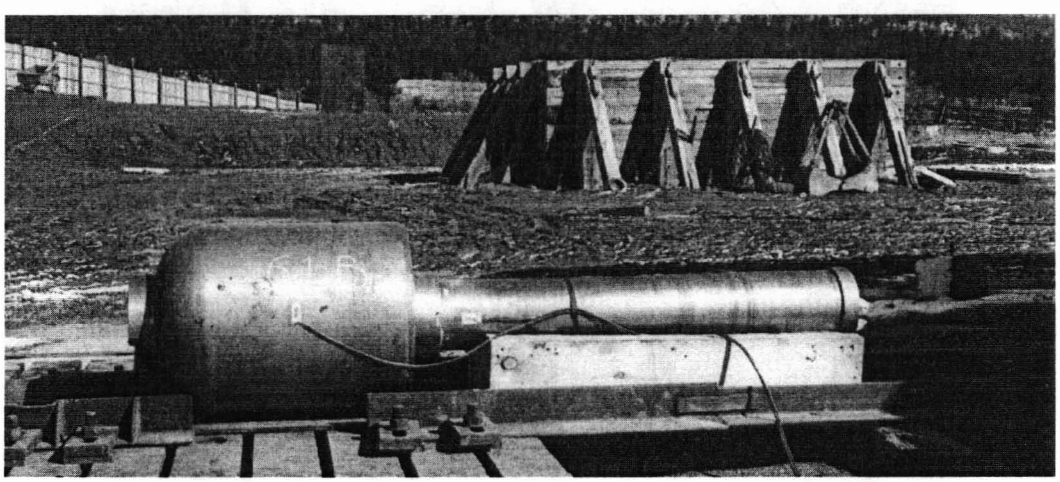




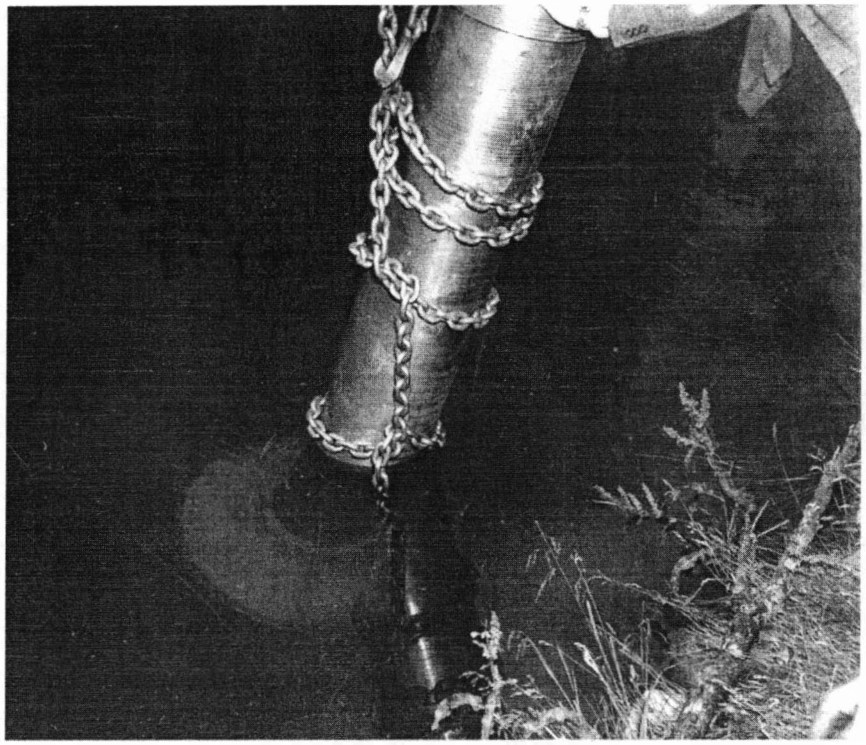
This Los Alamos drawing shows the 36" long target case (A) mounted vertically on the Comet Test Stand. The cross marks the core center. The target case adapter (B) is pictured at the bottom of the case along with a gun tube shortened to 10" (C). The projectile (D) was mounted on a hydraulic lift in order to raise it into the target case for experiments conducted as part of the *Little Boy* Replication Project. The photo next to it shows the actual experiment with the projectile at the bottom partially inserted into the gun tube. The bottom photo shows the original gun tube being prepared for shortening. The six Acme threads cut at two threads per inch can be seen at the front end of the tube where it had been attached to the adapter. (LANL)



Little Boy 6.5" bore gun tube (small tube inside larger 18" diameter tube seen on the right) being set-up for test firing a projectile in the free-recoil device at the Anchor Ranch test site. Note the two large tubes in the base to help absorb the massive shock during firing. Below shows a projectile being test fired at a target case.

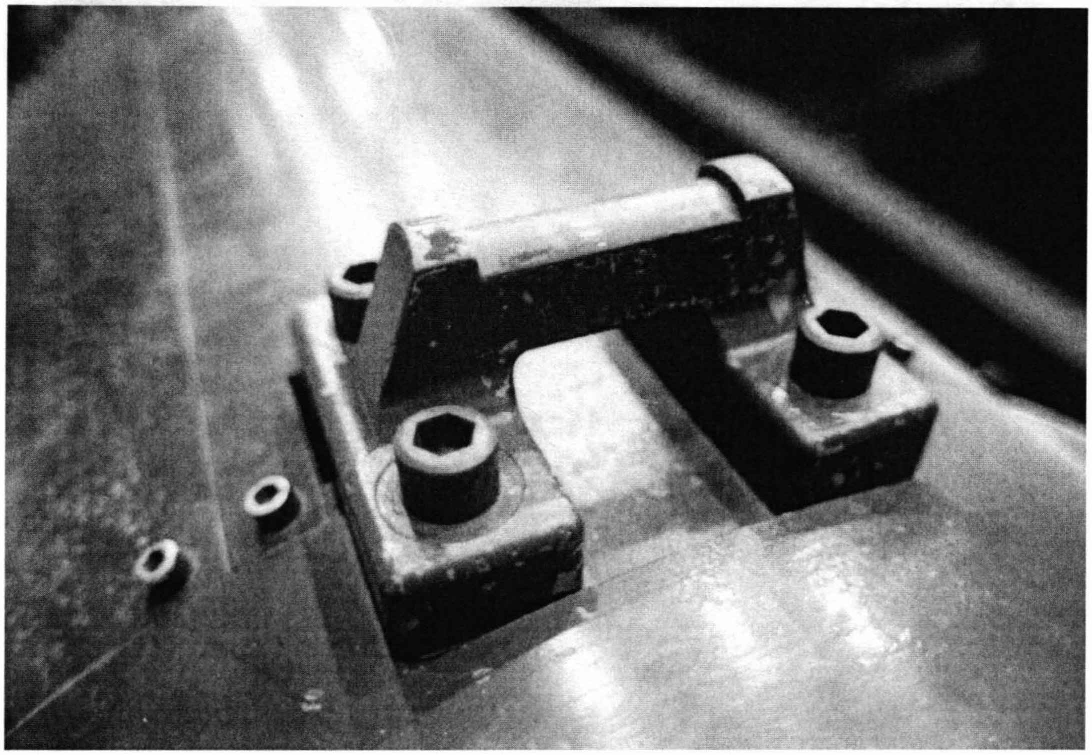


Little Boy target case attached to a gun tube at the Anchor Ranch. Note the sensors attached to both the gun tube and target case. The WC-filled, K-46 liner sleeve can be seen protruding from the front of the target case. The gun tube shown here was a tapered surplus naval gun barrel used for testing purposes. During the earlier test phase, the large, braced wood structure in the background contained sand and was sometimes used to hold the target case when it was not attached to the gun tube. The separate structure (not shown) containing the gun tube was to the far right. (LANL)

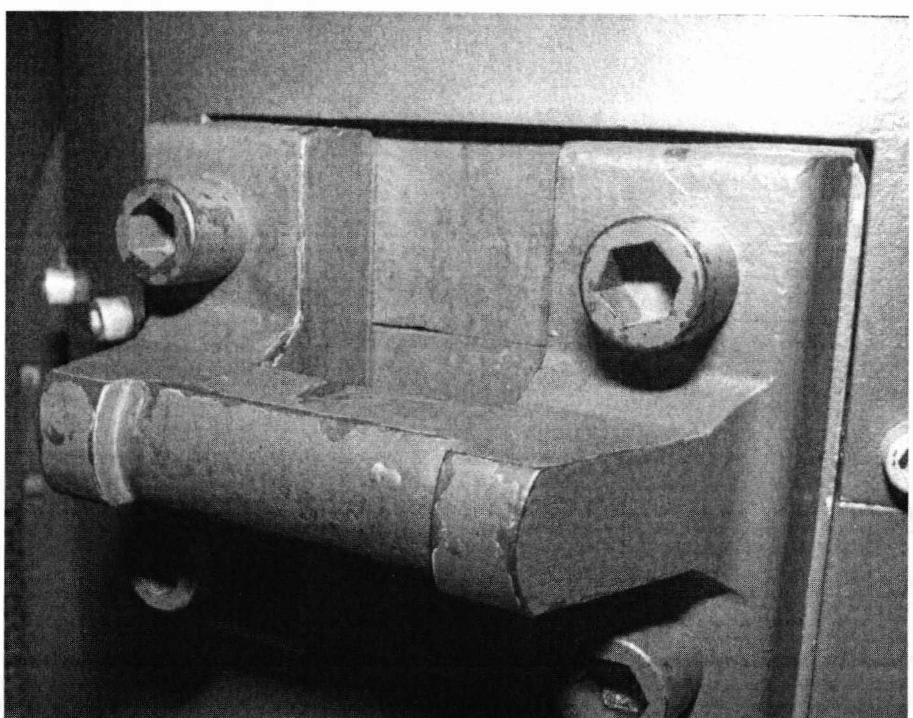


Little Boy gun tube attached to a target case shown submerged in a pond at Los Alamos to test for water leakage through the vent seals at the back of the target-case to gun-tube adapter. Note the scientist (with tie) at the top peering down the gun tube to check for the presence of water in the target case. Two of the four seals are barely visible underwater at the 6 and 9 O'clock positions on the aft end of the target case and the exposed surfaces of the uranium were plated with 0.005" of cadmium for safing the gun in case of immersion in water. (LANL)

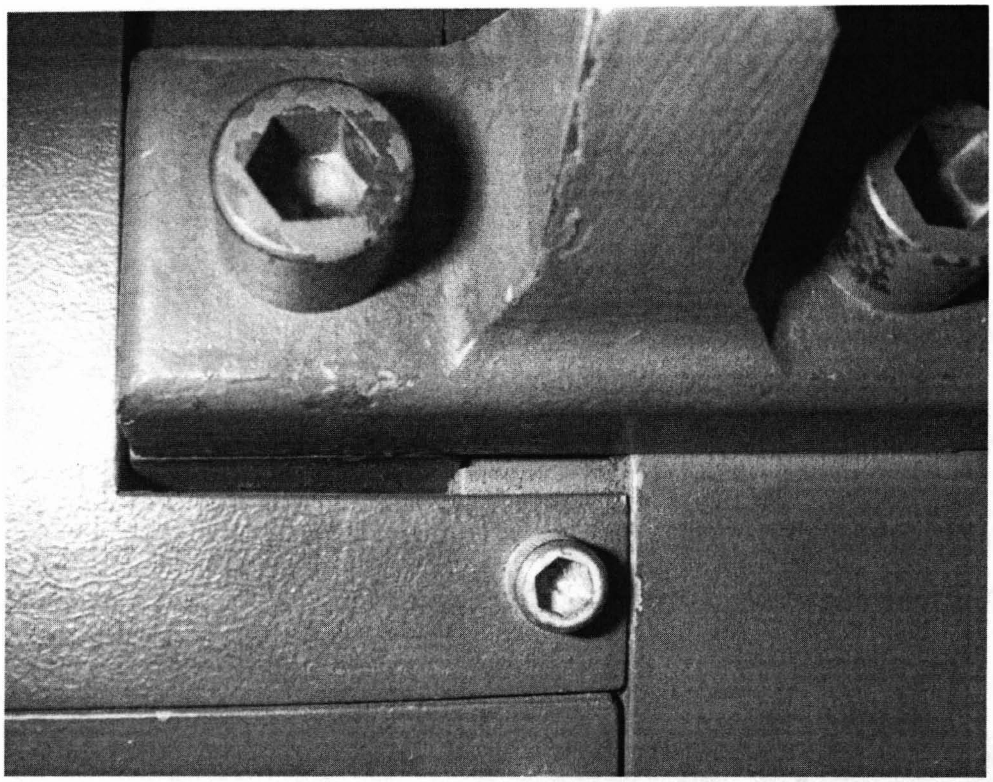
These are the three lead-lined steel cases used to transport the six U-235 target insert discs that arrived on Tinian August 28 and 29. Each case contained two discs. The scientist is shown securing the lids. (LANL)



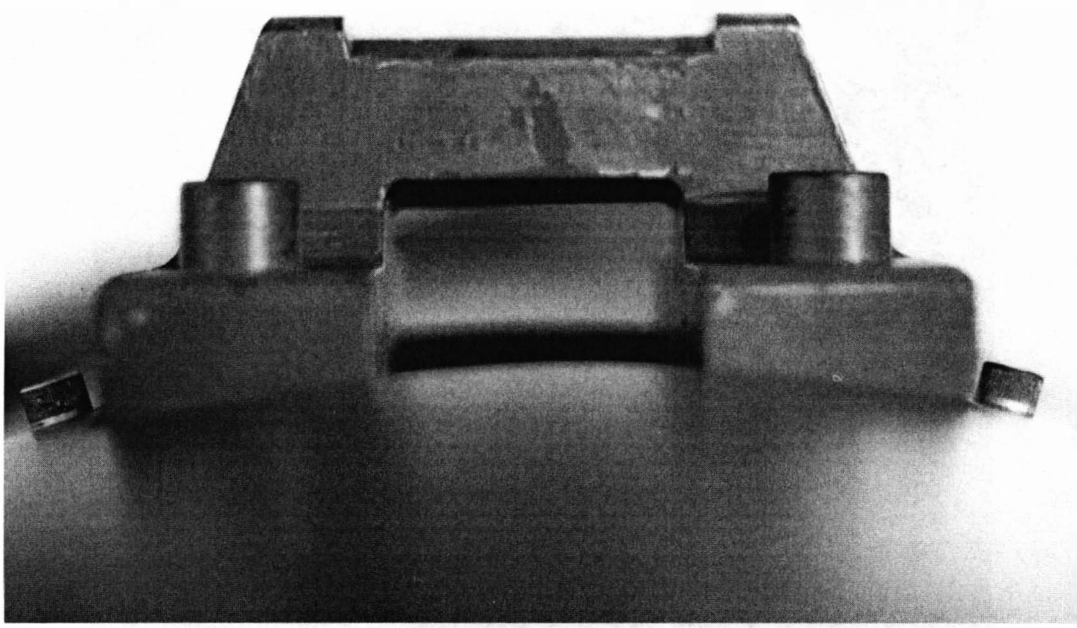
Lift lug used on both weapons. (Author)



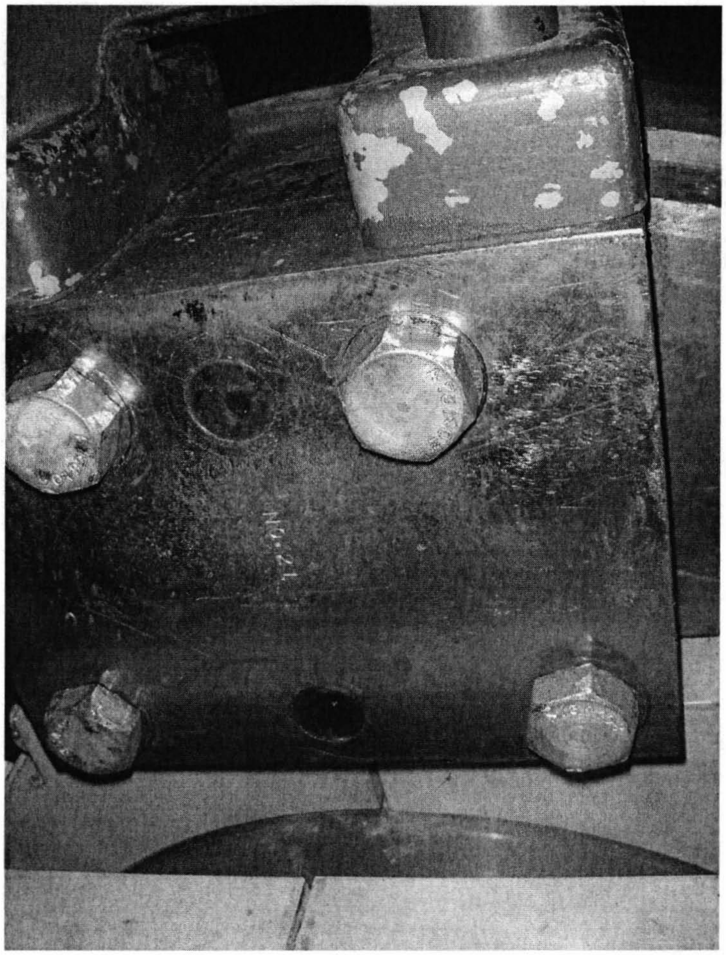
Another view of the lift lug. (Author)



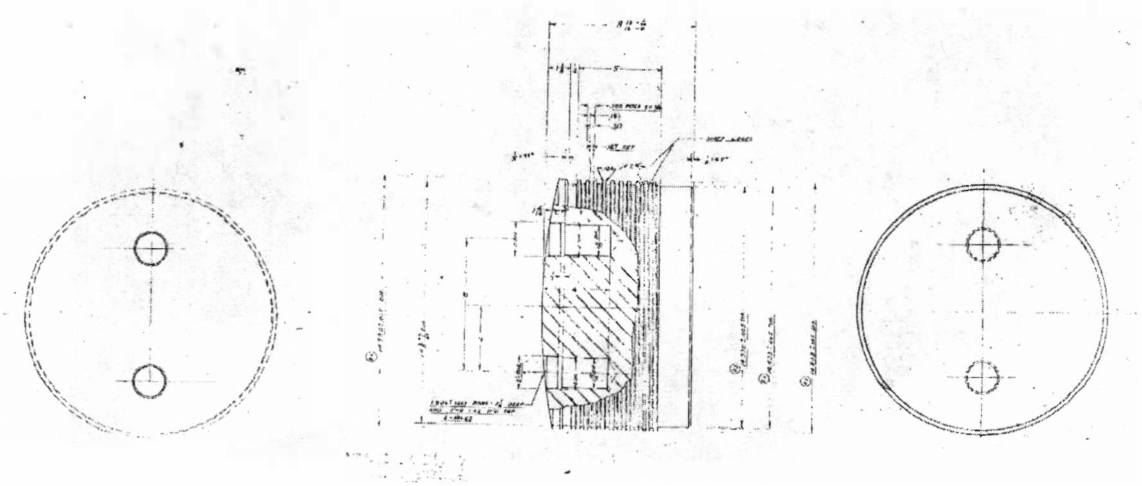
Close-up top view of the lug. The target case is on the right. (Author)



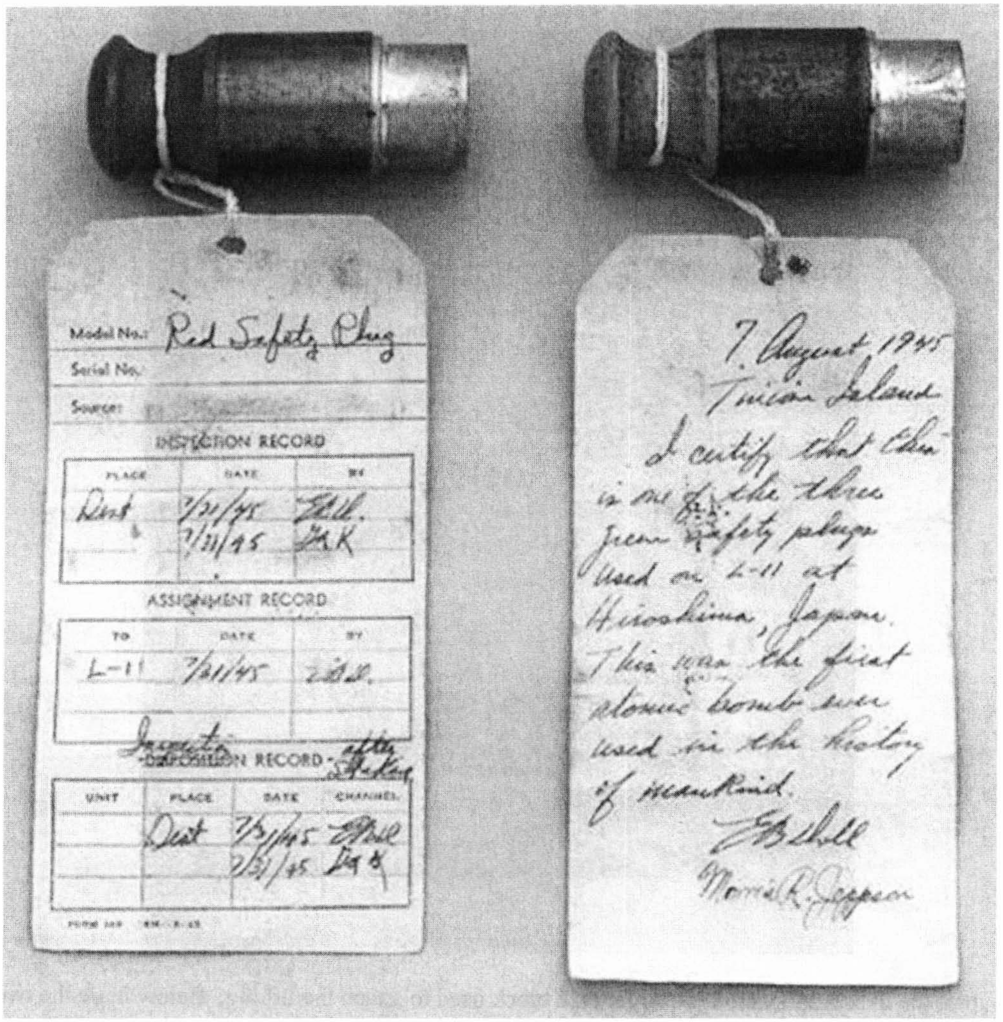
End view of the lift lug on *Little Boy.* (Author)



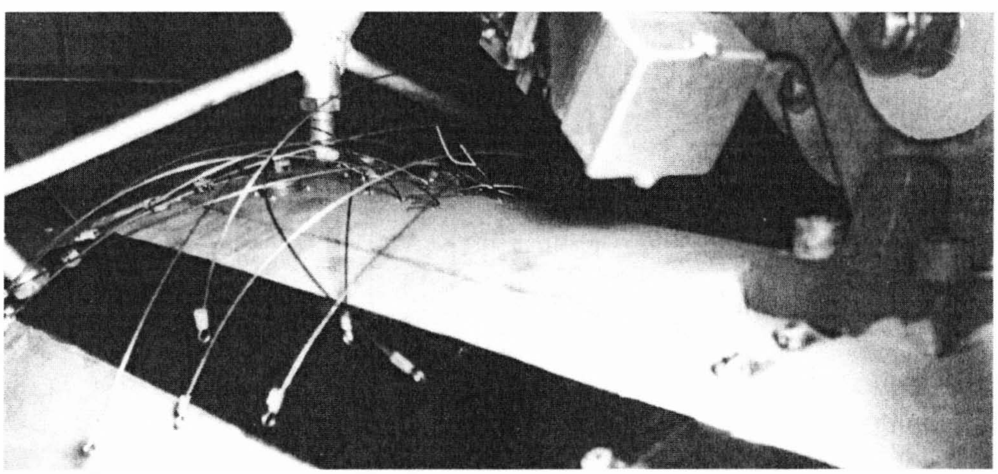
Close-up of the 2" x 5.25" x 6.6875" target case block used to attach the lift lug. Below it are the two split-ring locking collars used to attach the battery boxes to the target-case to gun-tube adapter which is visible between the collars. (Author)



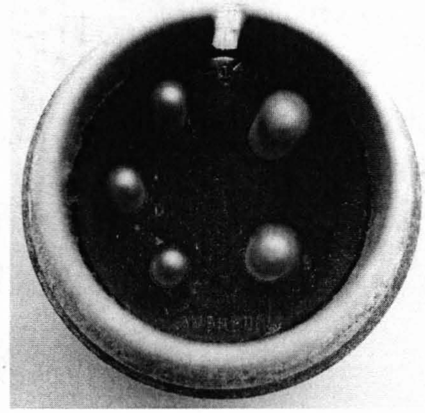
This 1944 drawing shows the target case nose nut without the 1" diameter threaded hole at 12 threads per inch for the cadmium plated draw bolt that held the uranium target insert discs. (Glen McDuff)

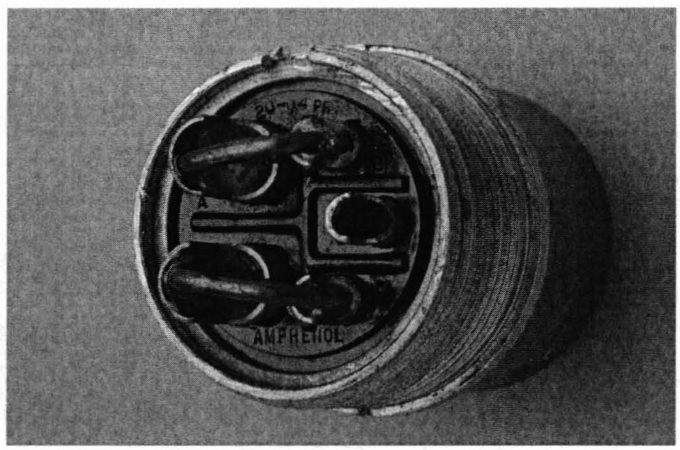


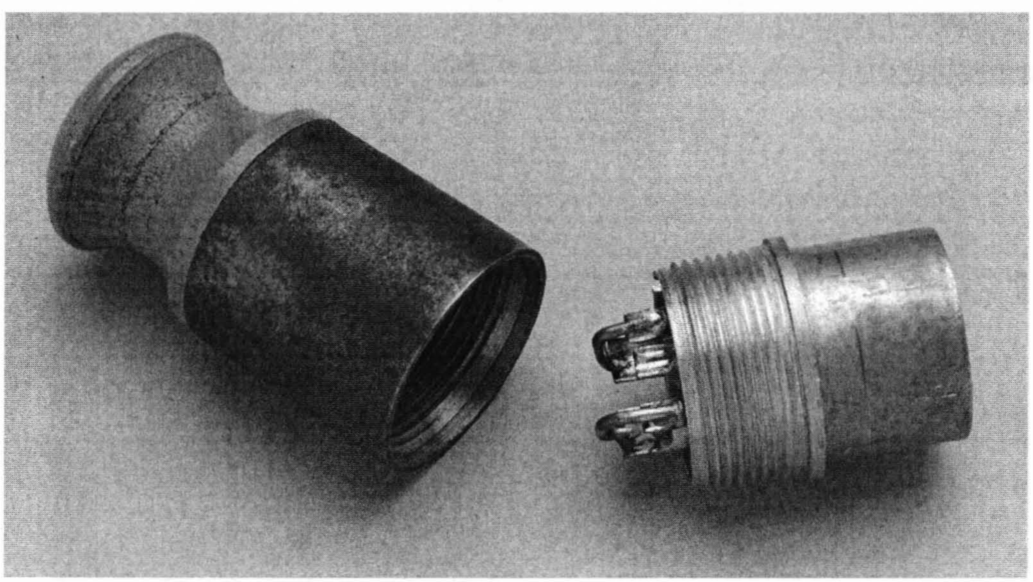
Red and green plugs with inspection tags removed from *Little Boy* by Jeppson. (Clay Perkins)



This view shows the top of a test LB in the bomb bay with the sway bracing in place (l) and the bomb release latch mechanism (r). The pullout wires are also seen before attachment to the clips in the bomb bay. (LANL)





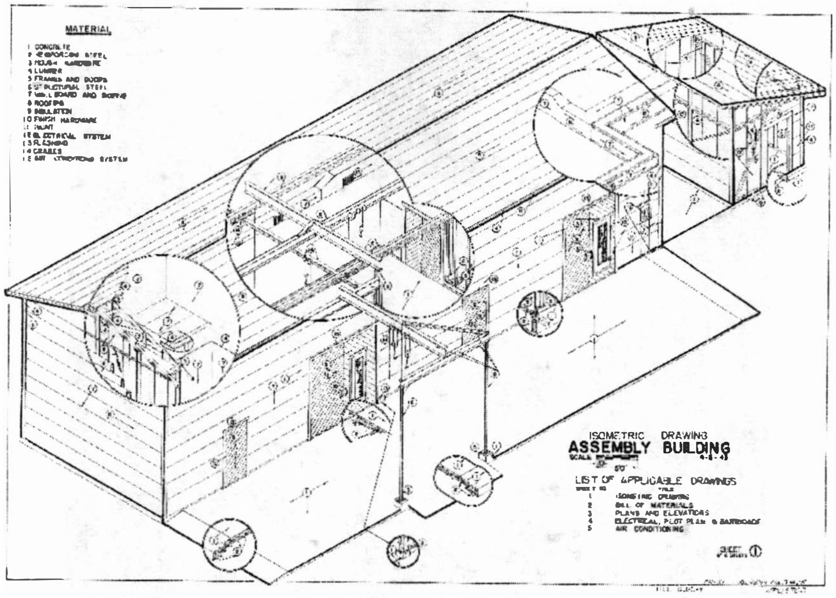


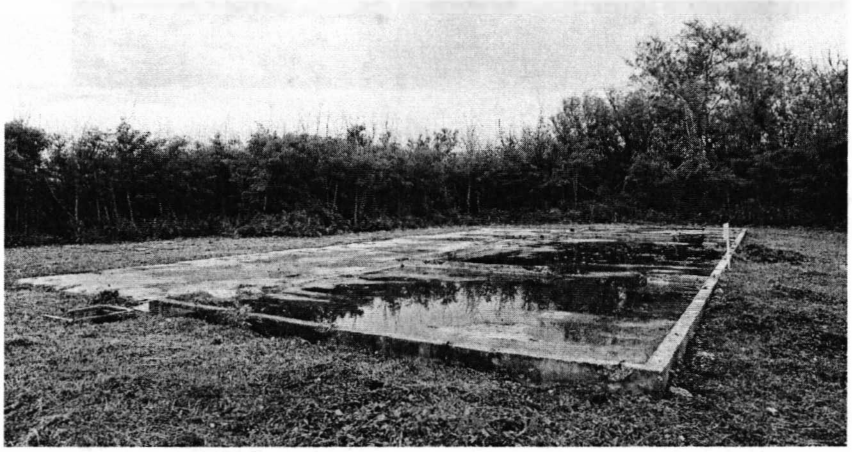
For the first time, this exclusive series of three photos show the bottom and interior of the green safing plug. The copper jumper wires connect the two large pins to the two smaller outside pins. In the red arming plug (not shown), the jumper wires connect the two large pins and the two smaller outside pins to each other. The small middle pin in both red and green plugs is not used. (Courtesy of Dave Nichols)

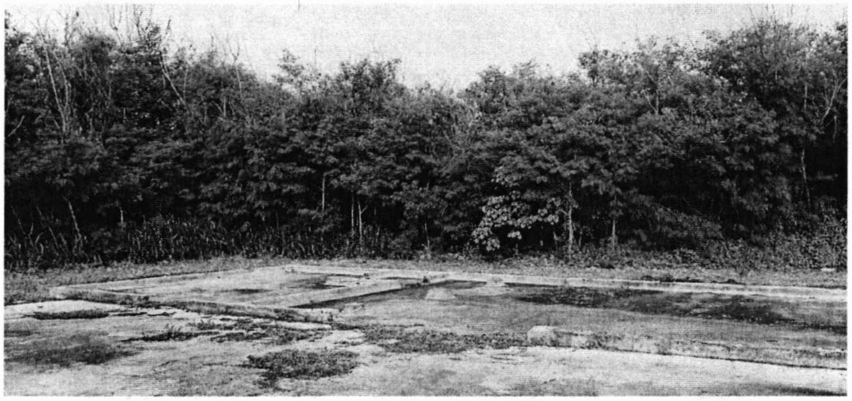
This is the Tinian *Little Boy* Assembly Building #1. (Photo courtesy of Mort Camac)

This movie frame still shows L-11 being wheeled out of Tinian Assembly Building #1 prior to its transport to the *Enola Gay*. (Author)

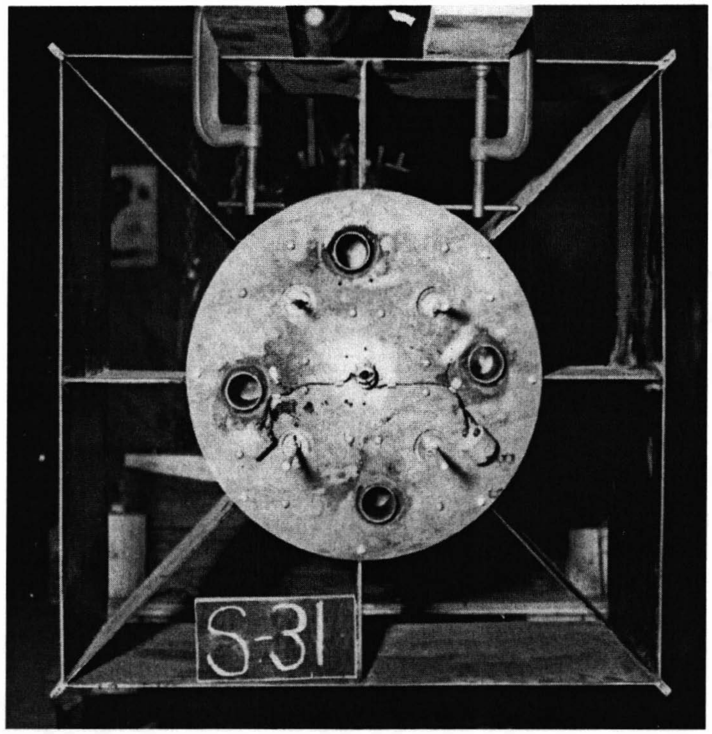
The same area in 2005 with former Los Alamos director (1970-1979) Harold Agnew standing in front to show scale. Agnew flew on the Hiroshima mission as part of the Yield Measurement Team. (Author)



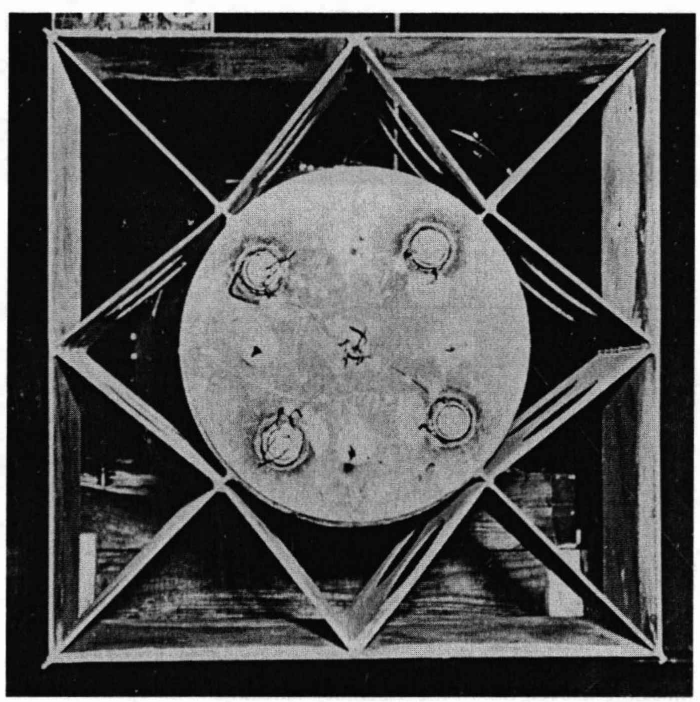




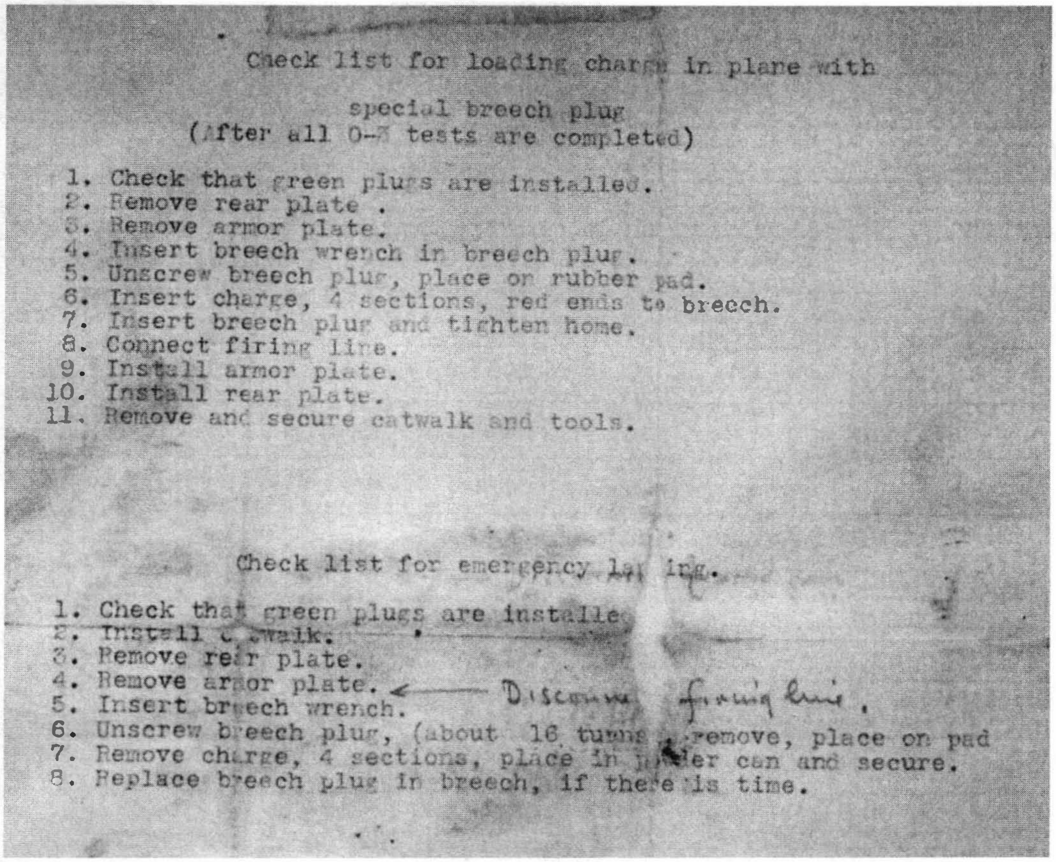
The drawing and these two photos taken in August 2005 represent the building shown on the previous page showing the L-11 unit being moved out of the assembly building. The opening for the double door can be seen at the bottom of the floor edge. The building was surrounded by a tall earthen berm that is hidden in the dense jungle area behind the floor area. For those wishing to explore in person or through satellite maps, the GPS coordinates for this historic assembly site are 15° 05’ 23” N, 145° 38’ 03.60” E. (Author)



Little Boy tail showing an earlier design. Smoke puff bombs are shown before insertion into their circular holding tubes. The smoke puff bombs were connected to electrical circuits in the bomb during testing since they could be seen by ground observers as an indication of when the particular circuit was activated. Also visible on the tail are the four short antennas used to transmit telemetry data during the drop test. (LANL)



This view shows the final tail design and also shows the arrangement of the smoke puff tubes. (LANL)



Check list for loading charge in plane with

special breech plug

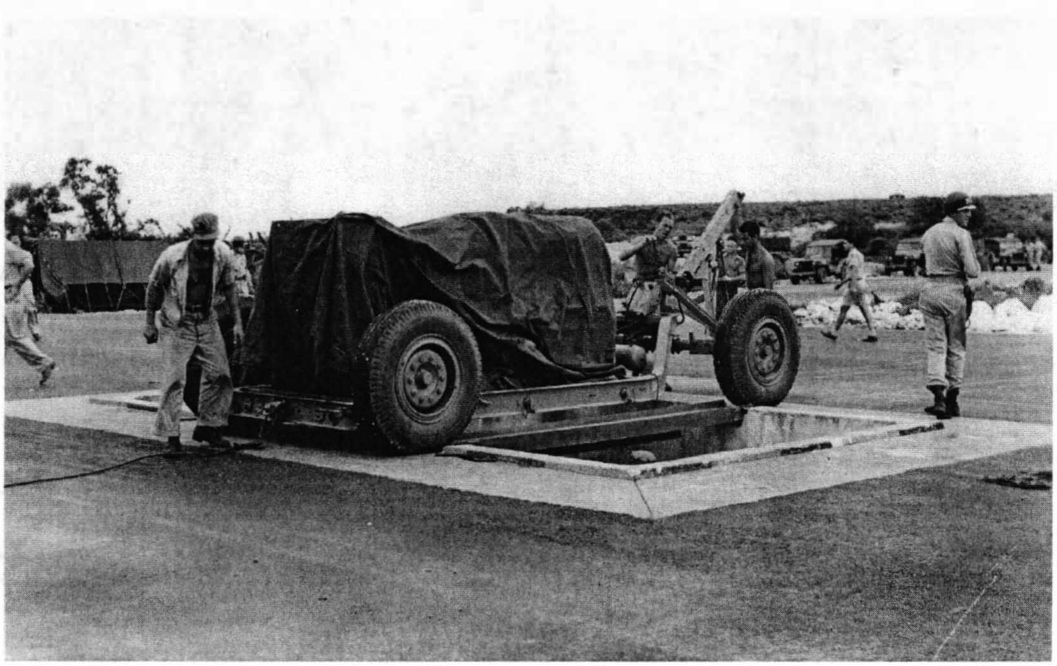
(After all O-K tests are completed)

1. Check that green plugs are installed.
2. Remove rear plate .
3. Remove armor plate.
4. Insert breech wrench in breech plug.
5. Unscrew breech plug, place on rubber pad.
6. Insert charge, 4 sections, red ends to breech.
7. Insert breech plug and tighten home.
8. Connect firing line.
9. Install armor plate.
10. Install rear plate.
11. Remove and secure catwalk and tools.

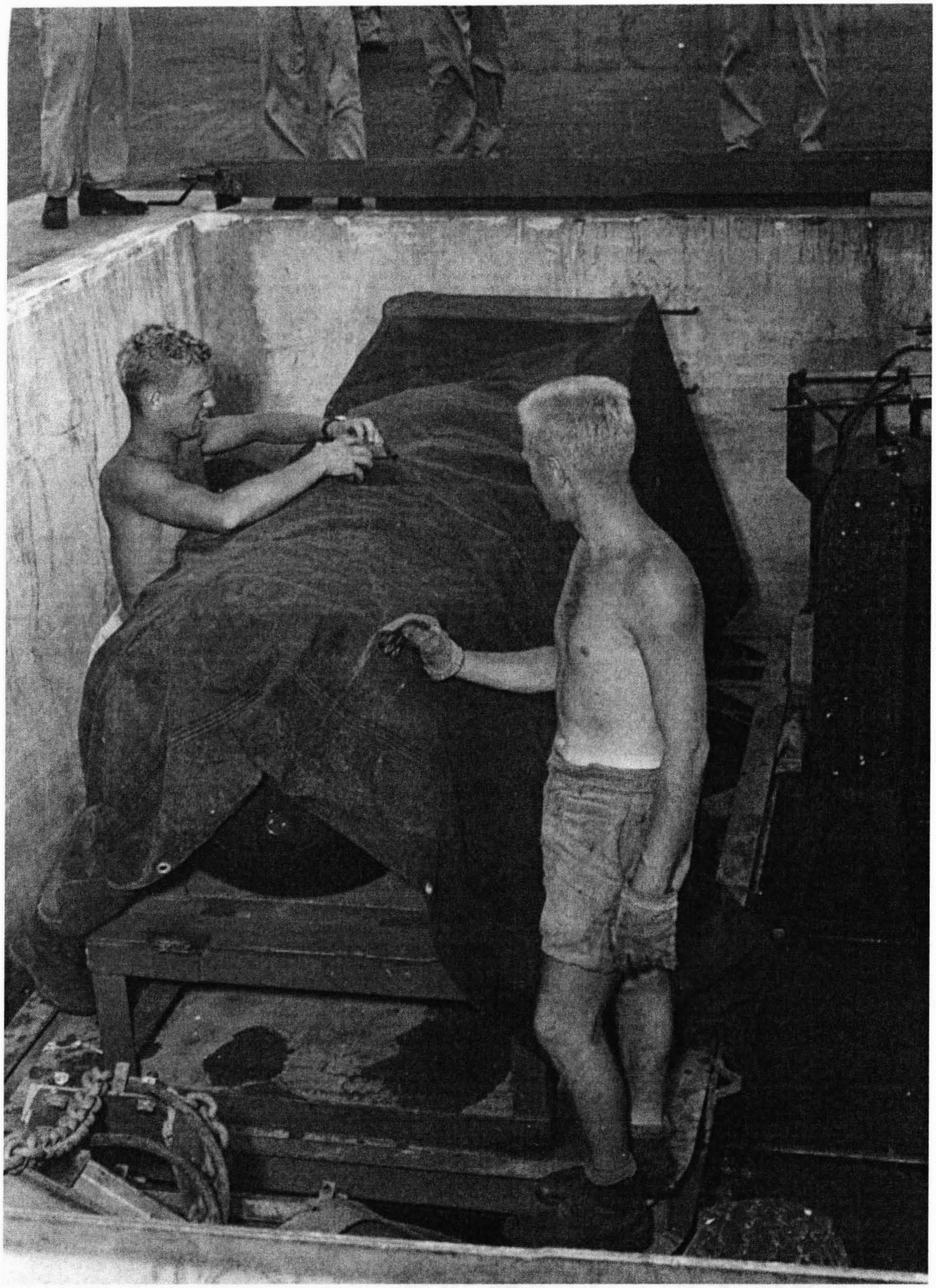
Check list for emergency landing.

1. Check that green plugs are installed.
2. Install catwalk.
3. Remove rear plate.
4. Remove armor plate. ← Disconnect firing line.
5. Insert breech wrench.
6. Unscrew breech plug, (about 16 turns), remove, place on pad
7. Remove charge, 4 sections, place in powder can and secure.
8. Replace breech plug in breech, if there is time.

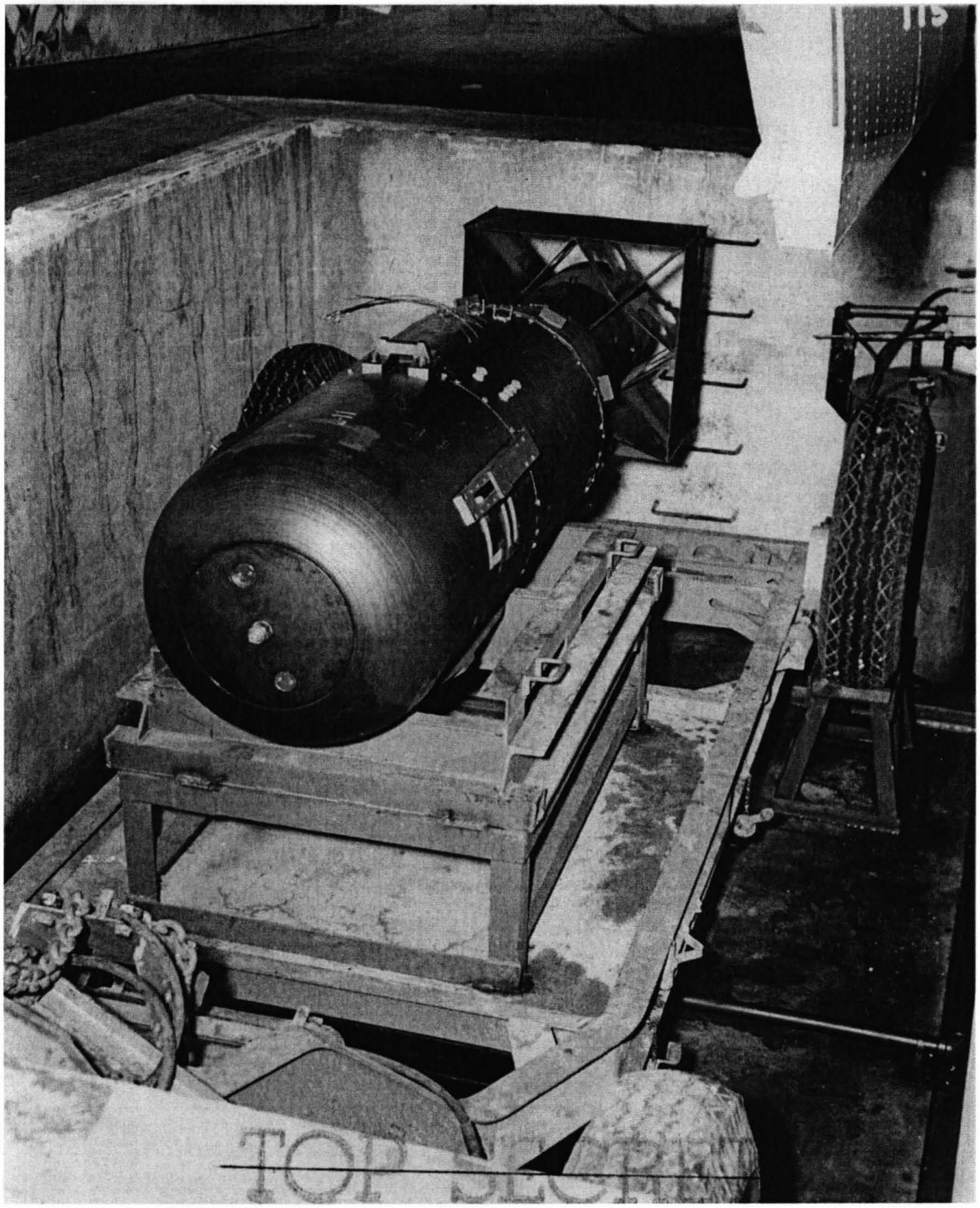
Parsons' actual LB checklist on display at the Navy Yard Museum in DC. (Author)



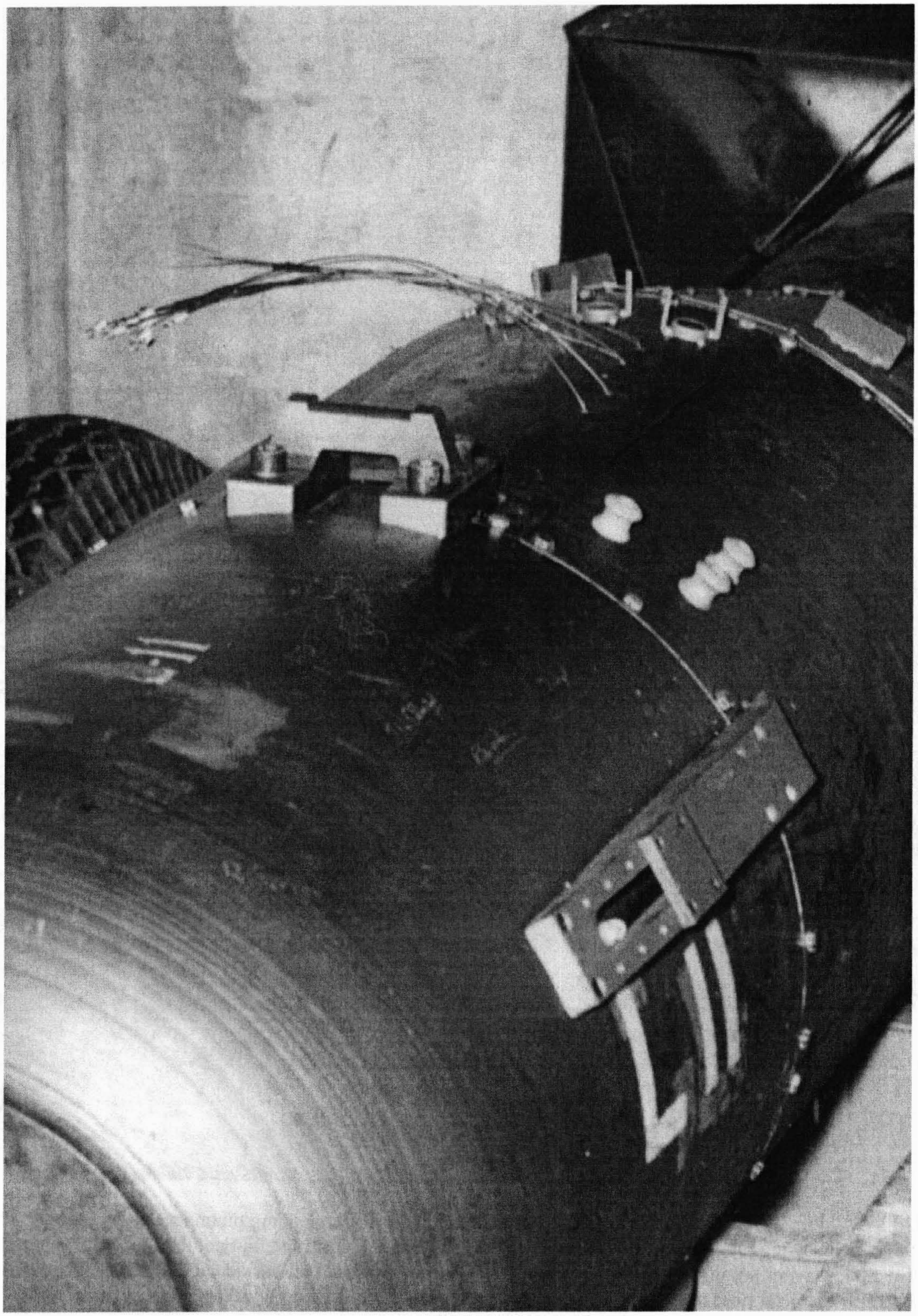
Canvas shrouded L-11 being positioned over Tinian loading pit. After the wheel ramps were removed, the entire unit was rotated clockwise 90° before lowering it into the pit. (National Archives)



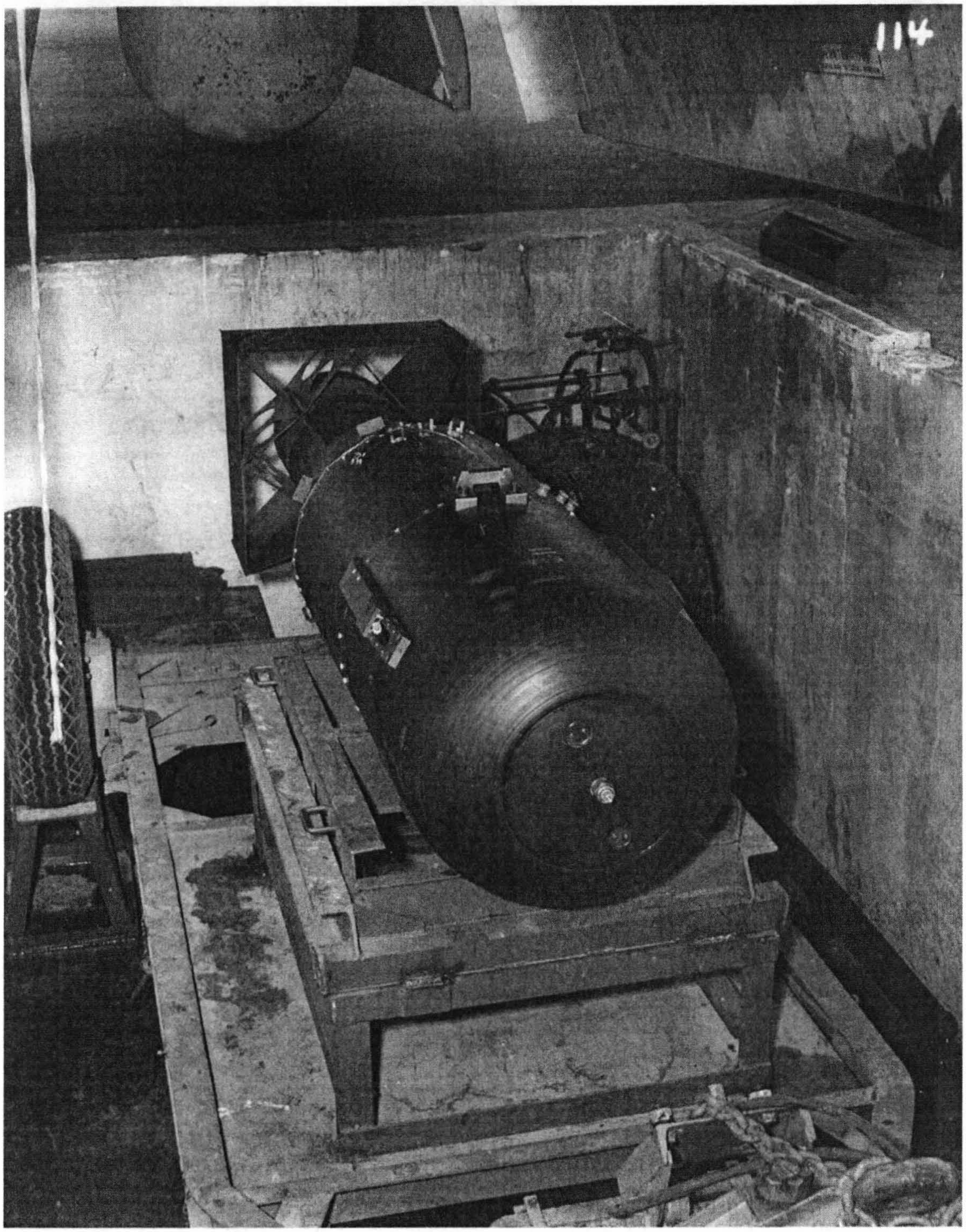
Workers start to remove canvas shroud from L-11 in Tinian loading pit. By using these photos, along with on-site inspection, in 2005 the author was able to prove conclusively that the *Fat Man* F-31 unit was also loaded from the same pit. (National Archives)



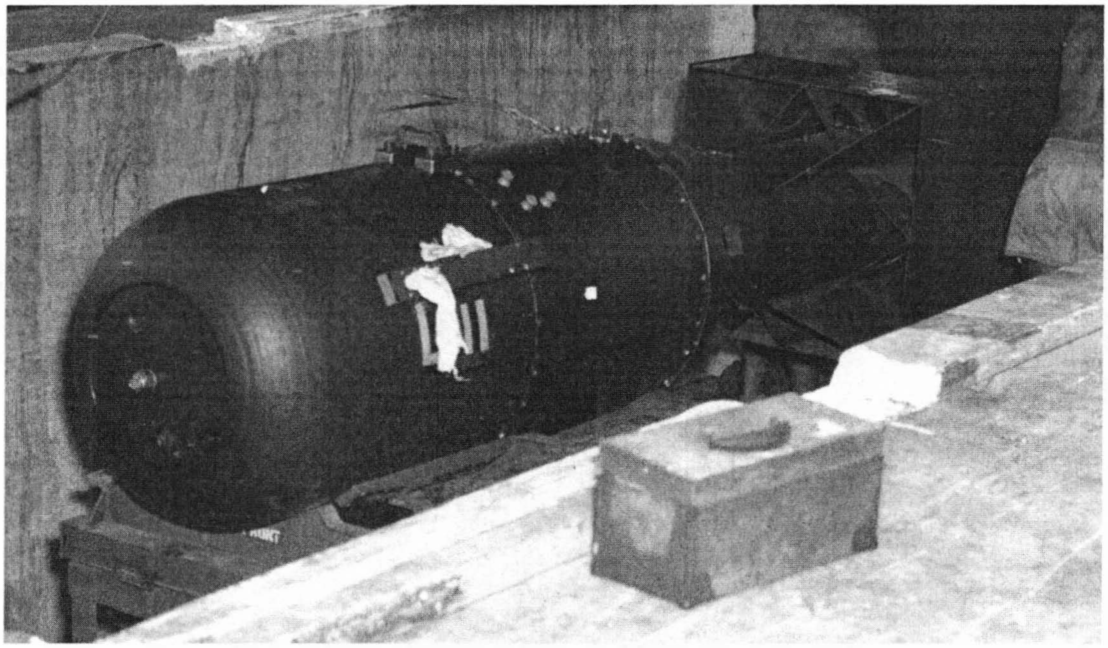
L-11 *Little Boy* sitting on its wheeled transport carriage in the Tinian loading pit under the *Enola Gay*. The three green safing plugs (just right of the lift lug) are installed at this point, but not the four Yagi antennas. The pullout wires are visible on the top and L-11 can be seen painted on the side and top of the target case. The 15.0" diameter nose nut and two smaller nose nut handling bolt hole plugs can also be clearly seen. The locknut securing the cadmium-plated draw bolt is visible in the center of the nose. The bomb bay door is visible on the upper right corner. (National Archives)



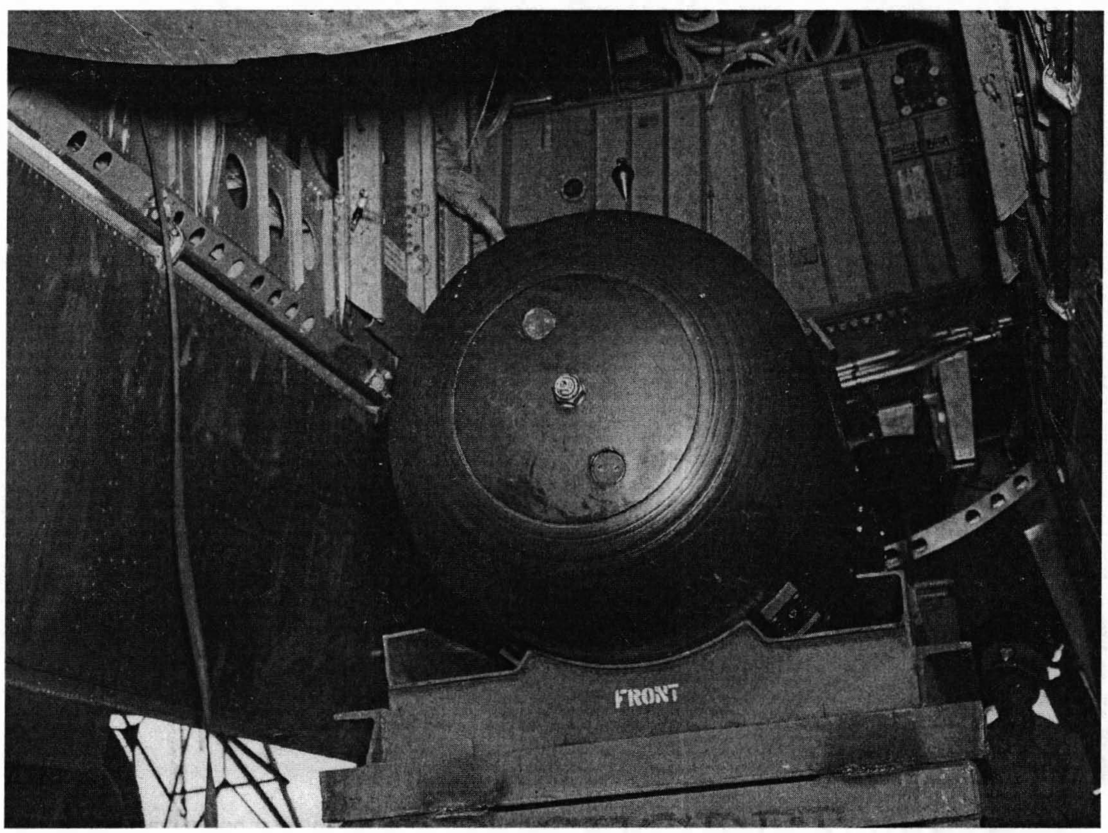
Here is a close-up of L-11 in the loading pit. Some of the signatures are visible on the top. Note there are no clips over the safing plugs. (National Archives)



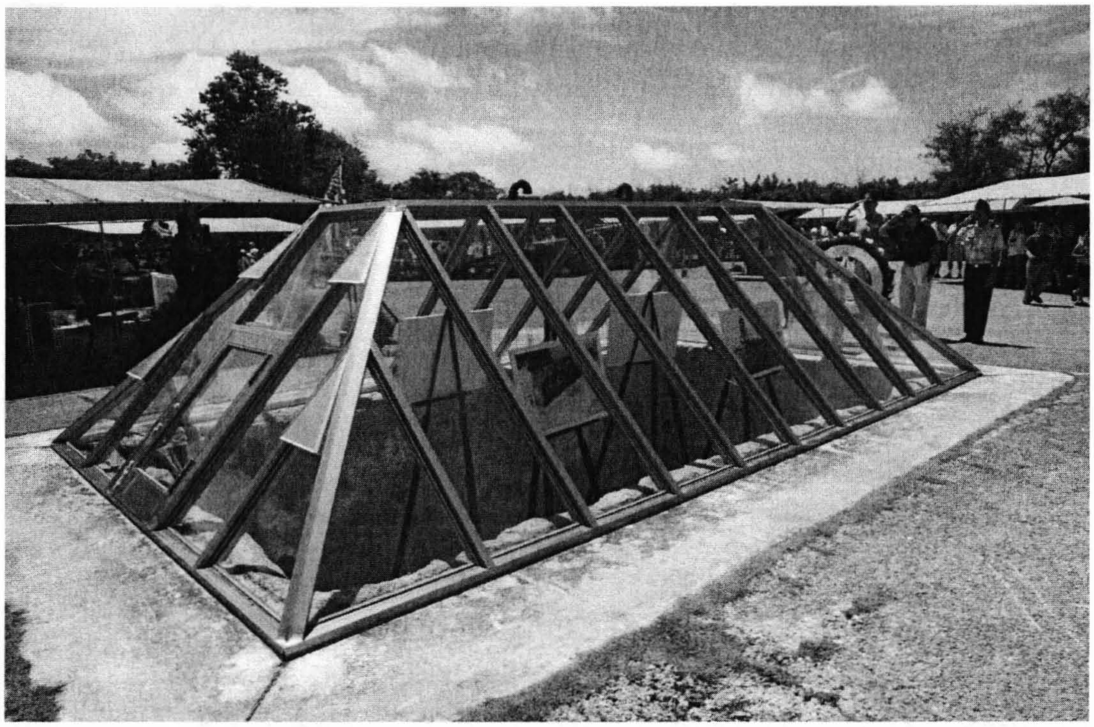
Another view of L-11 in the Tinian loading pit. This view also shows the rear bomb bay door open. (National Archives)

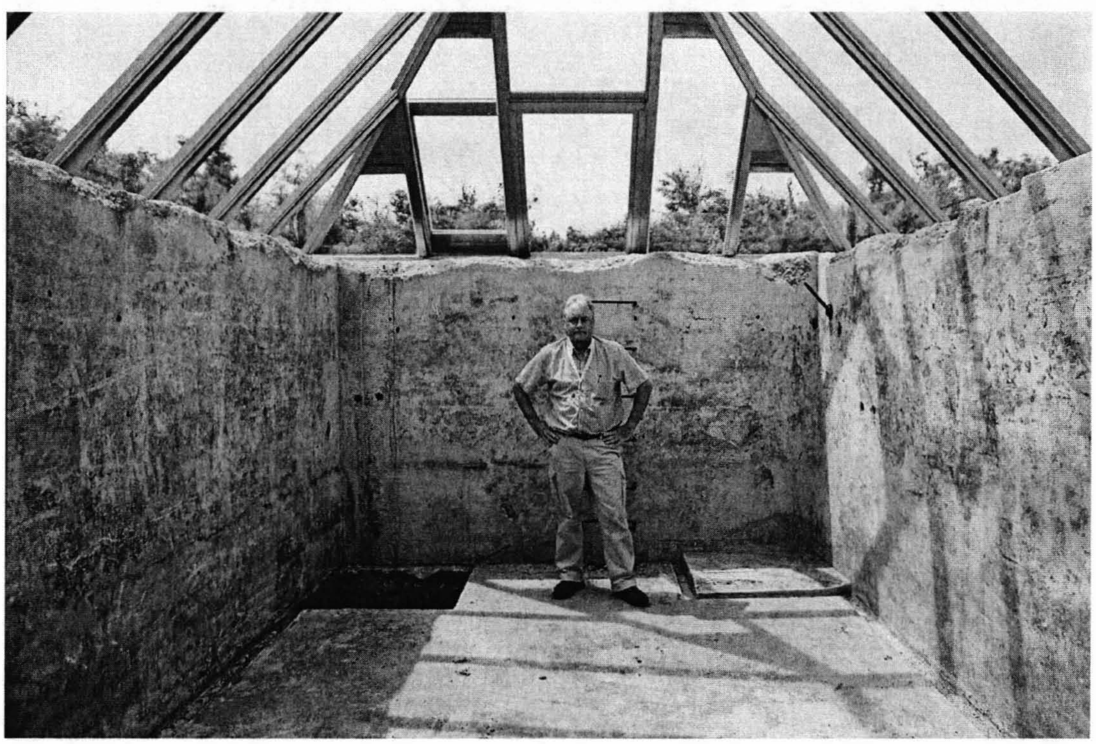


Side view of *Little Boy* L-11 in the loading pit on Tinian. (National Archives)



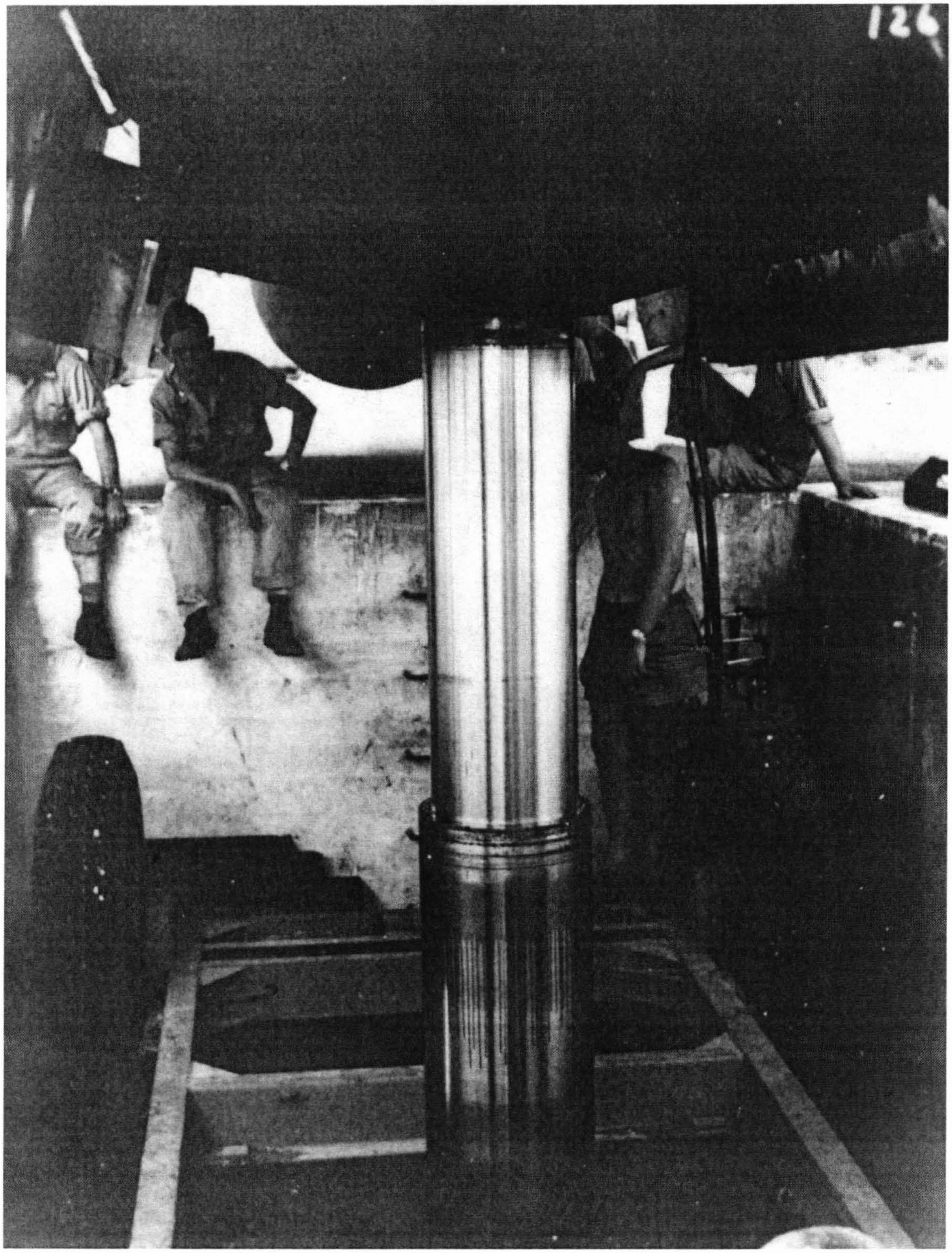
L-11 being raised into the *Enola Gay* bomb bay. The removable metal platform used by Parsons has not been attached to the aft end of the bomb bay at this point. (National Archives)



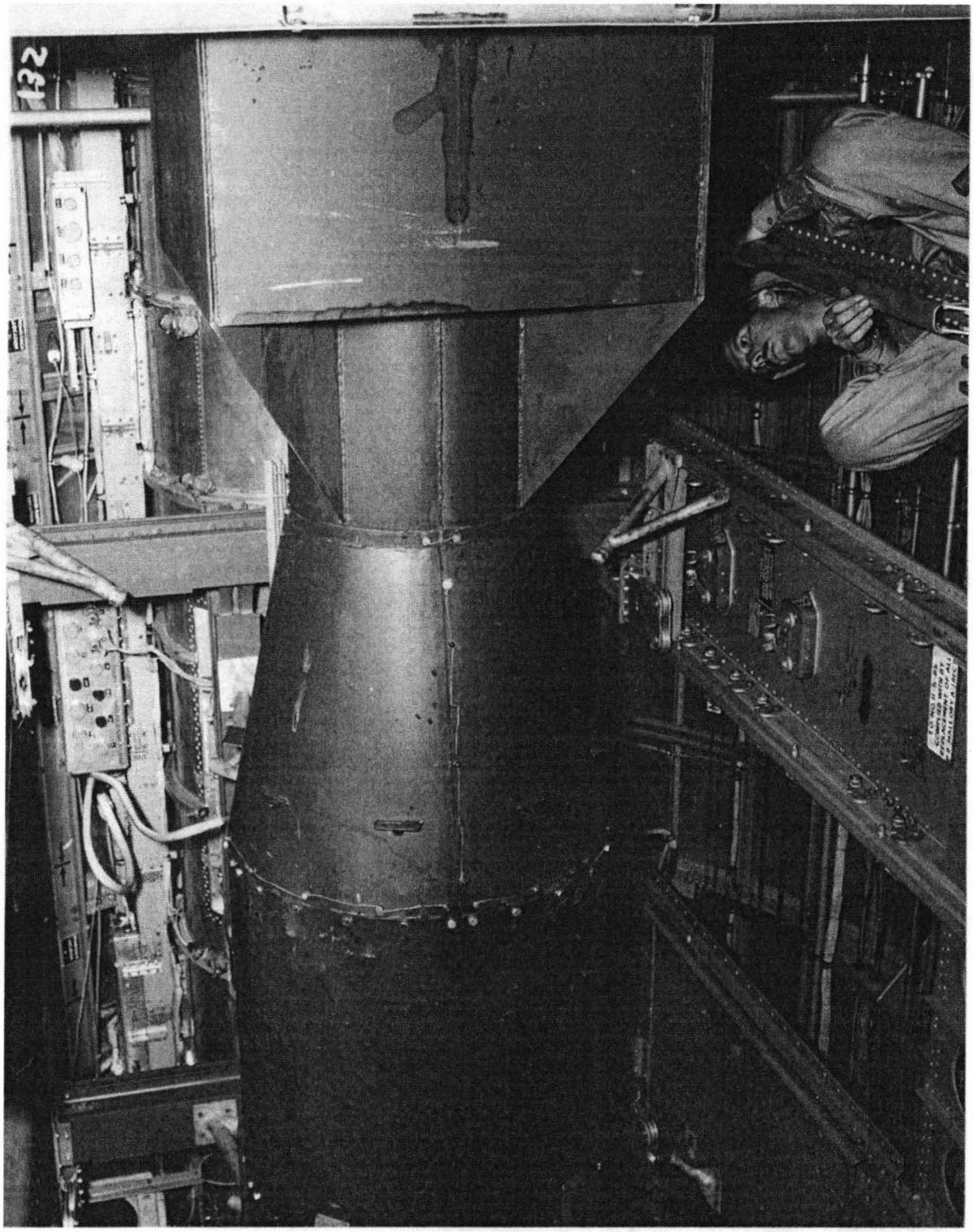


Here are two photos showing the loading pit. The glass structure above the pit was installed to protect it from the elements. The upper photo was taken during the 60th Anniversary Commemoration Hiroshima wreath laying ceremony on 8/6/05. The people standing in front of the wreath are *Indianapolis* survivors Woody James (l) and Mike Kuryla (r) along with one of the color guard. Tragically, James died one month later in a Salt Lake City auto accident on 9/20/05 and Kuryla died on 10/10/09. The lower photo shows the author in that pit to illustrate scale. (Author)

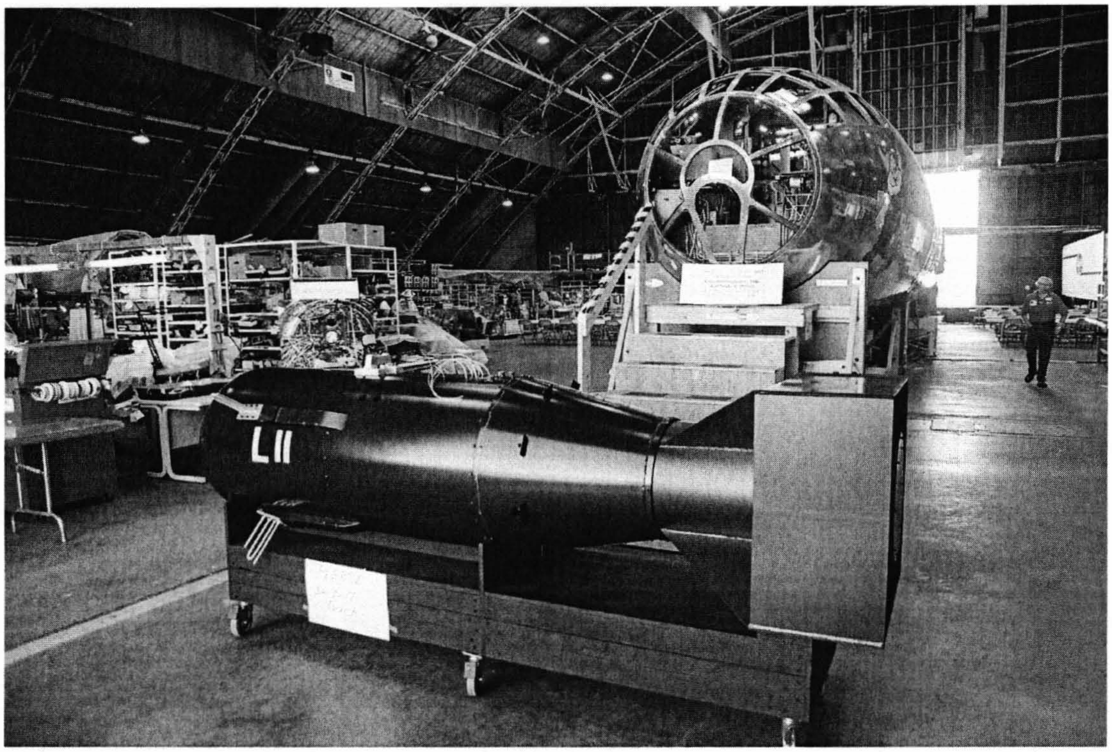
Here is a photo showing the interior of the loading pit taken in August 2005. Visible here is the hole in the rusted steel plate at the bottom where the hydraulic lift column was located. (Author)

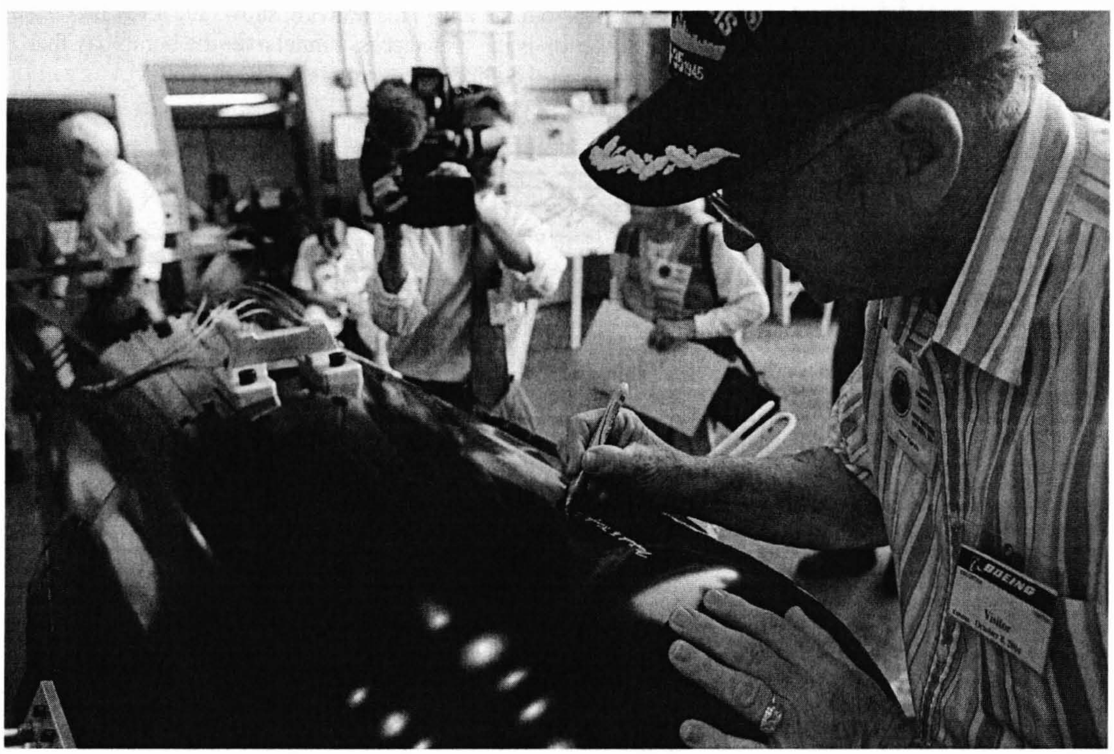


This photo taken on 8/5/45 from the same position shows the Joyce-Cridland telescoping hydraulic lift column as the L-11 is loaded up inside the *Enola Gay*. (National Archives/Courtesy of Steve Bice)

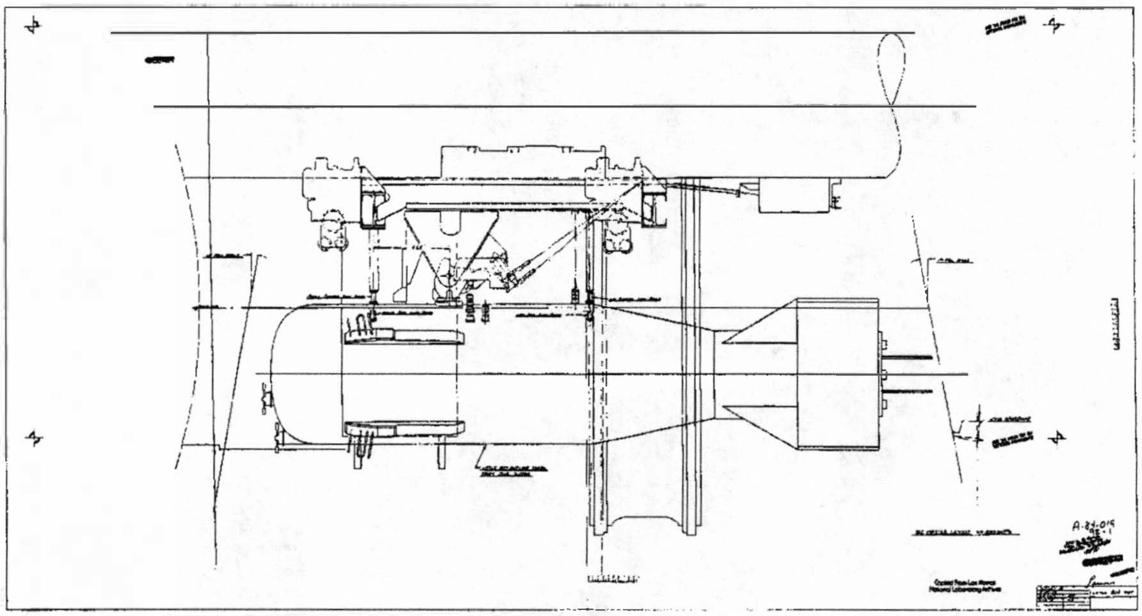


View looking up into *Enola Gay* after L-11 was loaded into the bomb bay. Sheldon Dike is visible on the right. Note the safety wires attached to all of the bolts on the tapered section of the tail. The bottom edge of the removable platform used by Parsons to arm the bomb is visible at the very top of the photo. (National Archives)

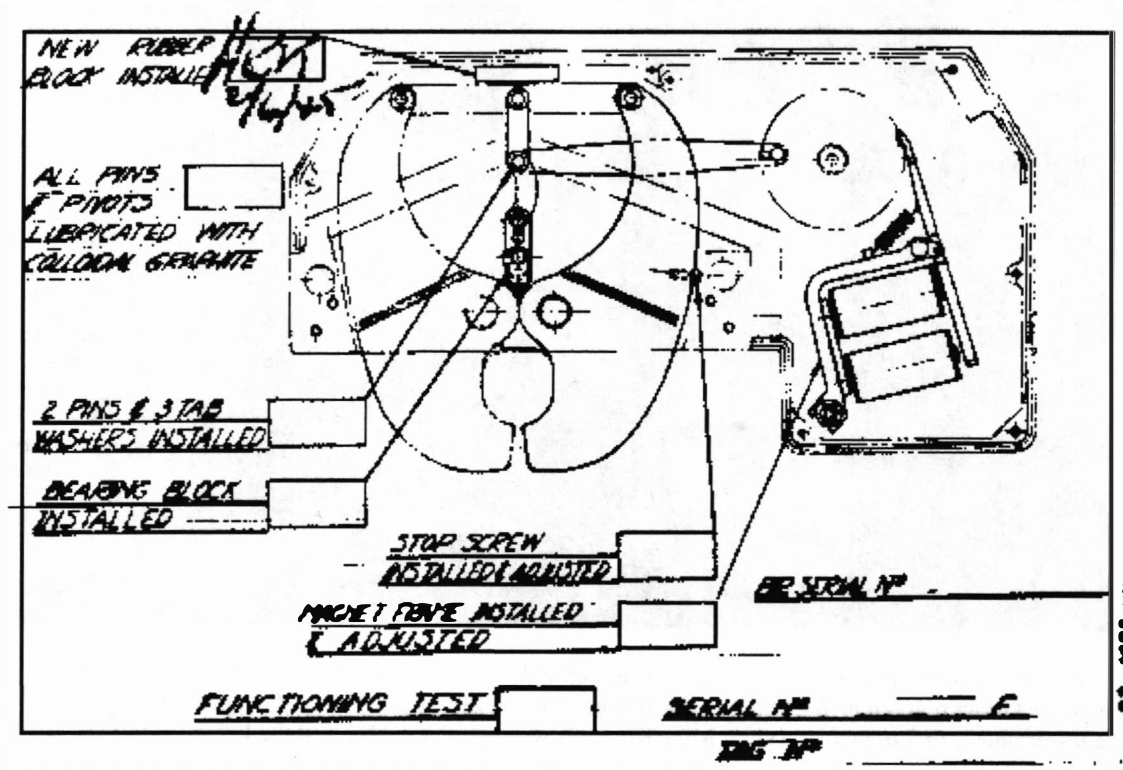




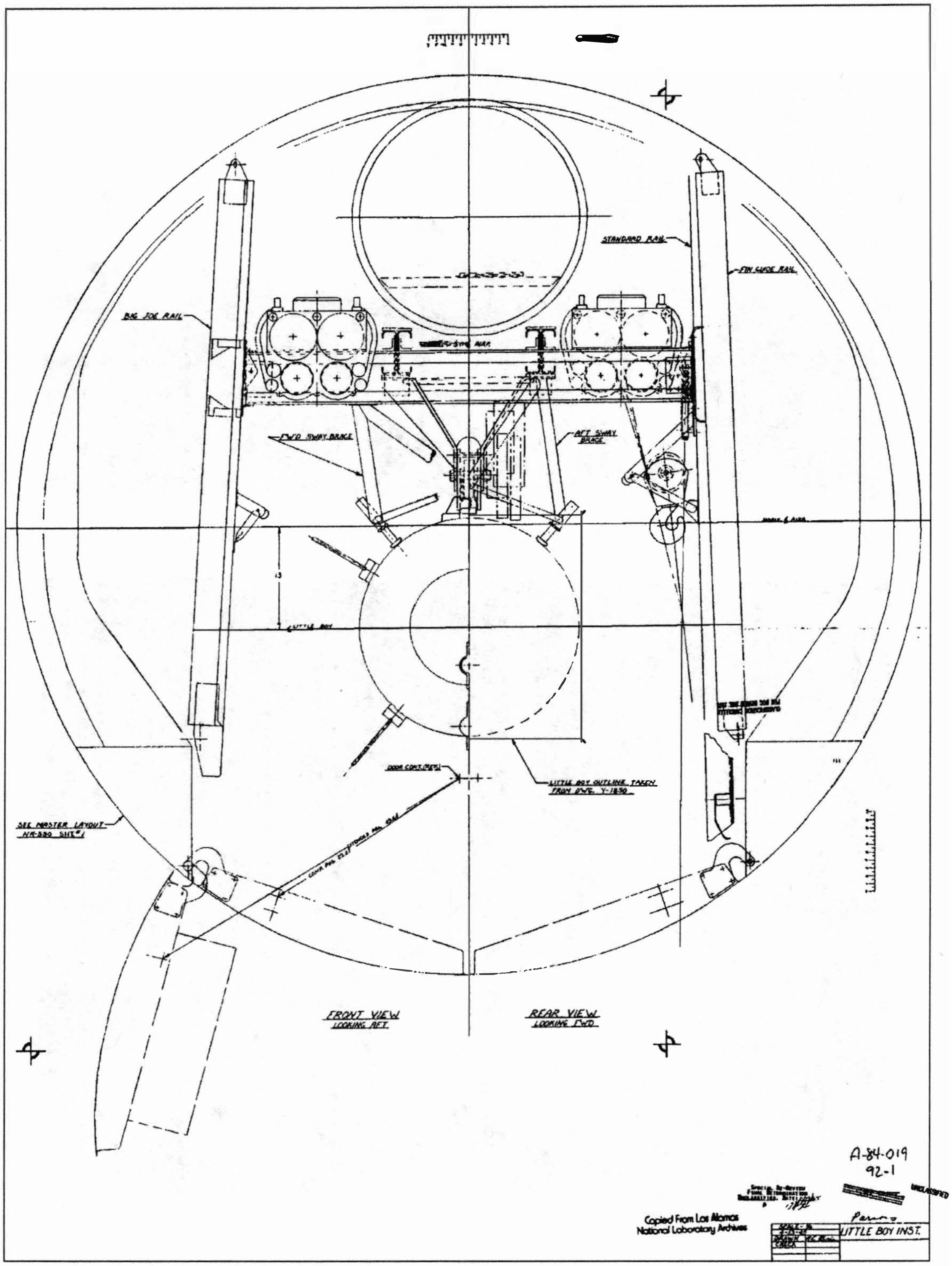
These two photos show the L-11 replica the author and his son constructed on display during the 509th Composite Group reunion in Wichita in 2004 in front of the B-29 "Doc" that was being restored at Boeing. In the lower photo, *Indianapolis* survivor Mike Kuryla is writing "For the boys of the U.S.S. *Indianapolis*" on the replica. (Author)



This 4/14/45 drawing shows *Little Boy* in B-29 bomb bay. This Y-1792 design was an earlier model which included nose contact fuzes and antennas protruding from the tail. This drawing shows the sway bracing and bomb release mechanism. The large tube at the top is the crew access tunnel over the bomb bay that connected the forward and aft pressurized compartments in the B-29. (LANL)



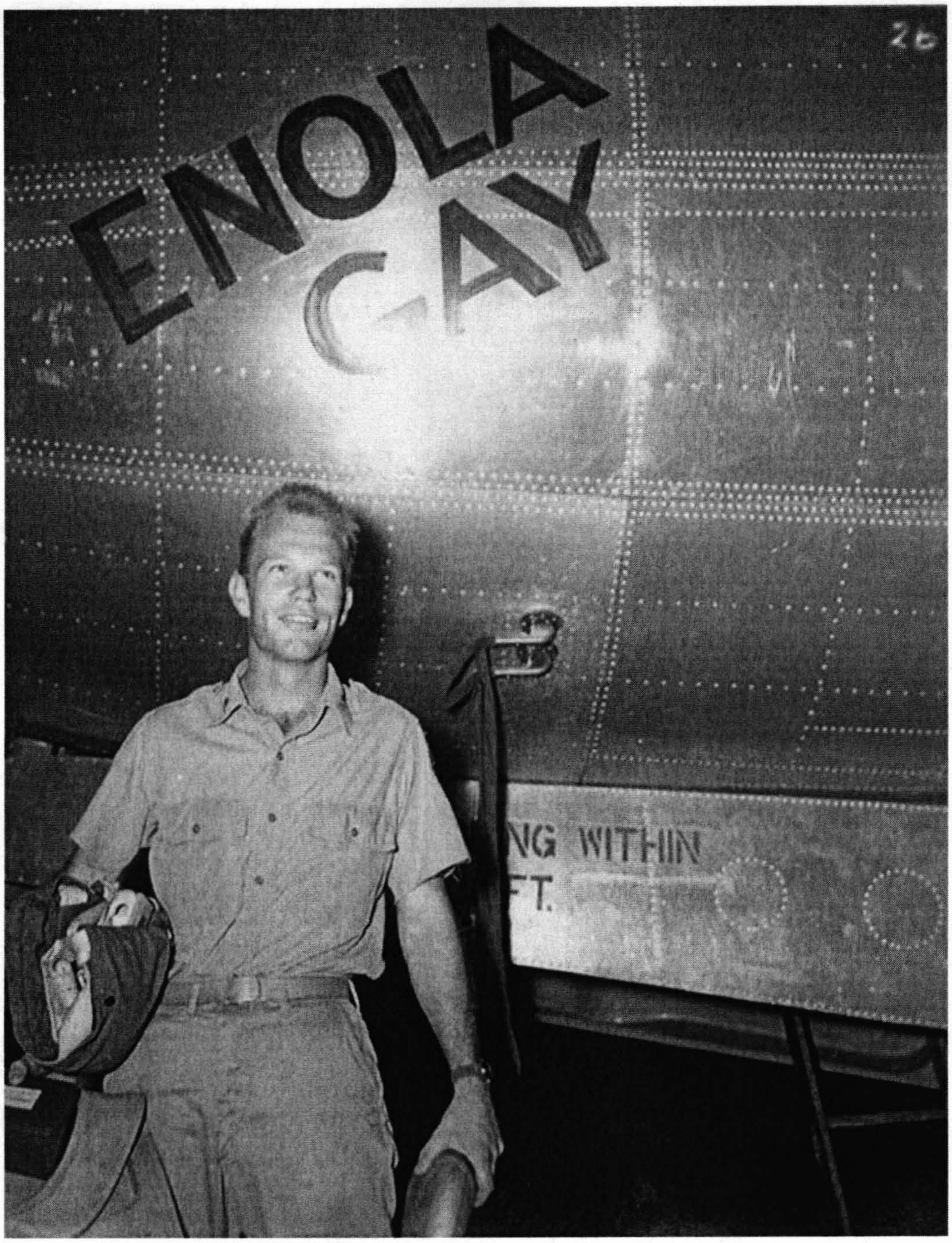
This drawing shows one of the designs for the bomb release latch mechanism. (LANL)



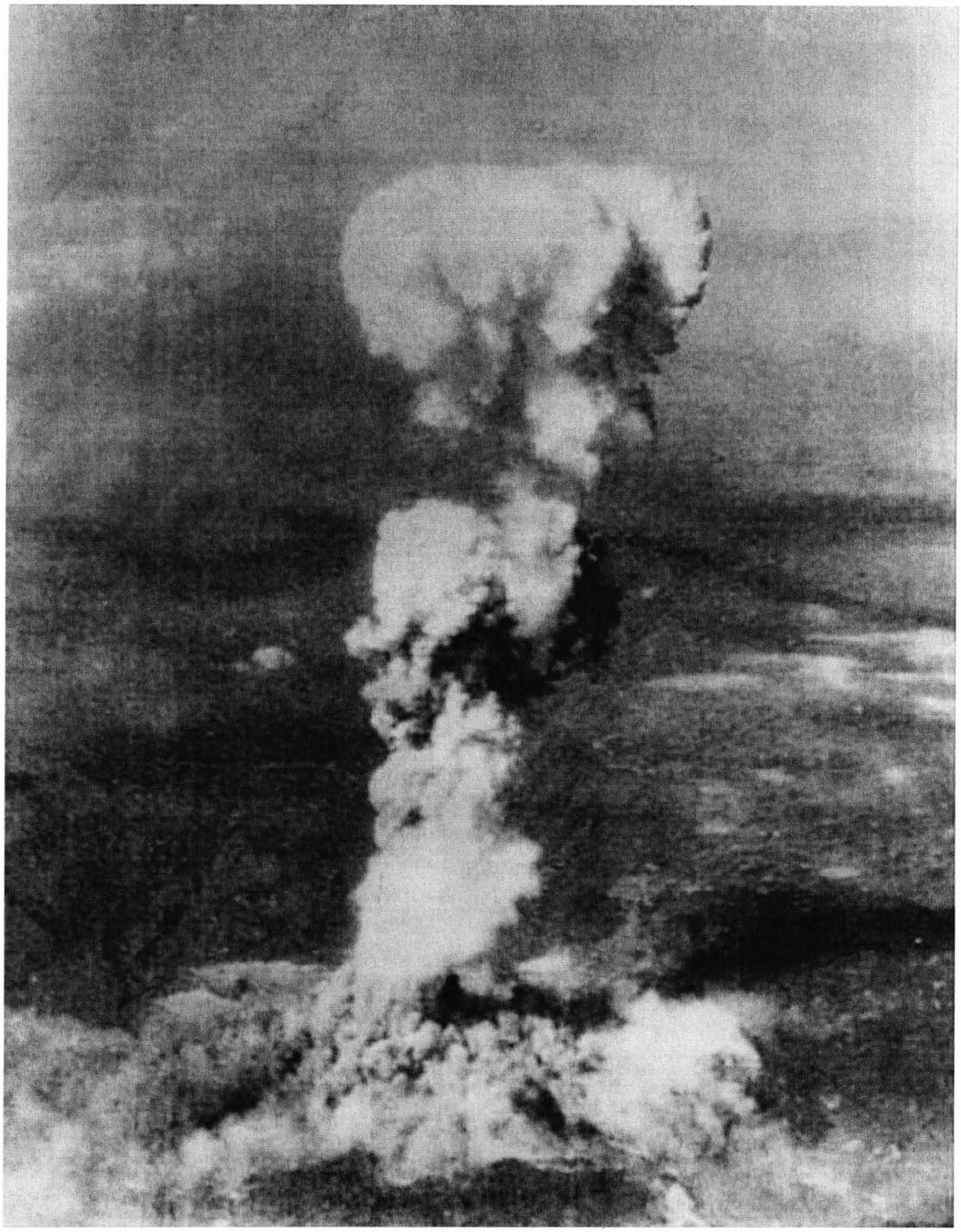
This 4/13/45 B-29 cross-section drawing shows the *Little Boy* Y-1850 design (front and rear views) in the bomb bay. The crew access tunnel, power lifting mechanisms, sway bracing, "Big Joe" side rails, bomb bay doors, and bomb latch are shown. (LANL)

The *Enola Gay* is pictured being backed over the loading pit containing L-11 on Tinian. (USAF)

The *Enola Gay* crew shortly before take off. Standing: Maj. Porter, Maj. Van Kirk, Maj. Ferebee, Col. Tibbets, Capt. Lewis, Lt. Beser. Kneeling: Sgt. Stiborik, S/Sgt. Caron, PFC. Nelson, Sgt. Shumard, S/Sgt. Duzenbury. Not shown are Capt. Parsons and Lt. Jeppson. (USAF)



Lt. Morris Jeppson, Electronics Test Officer. (USAF/Armen Shamlian)

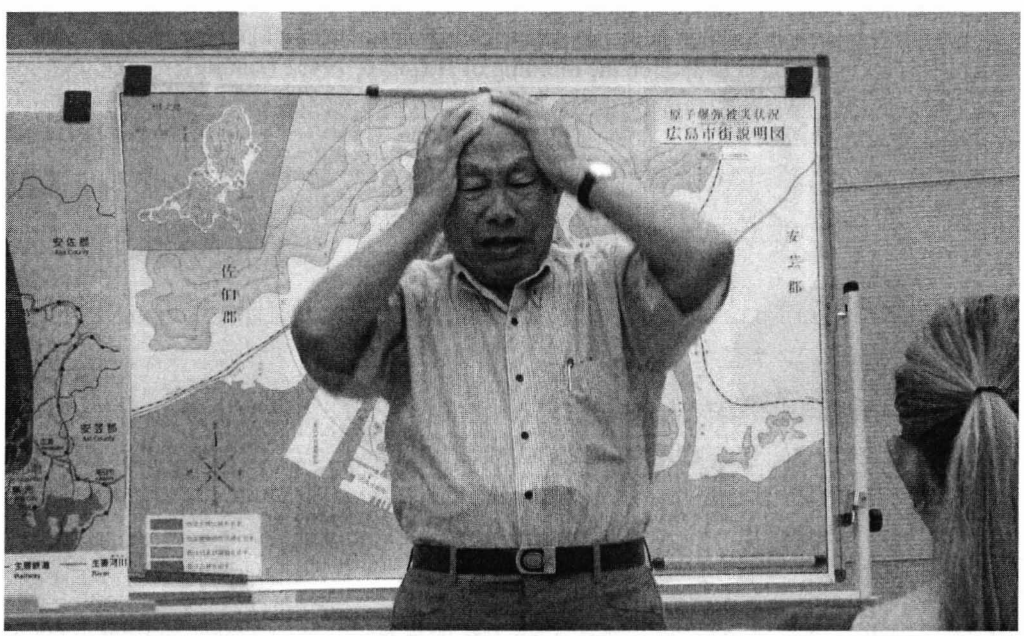


Mushroom cloud over Hiroshima. This photo was taken by the *Enola Gay* tail gunner S/Sgt. Robert Caron. (National Archives)

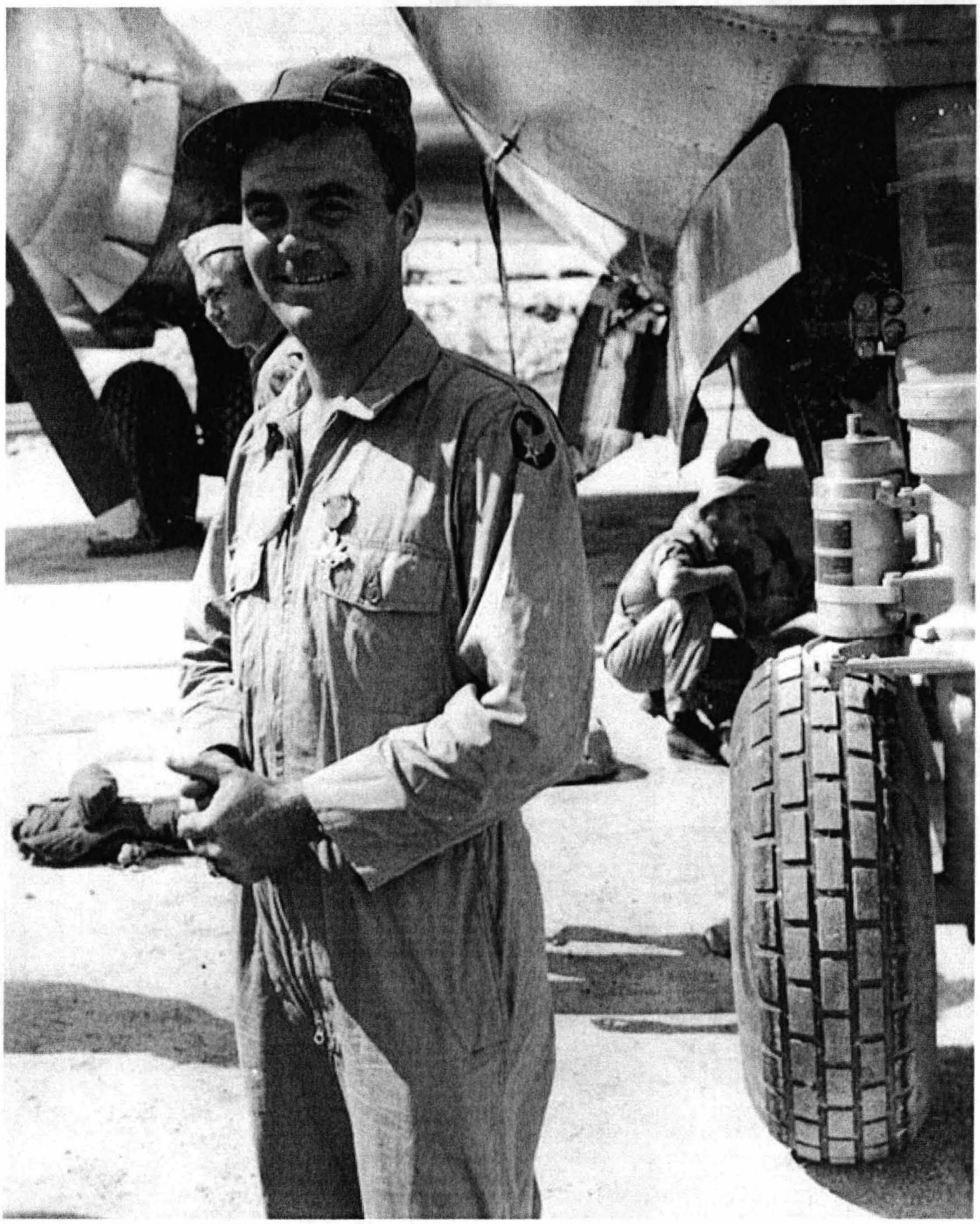
Based on calculations made by the author, this photo of the famous A-Bomb Dome in Hiroshima depicts the sun in the precise Hypocenter location in the sky (same elevation and azimuth) where *Little Boy* was when it exploded at 8:15 on the morning of August 6, 1945. (Author)

This debris was collected in 2010 by the author at low tide from the riverbed directly in front of the A-Bomb Dome. These objects were probably within a few hundred yards of the Hypocenter when *Little Boy* exploded 1968 feet overhead and show some of the effects of the extreme heat from the blast. The porcelain electrical insulator on the right has surface bubbling on the side facing the Hypocenter while the other pieces show similar surface bubbling and melting. (Author)

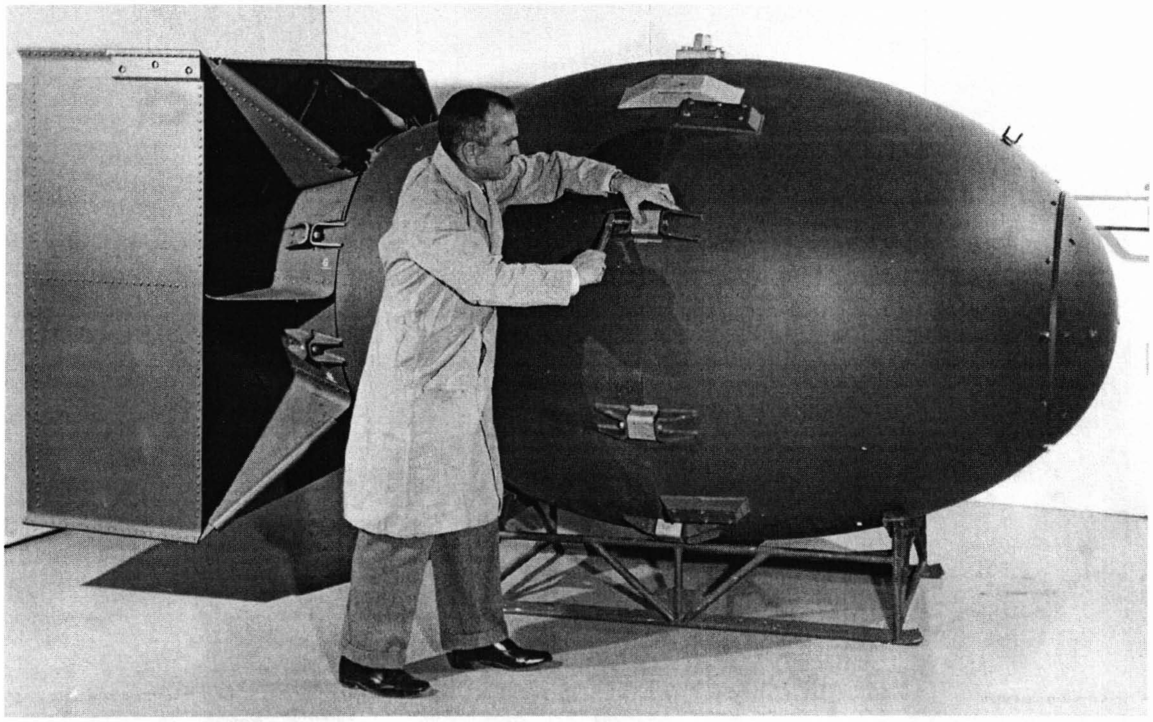
Hibakusha Keijiro Matsushima is shown in 2010 standing in front of the former Hiroshima Army Clothing Depot where he was forced to work during the summer of 1945 before becoming a student at the Hiroshima National Technical College. Although this structure is almost 1.75 miles from the Hypocenter, most of the heavy steel covers over the windows were blown inward by the massive shockwave. (Author)



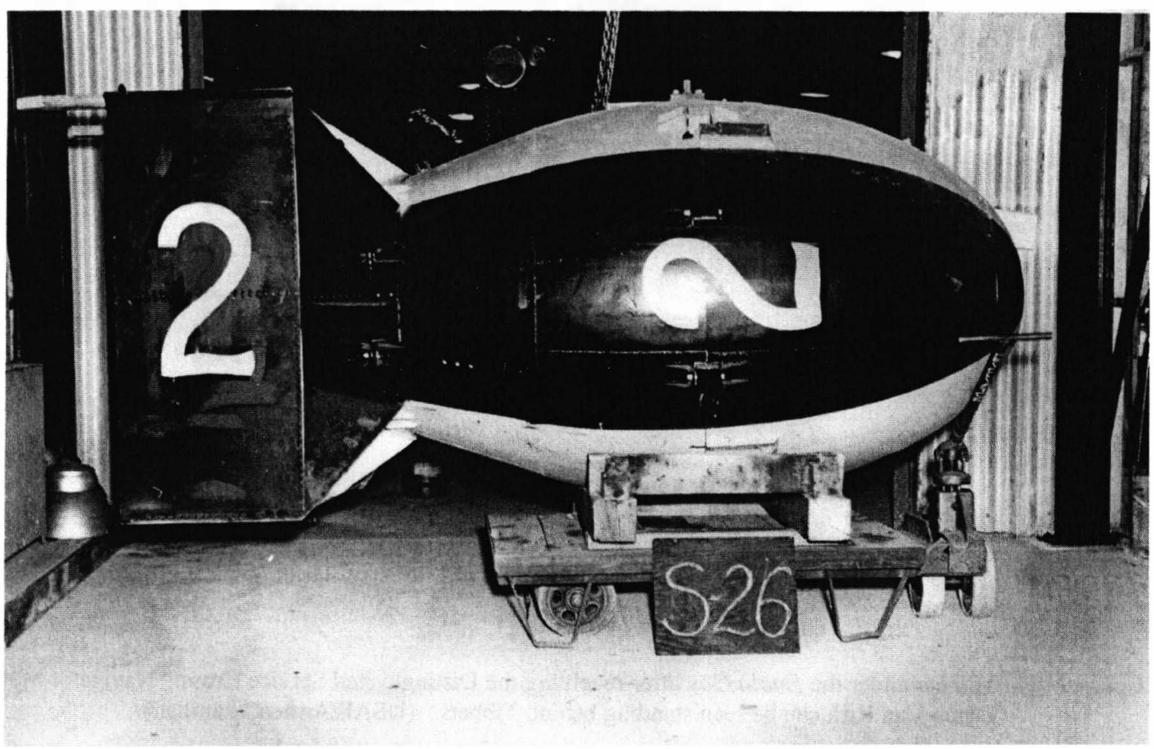
Keijiro Matsushima was only 16 when he looked out his classroom window and saw the *Enola Gay* overhead moments before *Little Boy* exploded a few miles from his school. Here he is in 2010 describing to an audience in the Hiroshima Peace Museum the horrors of what it was like when he awoke trapped in the rubble of his destroyed school after being knocked unconscious by the force of the blast. (Author)



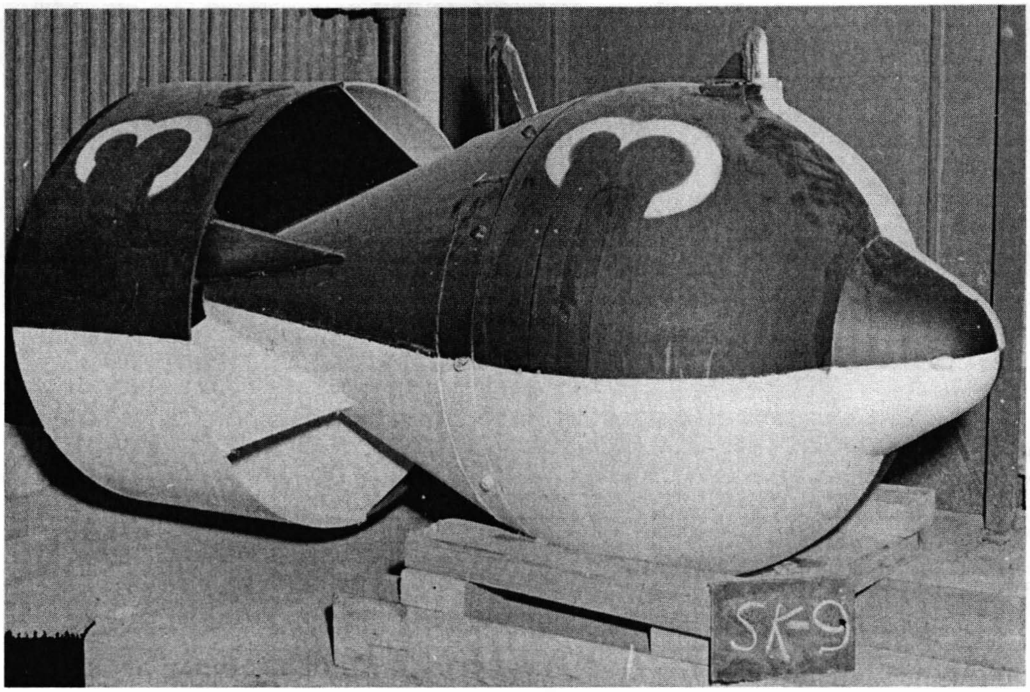
Colonel Paul Tibbets under the *Enola Gay* after receiving the Distinguished Service Cross. Navigator Maj. Dutch Van Kirk can be seen standing behind Tibbets. (USAF/Armen Shamlian)



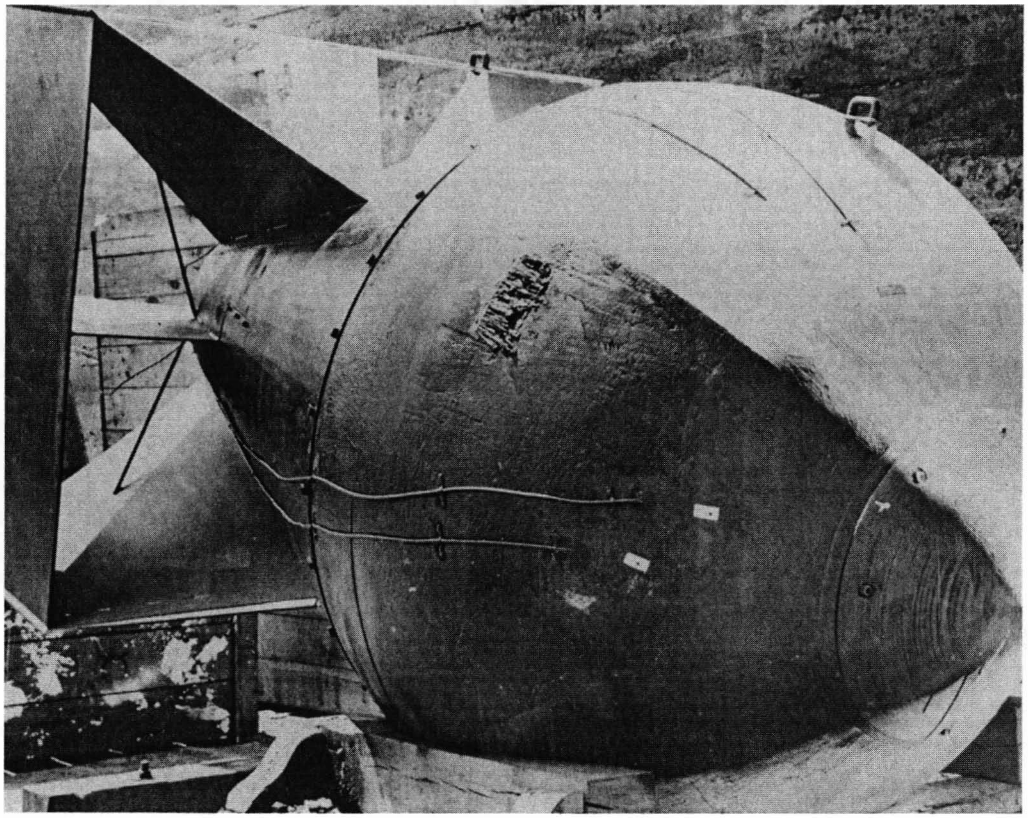
Technician makes final adjustments to one of the ballistic case draw bolts on a Mark III *Fat Man* postwar stockpile unit. (LANL)



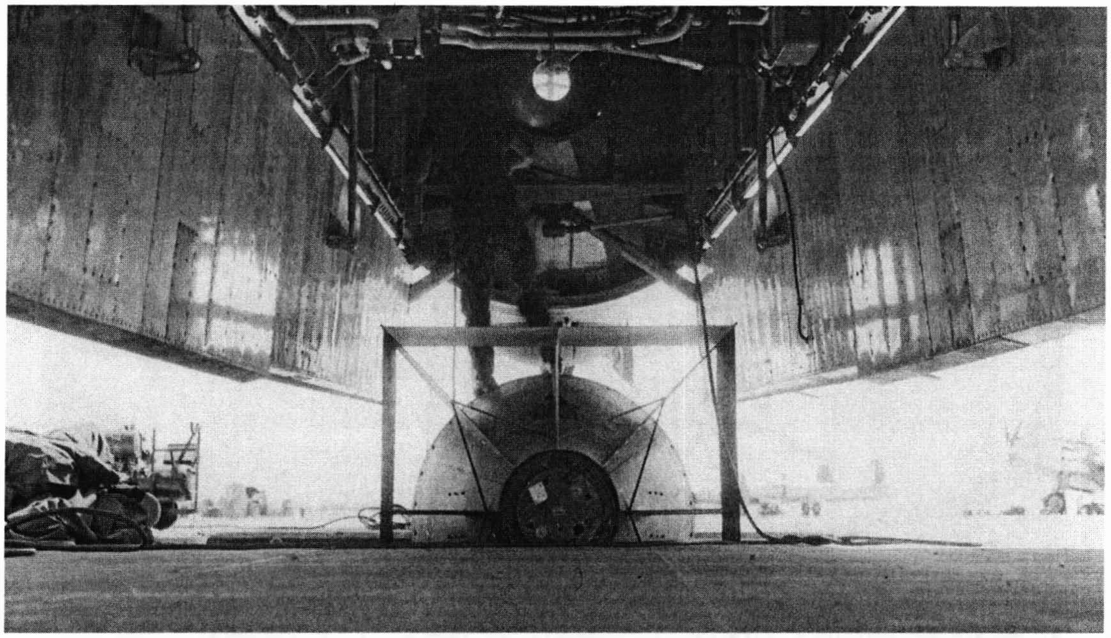
Early Wendover *Fat Man* test unit. (LANL)



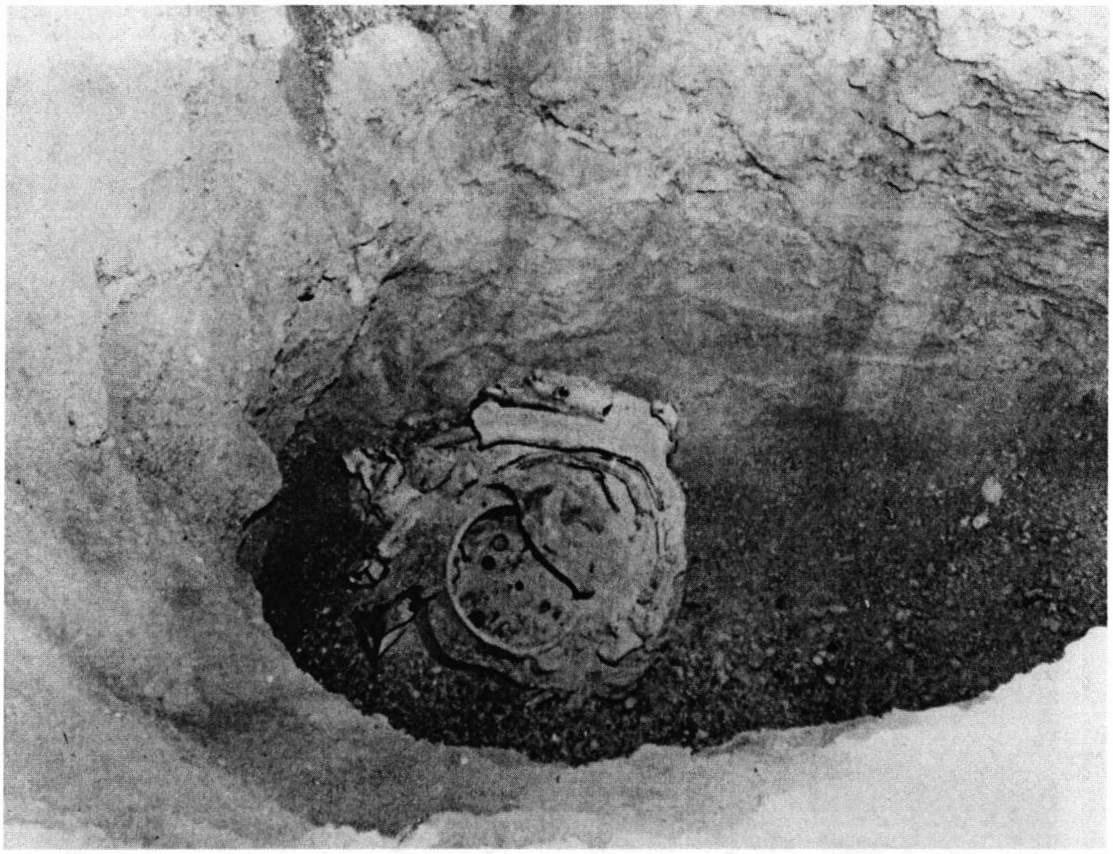
Early *Fat Boy* prototype test shape. Note the circular tail shape. (LANL)



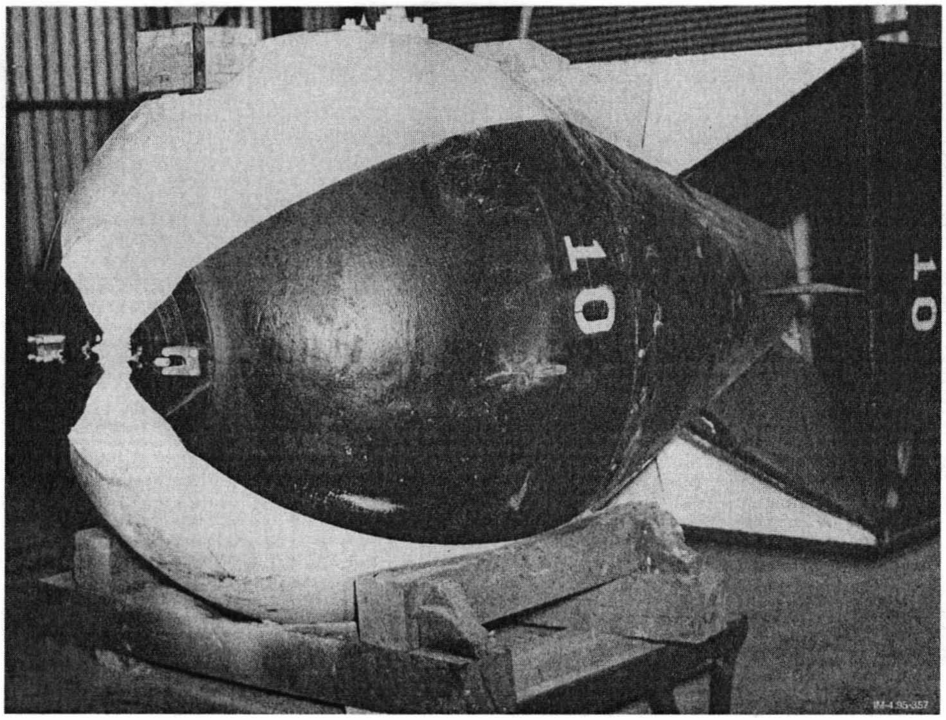
Early *Fat Man* test unit at Muroc. (LANL)



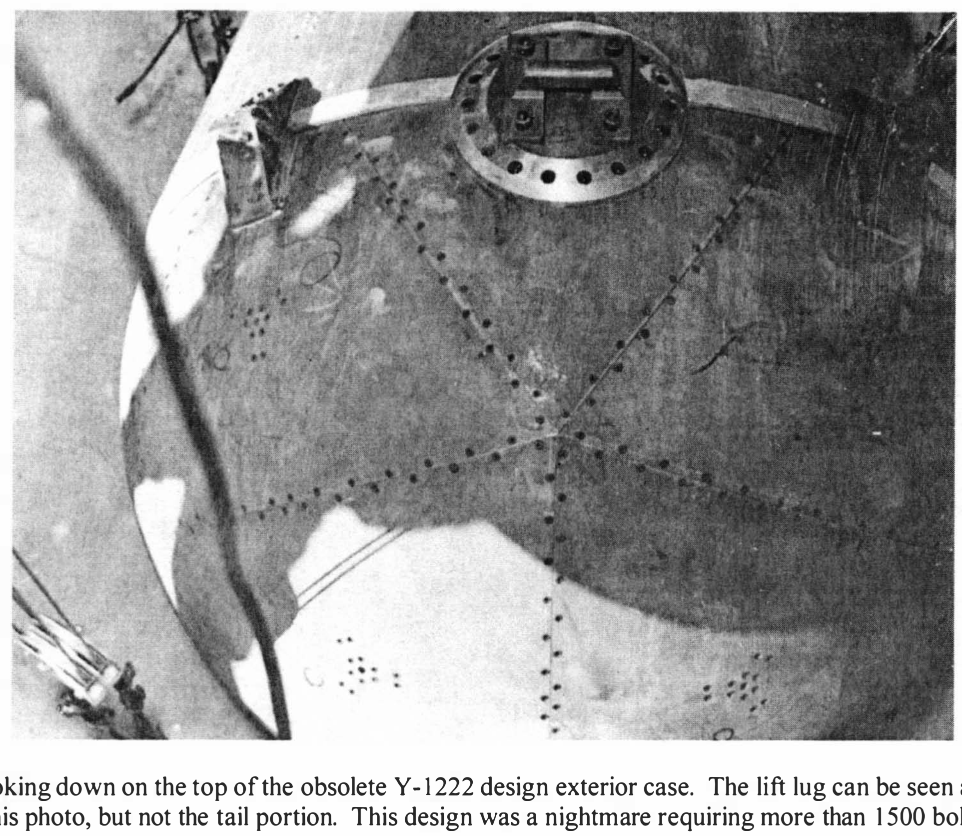
Early *Fat Man* test unit inside loading pit under a B-29 bomb bay at Muroc. (LANL)



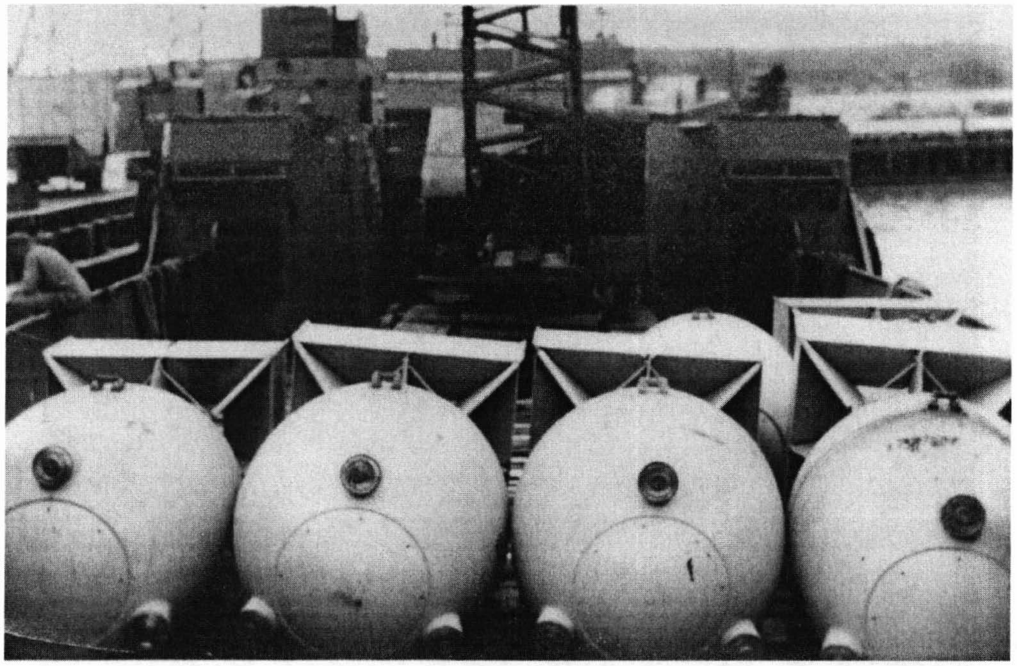
After being dropped from a high altitude by a B-29, the wreckage of an unexploded *Fat Man* test unit lies at the bottom of this newly-created bomb crater. (LANL)



Early *Fat Boy* test shape. (LANL)

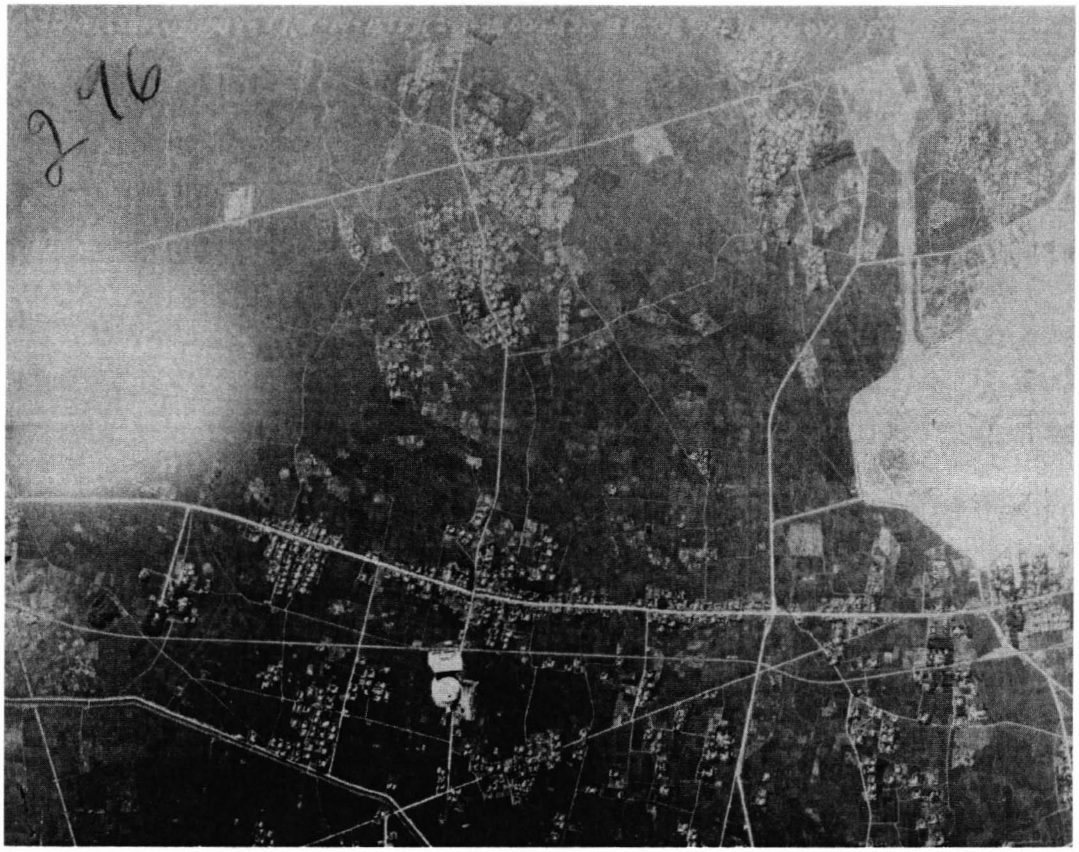


View looking down on the top of the obsolete Y-1222 design exterior case. The lift lug can be seen at the top in this photo, but not the tail portion. This design was a nightmare requiring more than 1500 bolts to assemble. (LANL)

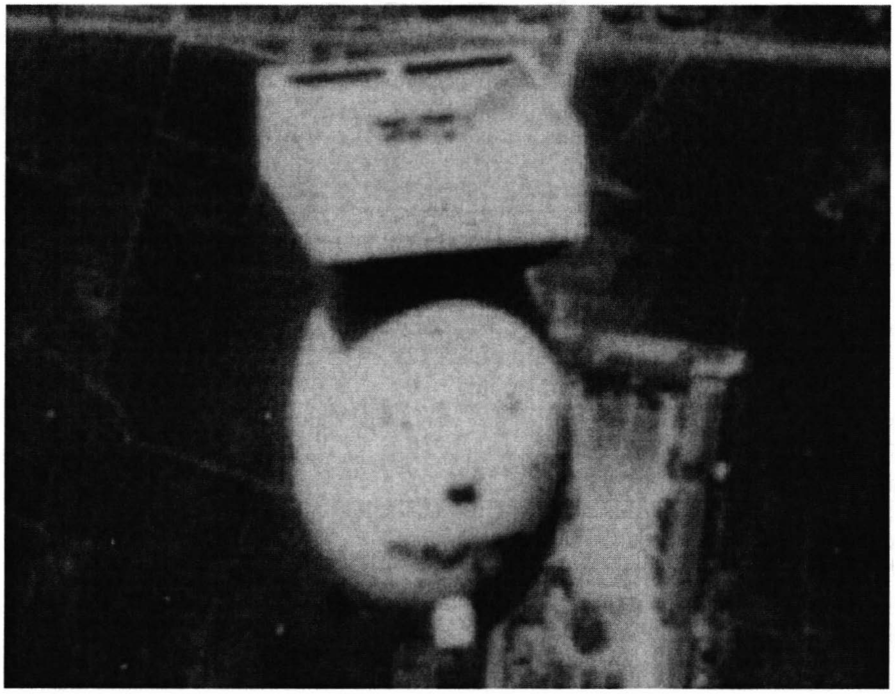


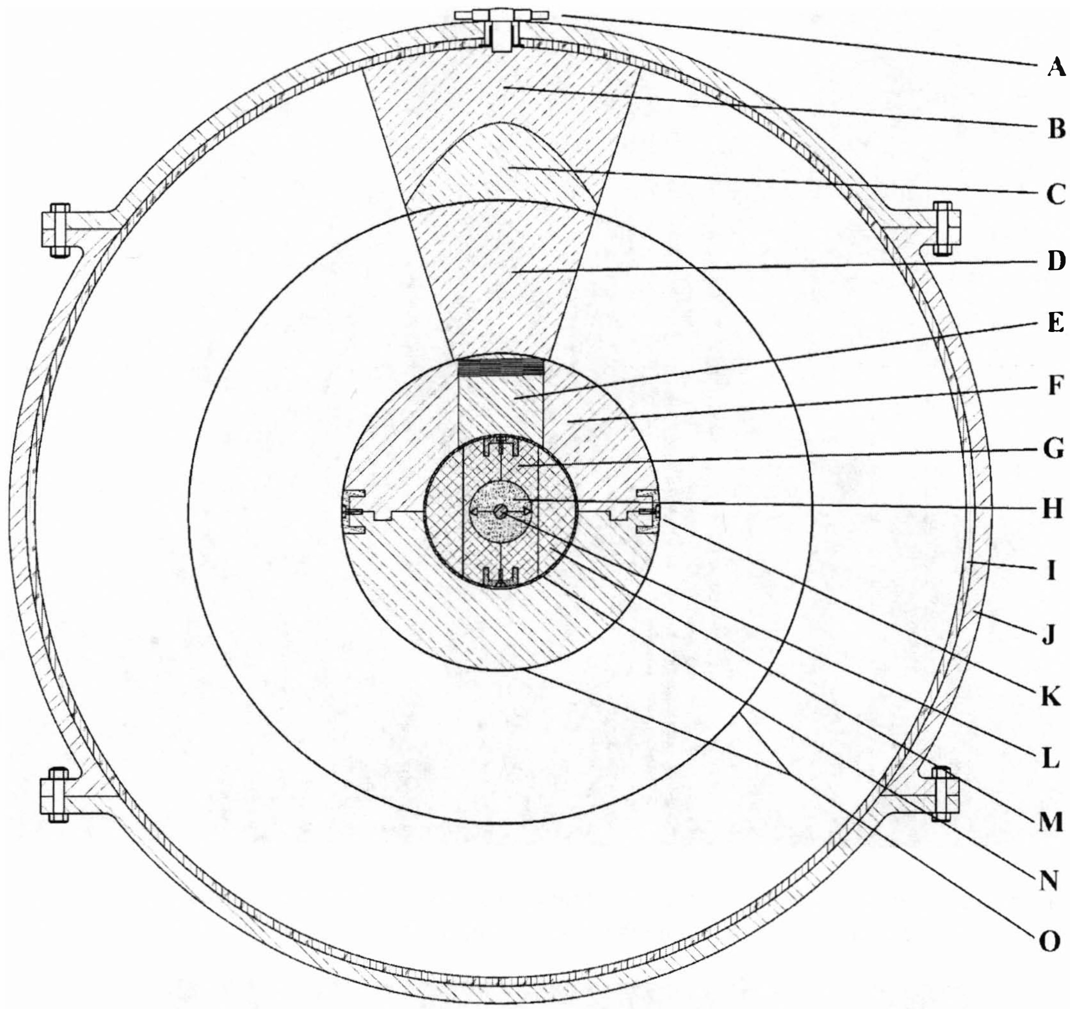
Pumpkins ready for unloading from a barge in the Tinian harbor in July 1945. The original negative is in the author's collection. (Hobart I. Reed/Richard Campbell)

Pumpkin on trailer at Wendover. Note three nose contact fuzes instead of the four used on *Fat Man*. (LANL)



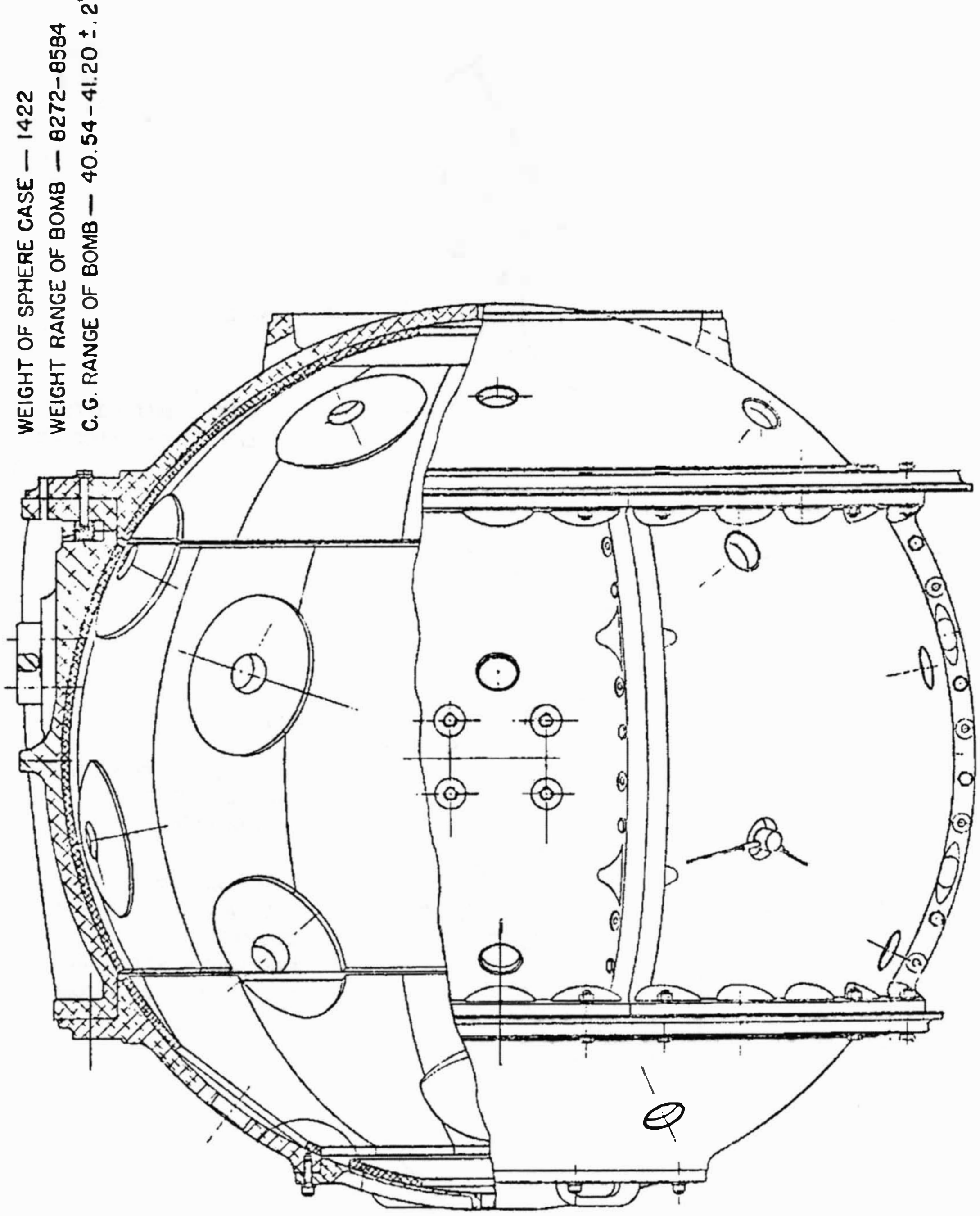
This photo taken from inside the B-29 shows a Pumpkin drop on 8/14/45 from 29,000 over Nagoya, Japan. Some believe this was the last bombing mission over Japan. (Enlarged view below) (USAF)



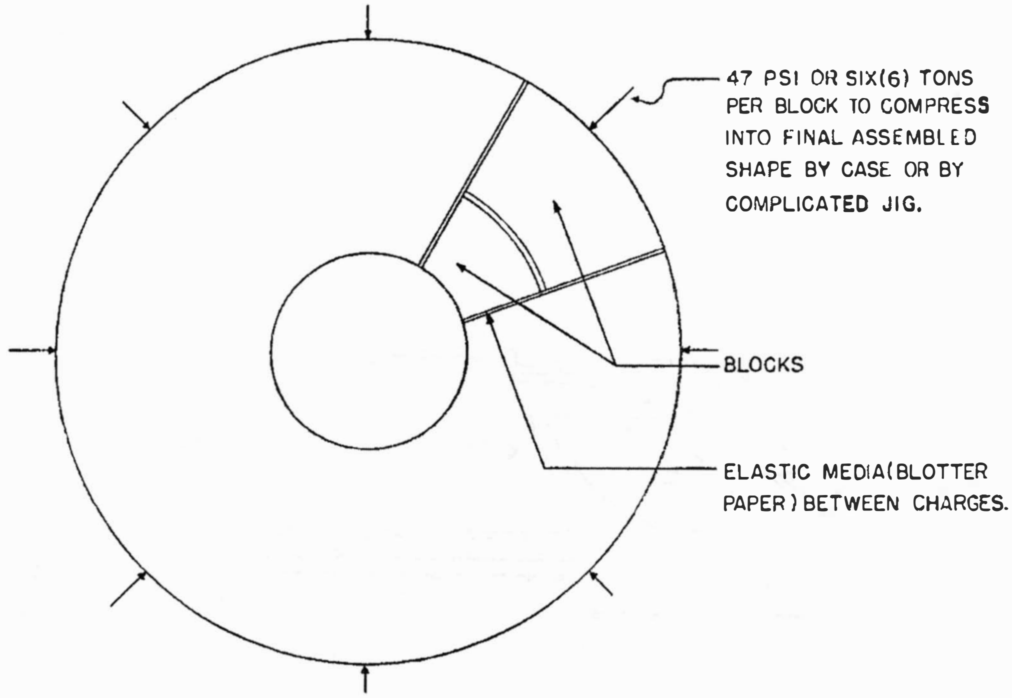


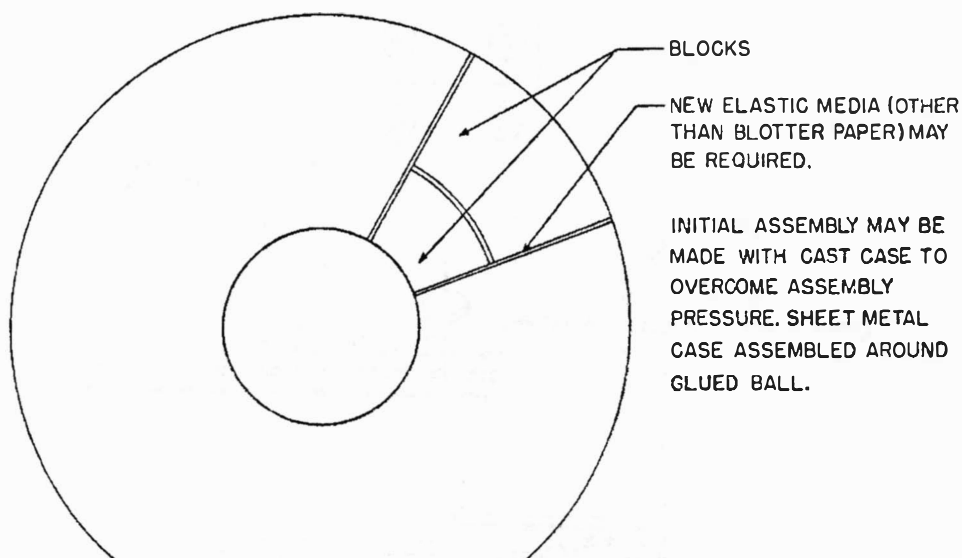
Cross-section drawing of the Y-1561 implosion sphere showing component placement. For simplicity, only one set of the 32 lenses, inner charges, and detonators is depicted. Numbers in ( ) indicate quantity of identical components. Drawing is shown to scale. (Author)

A) 1773 EBW detonator inserted into brass chimney sleeve (32)
B) Comp B component of outer polygonal lens (32)
C) Cone-shaped Baratol component of outer polygonal lens (32)
D) Comp B inner polygonal charge (32)
E) Removable aluminum pusher trap-door plug screwed into upper pusher hemisphere
F) 18.5" diameter Aluminum pusher hemispheres (2)
G) 5" diameter Tuballoy two-piece tamper plug
H) 3.62" diameter Pu-239 hemispheres with 2.75" I.D. jet ring
I) 0.5" thick Cork lining
J) 7-piece Y-1561 Duralumin sphere
K) Aluminum cup holding pusher hemispheres together (4)
L) 0.8" diameter Polonium-Beryllium Urchin initiator
M) 8.75" diameter Tuballoy tamper sphere
N) 9.0" diameter Boron plastic shell
O) Felt padding layer under lenses and inner charges

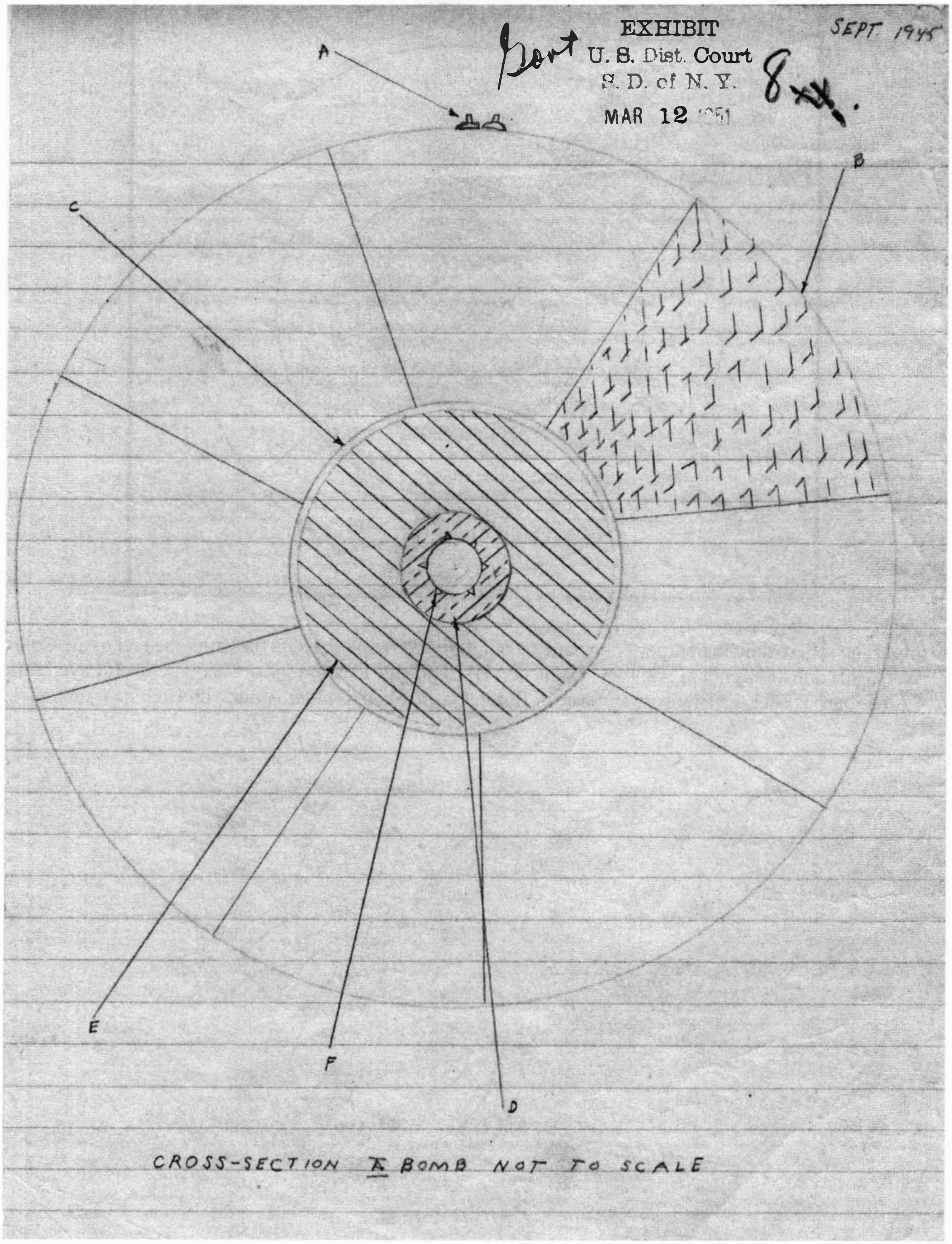


This declassified drawing shows the aluminum sphere case for the postwar Mark 6 implosion device. Except for some minor changes, this 32 detonator sphere case was basically the same design used for the Y-1561 *Fat Man* and the postwar Mark 4. It used handlebar EBW detonators and a ½" cork lining. The circular detonator pads are also visible in this drawing. (Sandia National Lab/Courtesy of Tom Cochran)

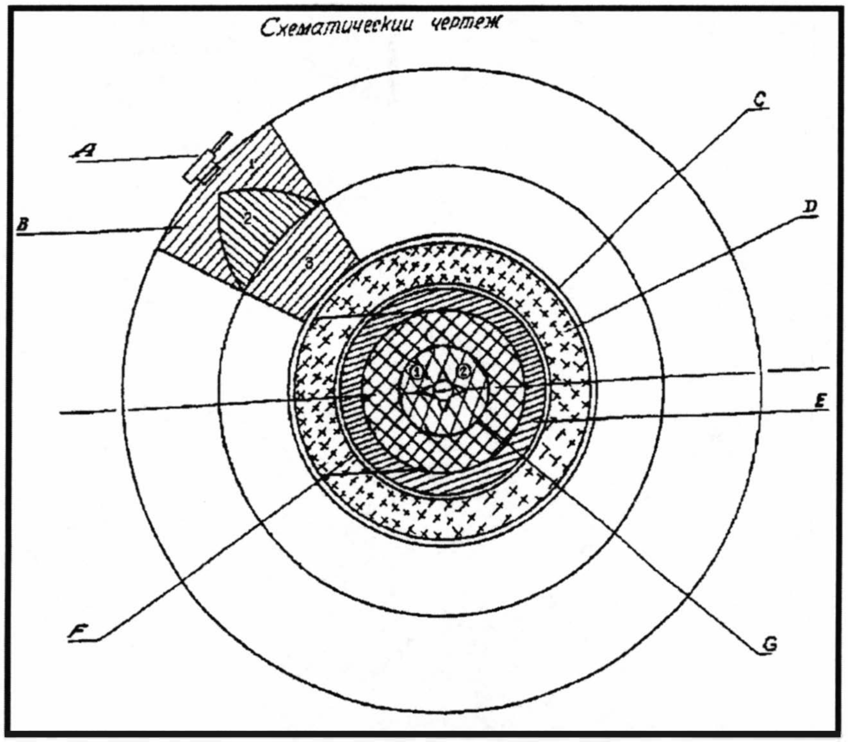




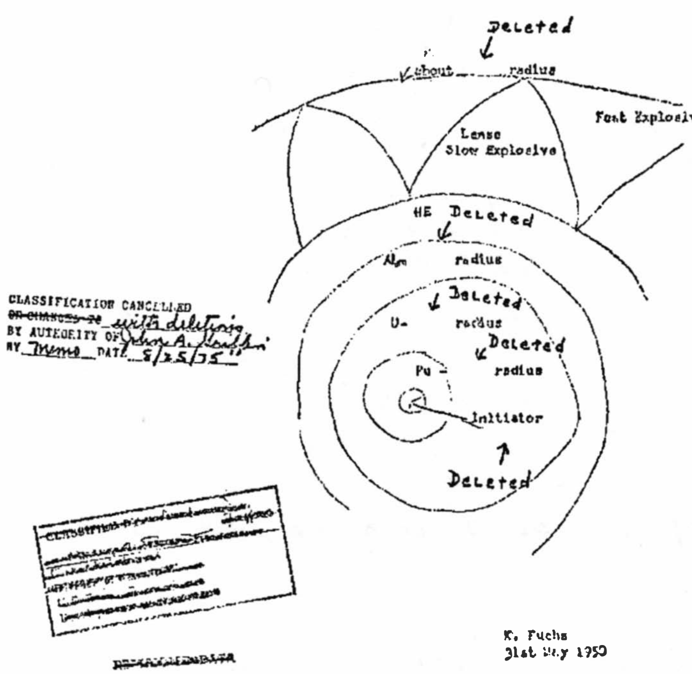
These declassified cross-section drawings show the HE layout and 18.5" pit for the postwar early 1950's era Mark 6 implosion device. The upper drawing shows the assembly technique for individual loose charges while the lower drawing depicts glued charges. The lens design in this model shows that the scientists had progressed to a design where the lens was thicker than the inner charges. They were still using the 1/2"' thick cork lining and blotter paper on the HE block sides. (Sandia/Courtesy of Tom Cochran)



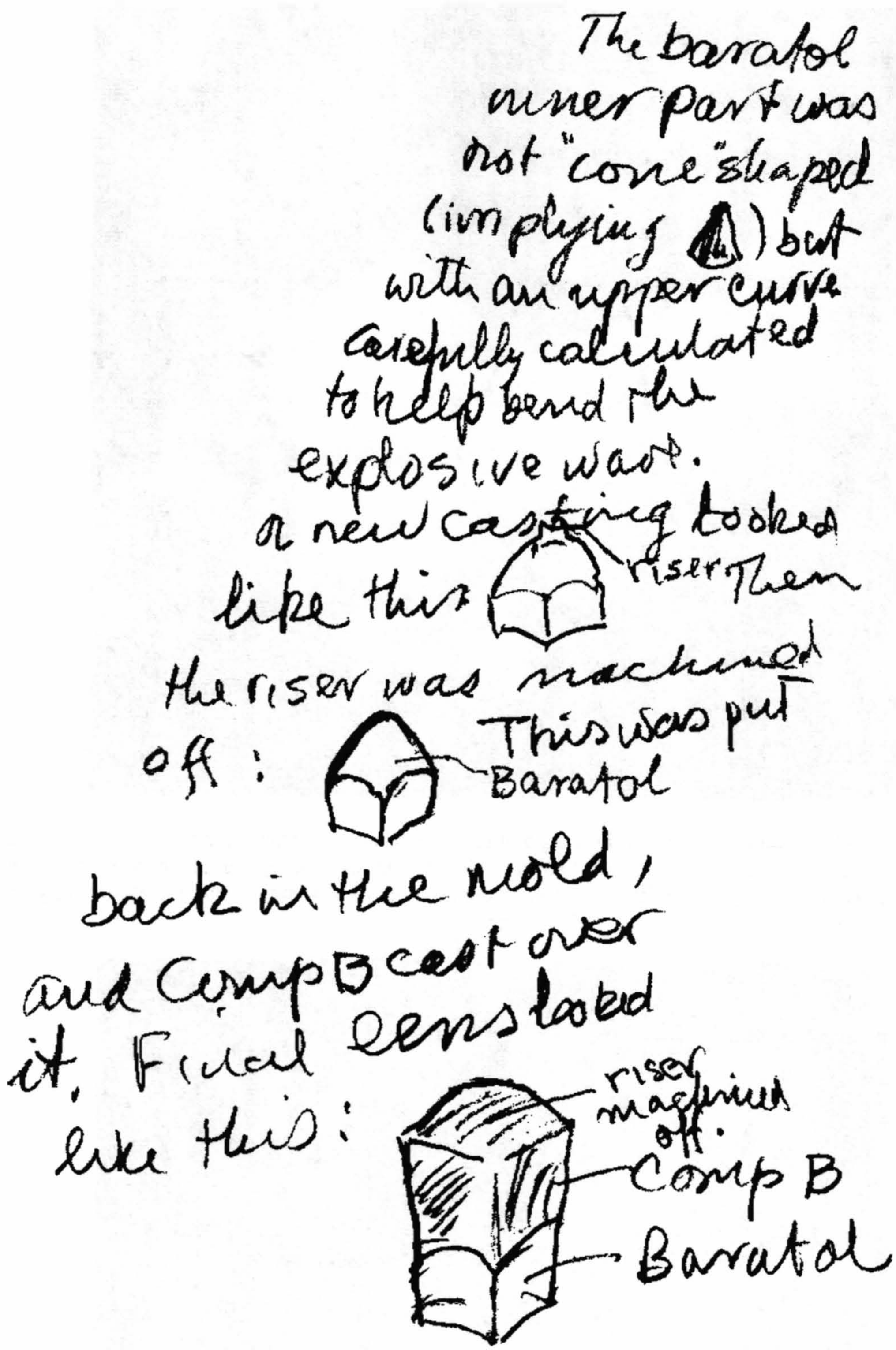
Implosion sphere cross-section used in 1951 Rosenberg spy case. (National Archives/Courtesy of Alex Wellerstein)



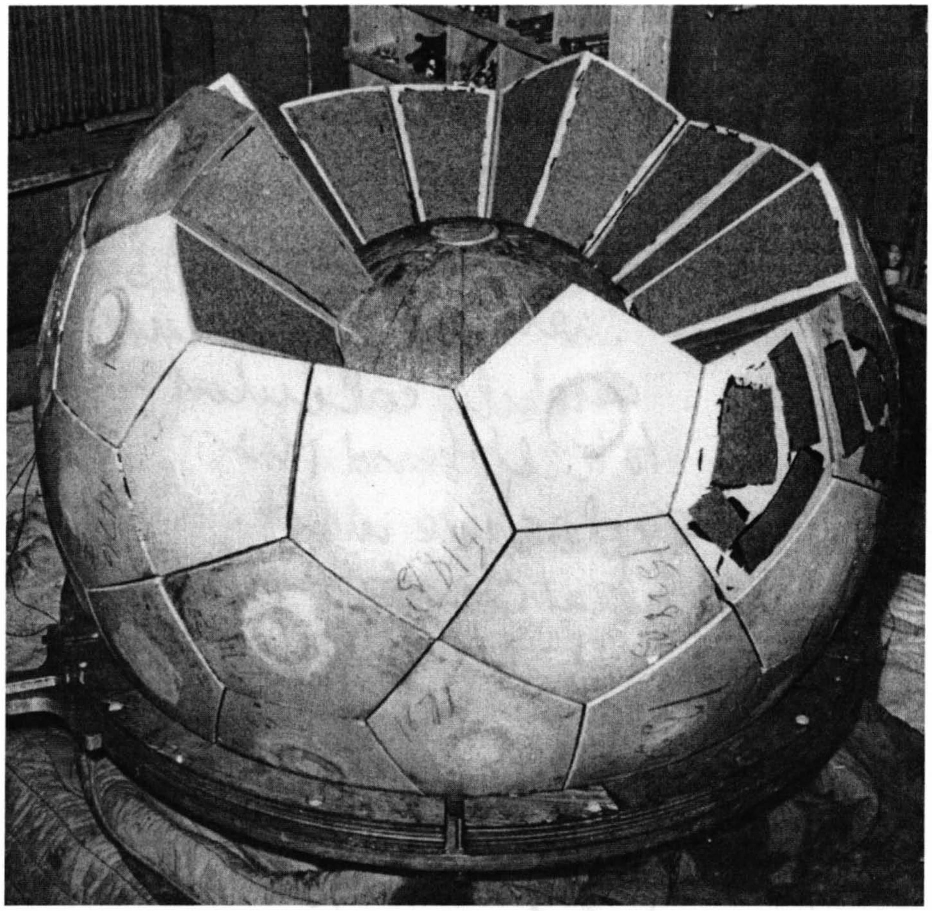
Implosion sphere drawing purportedly made by Klaus Fuchs found in KGB files after the end of the Cold War. This drawing is not to scale. A) Detonator, B) Explosive lens and Inner Charge, C) Felt Layer, D) Aluminum Pusher, E) Uranium Tamper, F) Boron Plastic Shell, G) Plutonium with Urchin. (Author)



Another Fuchs drawing from the same period. (FBI)



This exclusive drawing by Manhattan Project SED MacAllister Hull shows the procedure involved for casting an explosive lens. (Author)



The 72-block Y-1222 implosion design showing blotter paper-faced solid Comp B non-lens HE blocks and 24.5" diameter felt-covered aluminum pusher sphere. Note the use of both regular and irregular pentagonal shaped charges in this design. No detonator holes were used in this test unit. (Courtesy of James Lyons, Sr.)

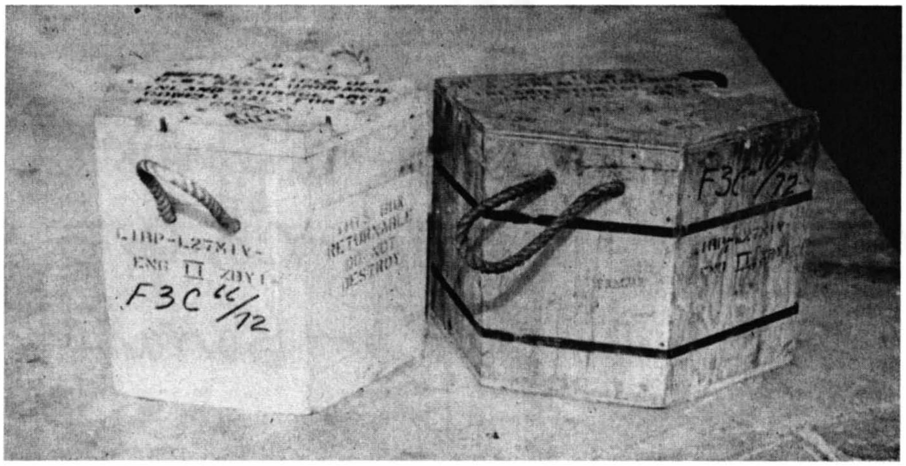
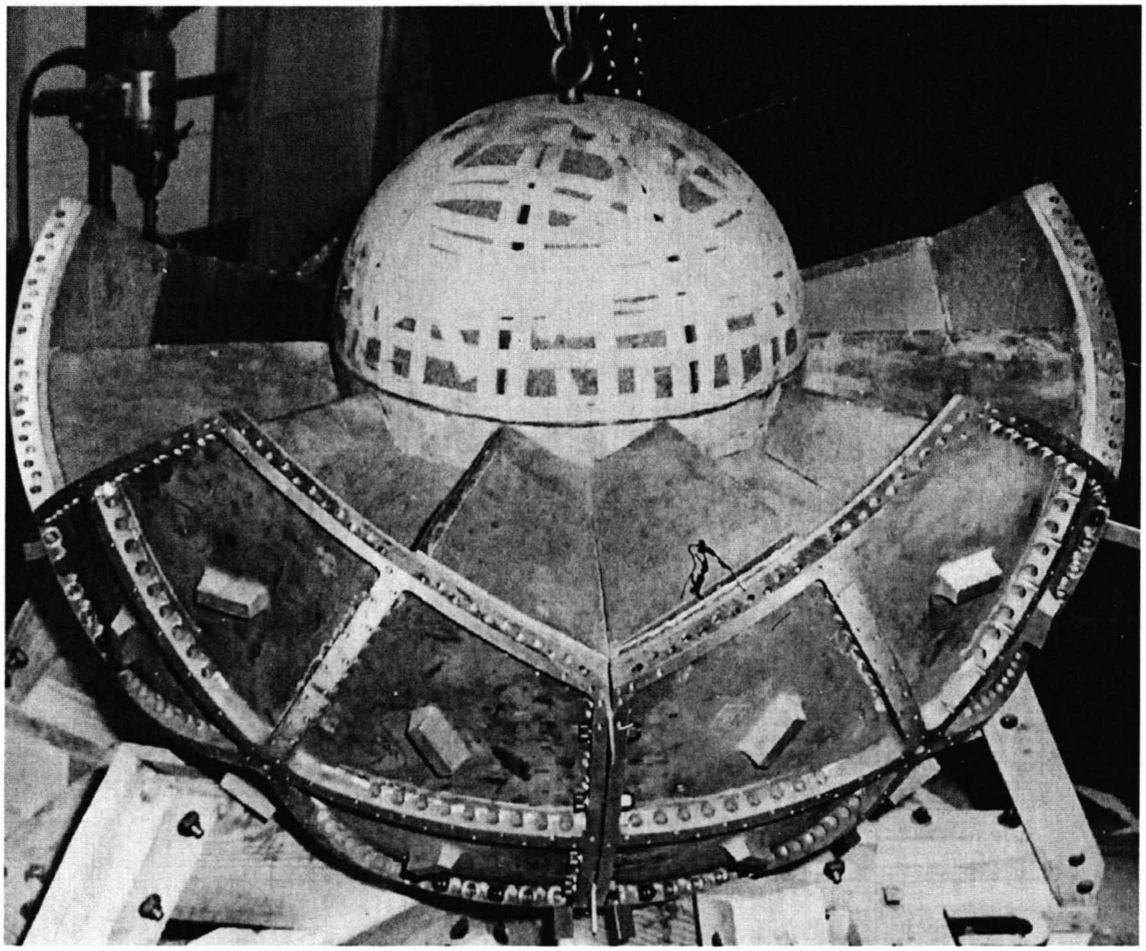
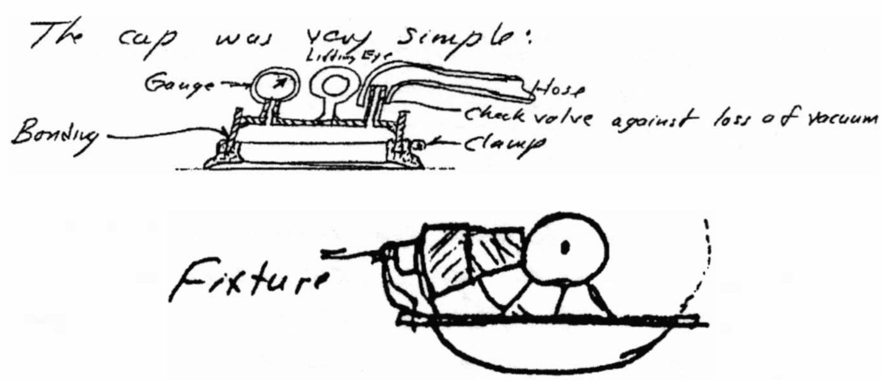


Photo shows the two sizes of shipping crates used to transport the pentagonal Comp B charges for the 72-block design. Note the number of each block written on the cases. (National Archives/Courtesy of Steve Bice)



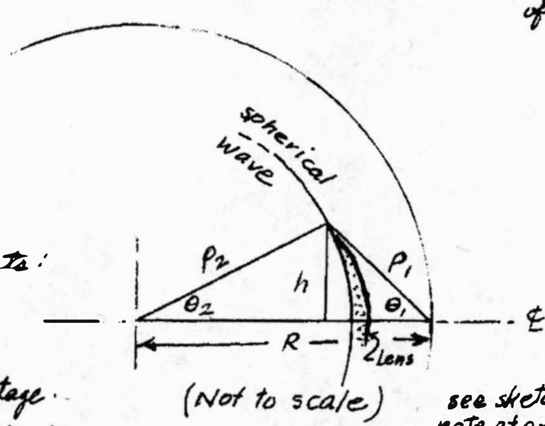
Same Y-1222 implosion design with six of the 12 large hexagonal Dural external sphere plates bolted in place over the HE blocks. The 1/2" cork lining is visible on the inner surface of the Dural sphere along with the tape used to hold the felt covering in place over the 24.5" aluminum pusher sphere. Since this was an early test unit, no detonator holes were drilled into the Dural sphere. The same 72-block non-lens design with the 24.5" pit was also used in the later Y-1291 model, which ultimately utilized the Y-1561 Dural case. (LANL/Courtesy of James Kunteka)



These exclusive drawings by Manhattan Project scientist Richard Bice shows both the vacuum cup used to move the HE blocks along with one of the fixtures, attached to the lower polar cap, that helped secure the HE blocks during the later 1561 sphere assembly process. (Courtesy of Steve Bice)

LENS

assume constant velocities v of explosion travel in both outer (1), and inner (2), components:



see sketch note at end.

① refraction index $\mu = \frac{v_1}{v_2}$

② $h = \rho_1 \sin\theta_1 = \rho_2 \sin\theta_2$ at any stage.

③ Times: $T = T_1 + T_2 = \frac{\rho_1}{v_1} + \frac{\rho_2}{v_2}$ = constant

④ ℄ Distance: $R = R_1 + R_2 = \rho_1\cos\theta_1 + \rho_2\cos\theta_2$

$$\underset{(4)}{R_1} = \rho_1\cos\theta_1 = \rho_1\sqrt{1-\sin^2\theta_1} \underset{(2)}{=} \rho_1\sqrt{1-\left(\frac{\rho_2}{\rho_1}\sin\theta_2\right)^2} \underset{\substack{(3)\\(1)}}{=} (v_1T-\mu\rho_2)\sqrt{1-\left(\frac{\rho_2\sin\theta_2}{v_1T-\mu\rho_2}\right)^2}$$

whence from ④:

$$R_1 + R_2 = (v_1T-\mu\rho_2)\sqrt{1-\left(\frac{\rho_2\sin\theta_2}{v_1T-\mu\rho_2}\right)^2} + \rho_2\cos\theta_2 = R$$

$$\sqrt{1-\left(\frac{\rho_2\sin\theta_2}{v_1T-\mu\rho_2}\right)^2} = \frac{R-\rho_2\cos\theta_2}{v_1T-\mu\rho_2}$$ Square both sides

$$1-\left(\frac{\rho_2\sin\theta_2}{v_1T-\mu\rho_2}\right)^2 = \frac{(R-\rho_2\cos\theta_2)^2}{(v_1T-\mu\rho_2)^2}$$

$$v_1^2T^2 - 2v_1T\mu\rho_2 + \mu^2\rho_2^2 - \rho_2^2\sin^2\theta_2 = \frac{R^2 - 2R\rho_2\cos\theta_2 + \rho_2^2\cos^2\theta_2}{1}$$

$\sin^2\theta_2 + \cos^2\theta_2 = 1$

⑤ $\therefore\ v_1^2T^2 - 2v_1T\mu\rho_2 = R^2 - (\mu^2-1)\rho_2^2 - 2R\rho_2\cos\theta_2$ whence

⑥ $$\cos\theta_2 = \frac{R^2 - (\mu^2-1)\rho_2^2 + 2v_1T\mu\rho_2 - v_1^2T^2}{2R\rho_2}$$

in which T can be found from initial ℄ dimensions, and the lens curve plotted for selected values of ρ_2. These points can be converted, if desired, to x, y coordinates as usual by $x = \rho_2\cos\theta_2$ and $y = \rho_2\sin\theta_2$.

If, instead, it is preferred to calculate ρ_2 as a function of θ_2, (5) yields

(7) $$(\mu^2-1)\rho_2^2 + 2(R\cos\theta_2 - N_1\mu T)\rho_2 + N_1^2 T^2 - R^2 = 0$$

which can be solved by quadratic formula for ρ_2.

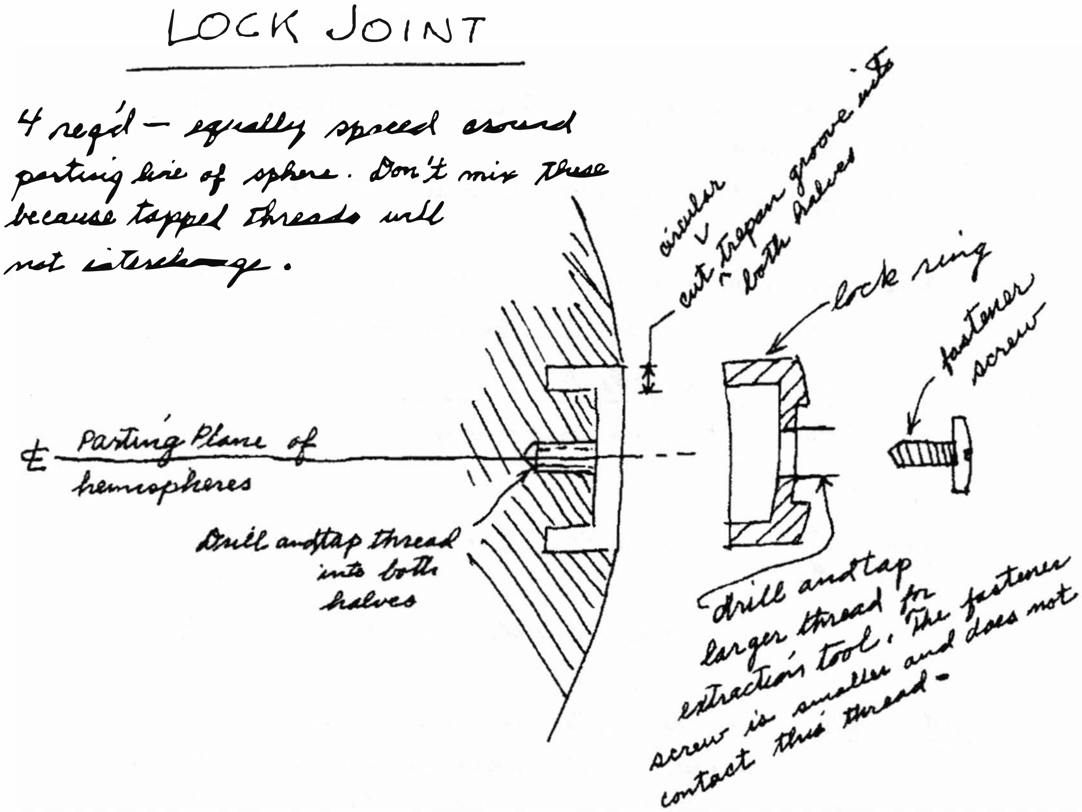
Also from (5) or (7), by differentiating:

(8) $$\frac{d\rho_2}{d\theta_2} = \frac{R\sin\theta_2\ \rho_2}{(\mu^2-1)\rho_2 + R\cos\theta_2 - N_1\mu T}$$

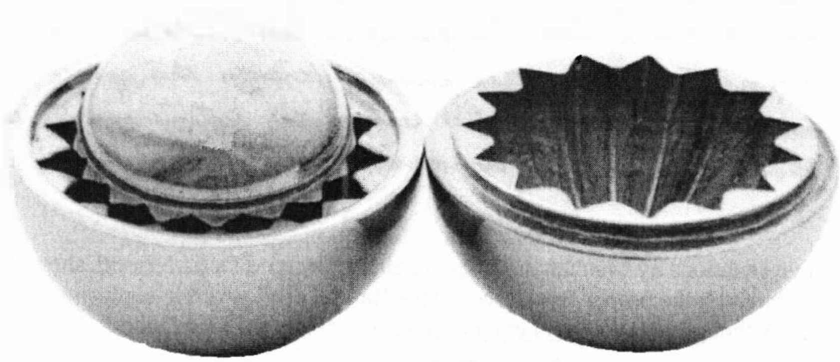
<u>note</u>: $\frac{d\rho_2}{d\theta_2} \to 0$ as $\theta_2 \to 0$, so the curve begins at the ℄ with a central circular arc of radius ρ_2.

<u>Sketch Note</u>: As the explosion speeds out along the lens surface, the wave in the inner slow compt is spherical all the way back to the ℄. When h reaches the casting boundary, the entire wave is spherically formed. It will then continue to shrink spherically all the way to the center of the sphere, no matter what the rest of the space to the center is filled with. The only part of the casting segment (in principle) that needs the slow component is the dotted volume between this sphere and the lens surface. The rest of the casting inward can be H.E., or any other homogeneous material.

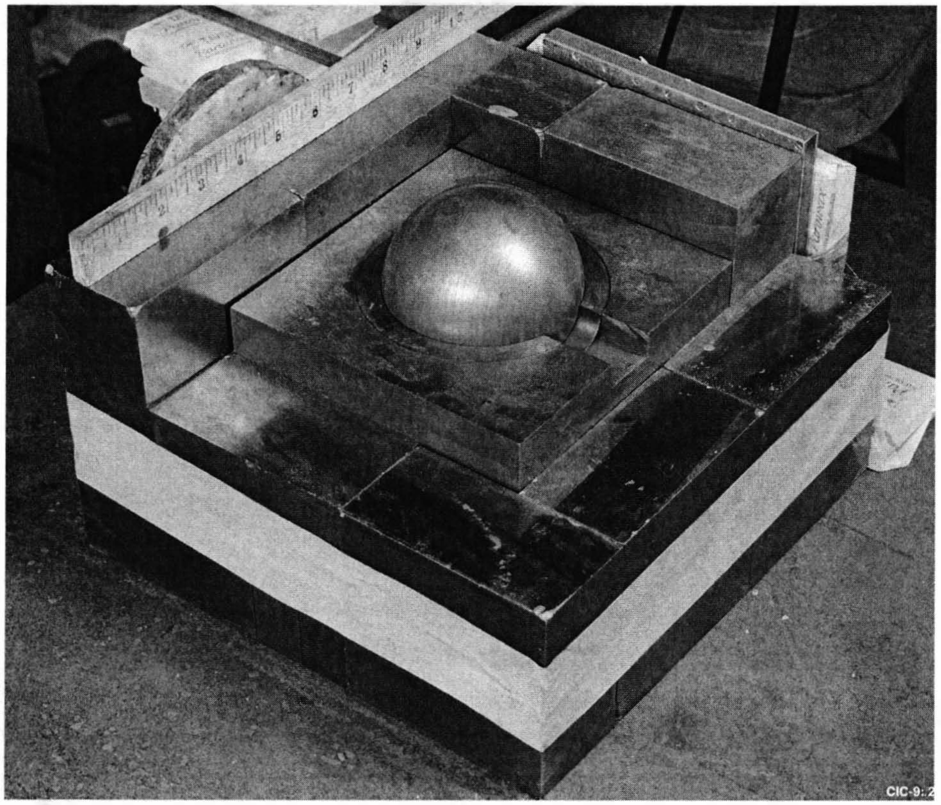
These exclusive equations by Manhattan Project engineer Leonard Della-Moretta show the principles involved in calculating the proper lens curve for the Baratol portion of the explosive lens used in the implosion device. Although <u>not the actual equations</u> used to create the lenses, these do illustrate the general principles involved. (Author)



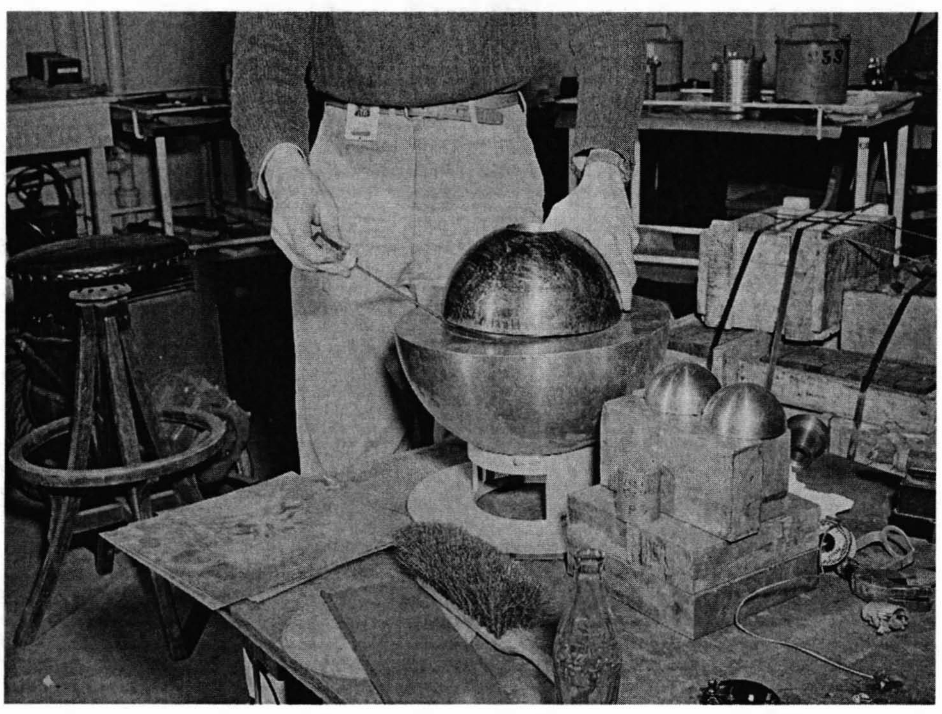
This exclusive sketch from Manhattan Project engineer Leonard Della-Moretta shows how the lock joint cups worked on the aluminum pusher hemispheres. The extraction tool mentioned was used in case the lock ring had to be removed so the pusher could be disassembled. The same principle was applied to the lock joint cups (trepanned rings) used to hold the two halves of the tamper plug together. (Author)



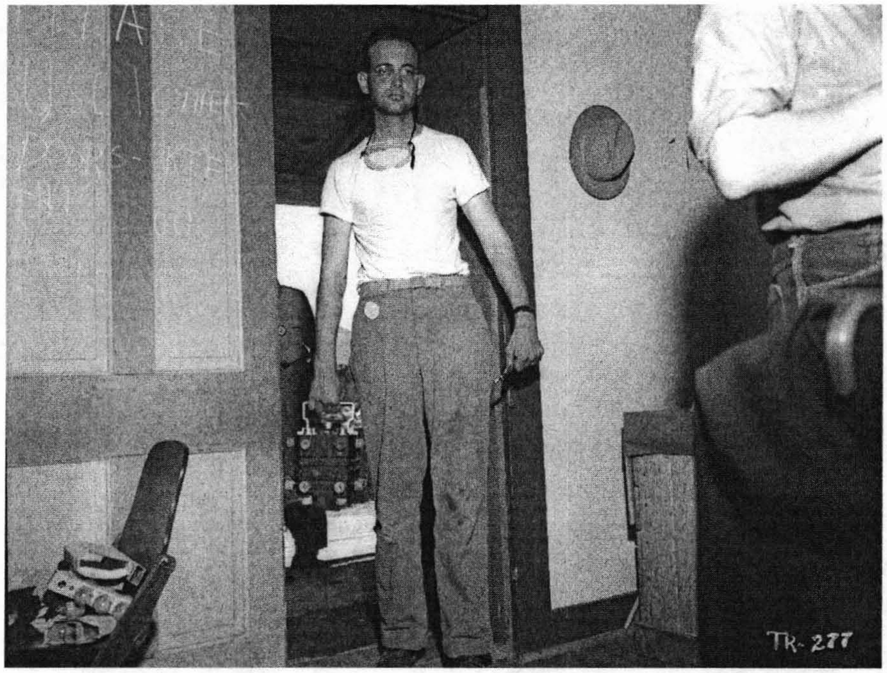
This is artist Jim Sanborn's interpretation of what the nickel and gold plated polonium-beryllium Urchin initiator might have looked like based on information found in the KGB files in the early 1990's. Los Alamos sources have told the author the interior was ribbed similar to what is shown here. (Author)

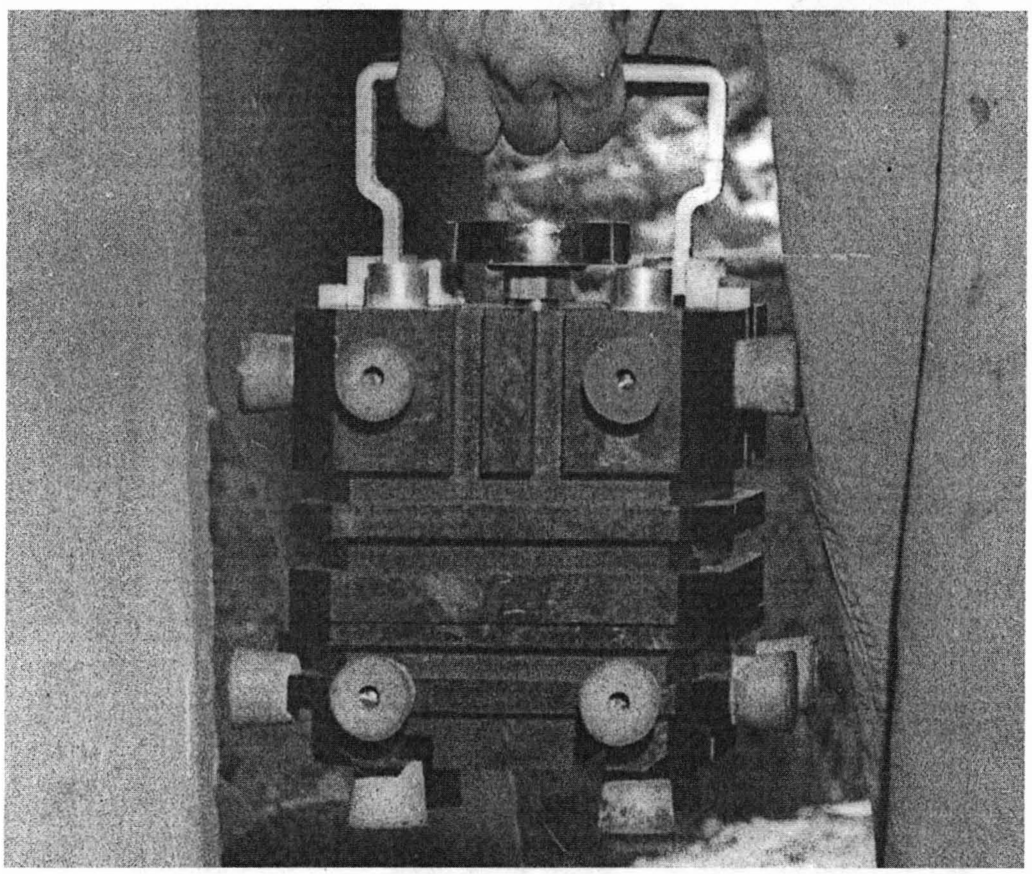


Daghlian accident reconstruction assembly showing Pu core surrounded by WC blocks. (LANL)



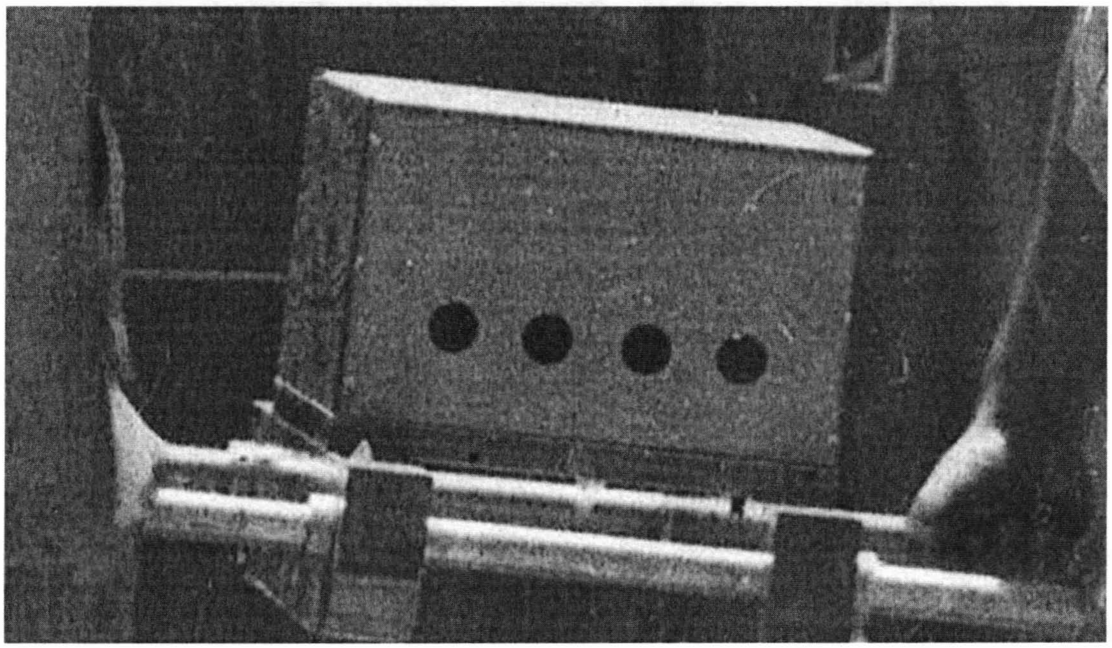
Slotin accident reconstruction assembly showing beryllium hemispheres. Note use of the screwdriver to hold the beryllium hemispheres apart and the two Pu hemispheres sitting atop the lead blocks. (LANL)



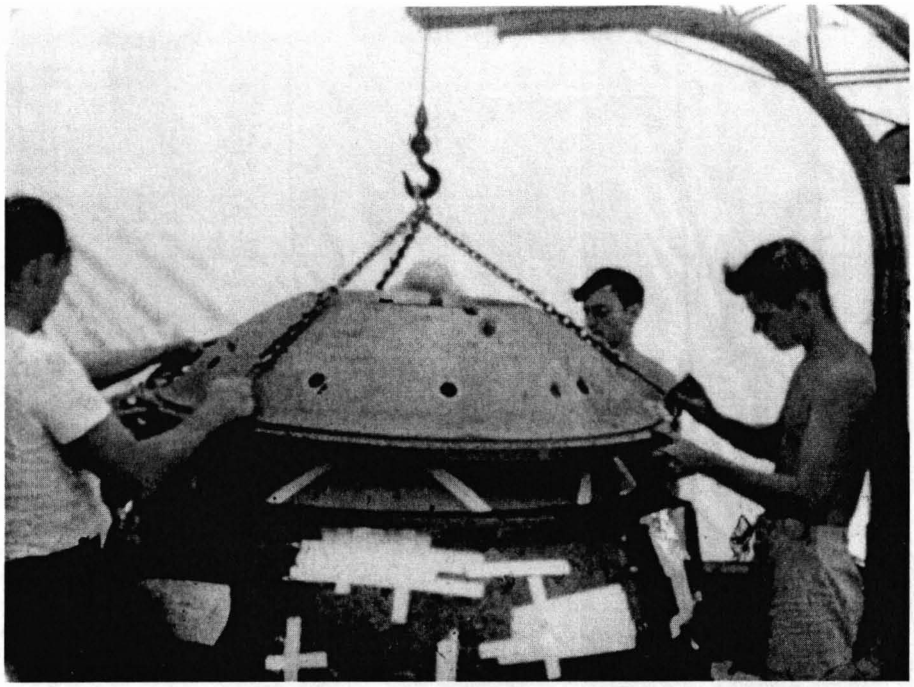


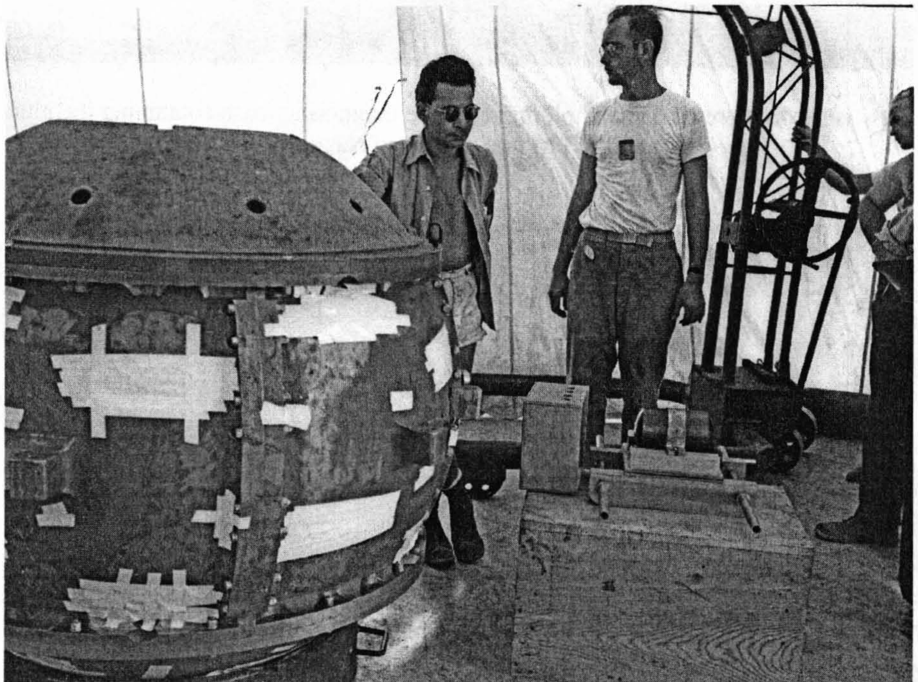
Herb Lehr carrying the magnesium case containing the Pu core and the initiators through the front doorway of the McDonald Ranch house. Robert Bacher's hat is shown hanging on the wall. The round thermometer on the top and the rubber bumpers on the sides and bottom can be seen in the close-up. (LANL)

Harold Agnew is shown here on Tinian holding the same magnesium case containing the plutonium core used in the F-31 FM that destroyed Nagasaki. (LANL)

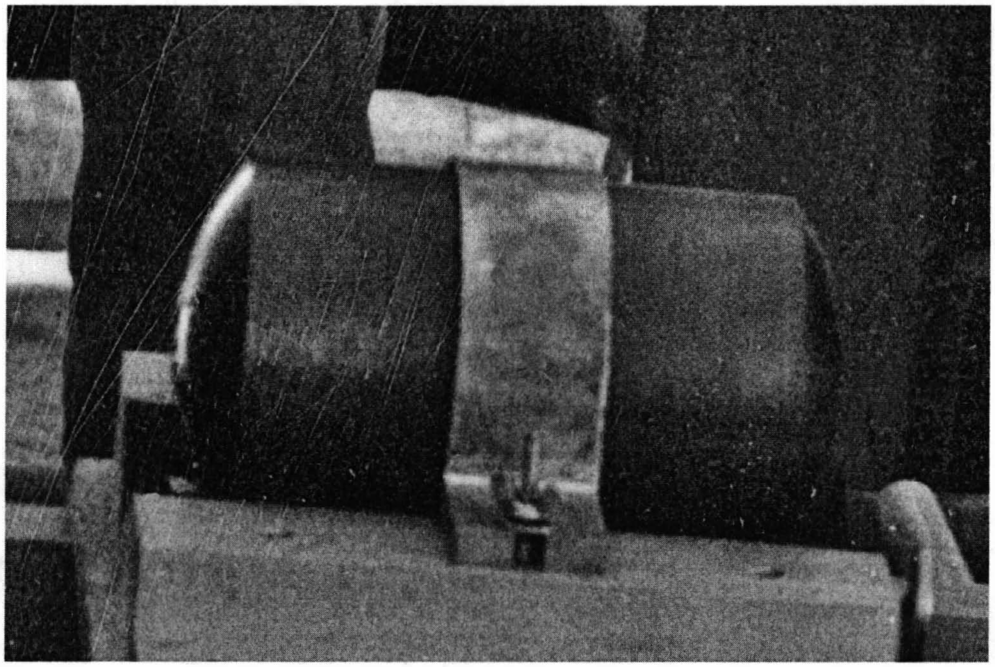


Close-up of ventilated wood box containing the plutonium-filled nuclear capsule carried by Lehr and Daghlian back out to the 1942 Plymouth after final assembly inside the McDonald Ranch house. (Author)

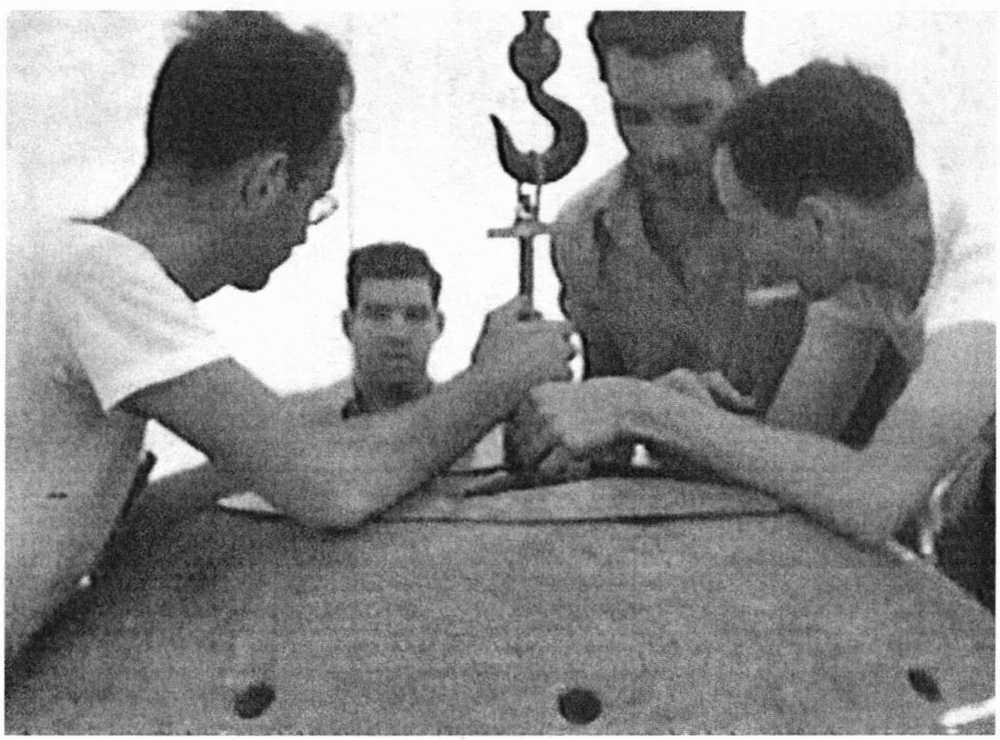




The upper photo shows the temporary polar cap, containing the opening for the copper funnel that protected the surrounding HE during the capsule loading process, being installed on the Dural sphere. The HE lenses with taped edges can be seen under the cap. In the lower photo, Lois Slotin is leaning on the Dural sphere while Herb Lehr stands next to him. They are preparing to use the Canton crane on the right to load the nuclear capsule into the sphere. Resting on top of the wood crate, this capsule is still strapped to the cradle Lehr and Daghlian loaded earlier into the 1942 Plymouth. This is the very first time these two photos have been seen in print. (LANL)

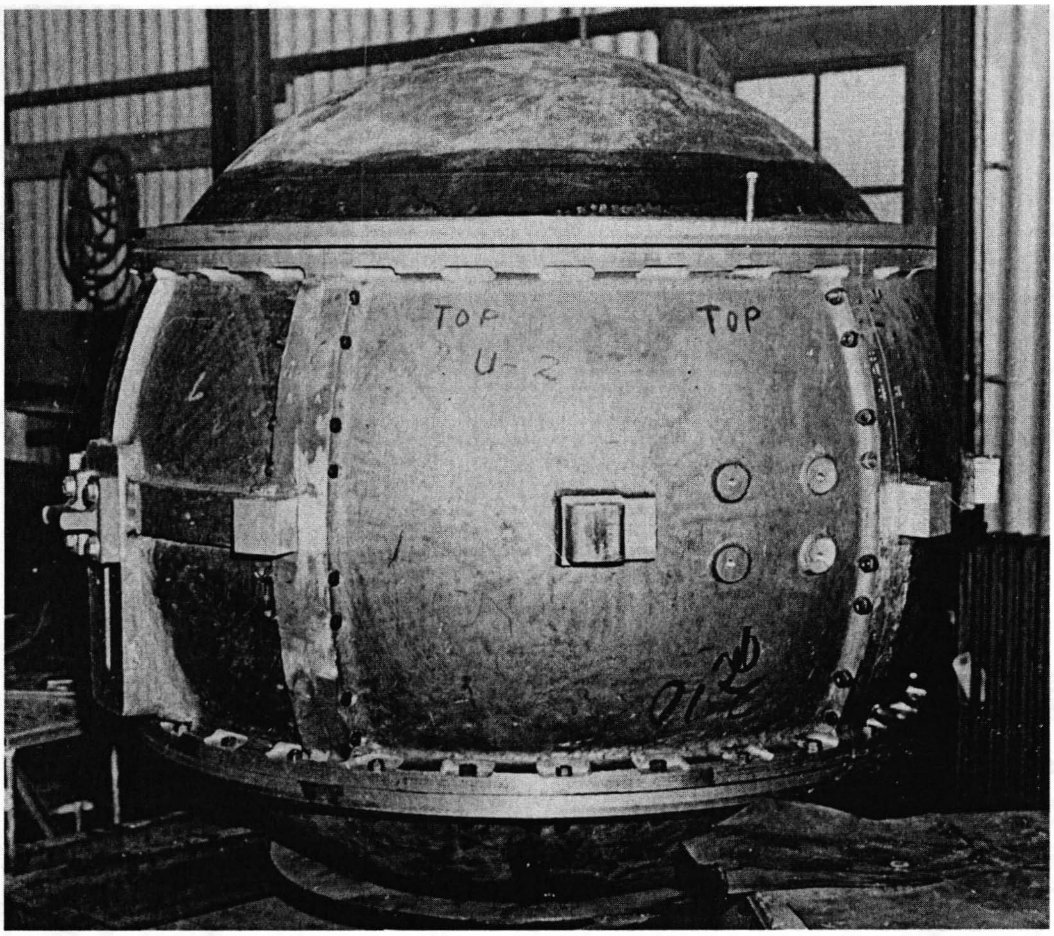


Here is a close-up of the 8.75" long, 5" diameter plutonium-filled nuclear capsule. (LANL)

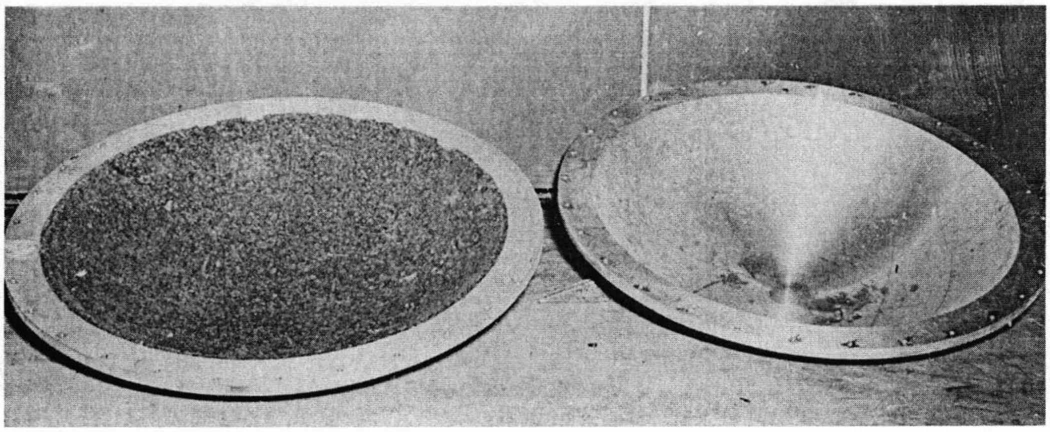


Still photo taken from the original color 8 mm movie footage showing the curved top and upper left edge of the nuclear capsule as it was being lowered into the opening in the top of the Dural sphere in the assembly tent at the Trinity site. Herb Lehr (l) looks on as Marshall Holloway (r) leans on the circular top of the copper funnel covering the opening in the specially modified polar cap and Louis Slotin looks over his shoulder. Holloway's fingers are shown resting on the capsule top. Harry Daghlian can be seen seated in the background. (Author)

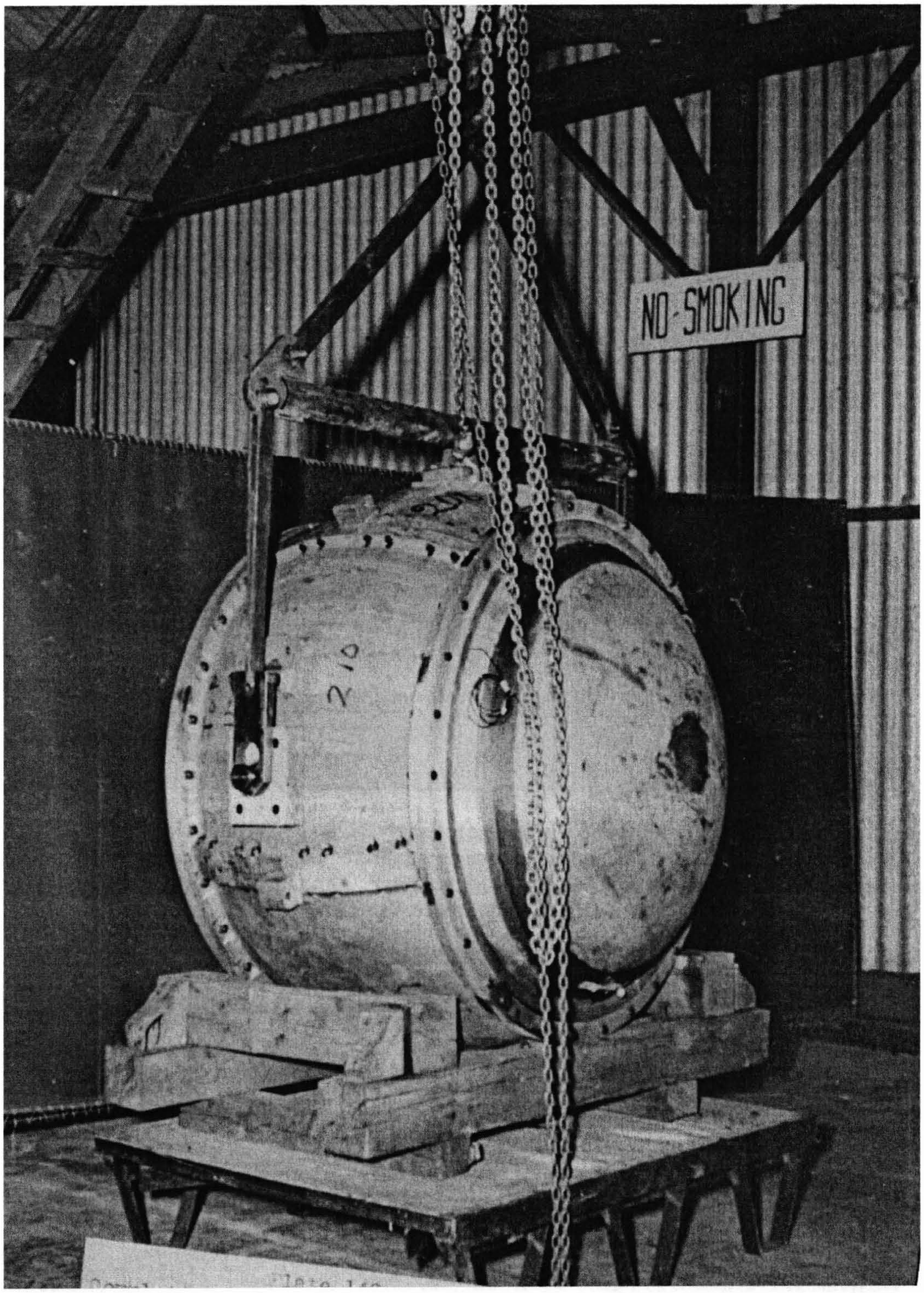
This very rare photo shows Raemer Schreiber steadying the 5" diameter Pu-filled uranium "capsule" as it is about to be loaded into the F-31 *Fat Man* Dural sphere inside Tinian Assembly Bldg. #3 in 1945. The top plate on this F-31 sphere is the same style as the one used on the Trinity sphere shown on the previous page. This top had a metal funnel built into it to protect the surrounding explosive blocks while it was being loaded into the 8.75" diameter Uranium tamper sphere down in the very center of that sphere. Schreib was present a few weeks earlier in the McDonald Ranch House to observe the assembly of that same style capsule for the Trinity device. In an extensive 1996 interview, he gave the author a complete description of exactly how that capsule was assembled. (Author)



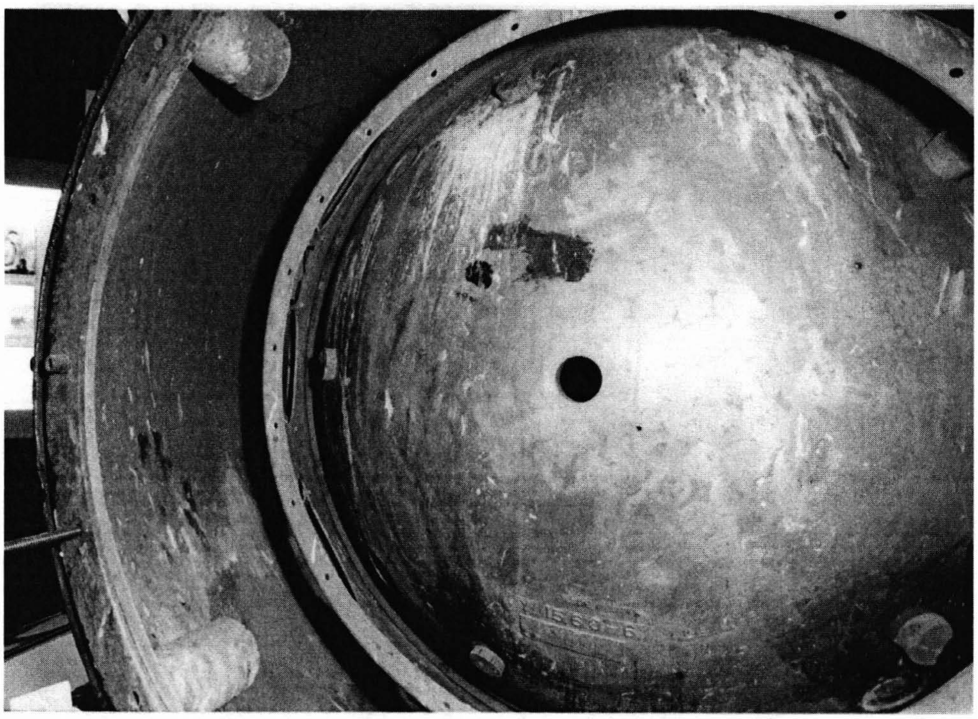
The Y-1561 Dural sphere is shown here inside the assembly building. The unit is resting on one of the polar caps and the lift lug is visible on the left side of the sphere. Several of the cubes used to hold the ballistic case are also visible around the middle of the sphere. This unit does not have detonator holes drilled in the sphere. (LANL)



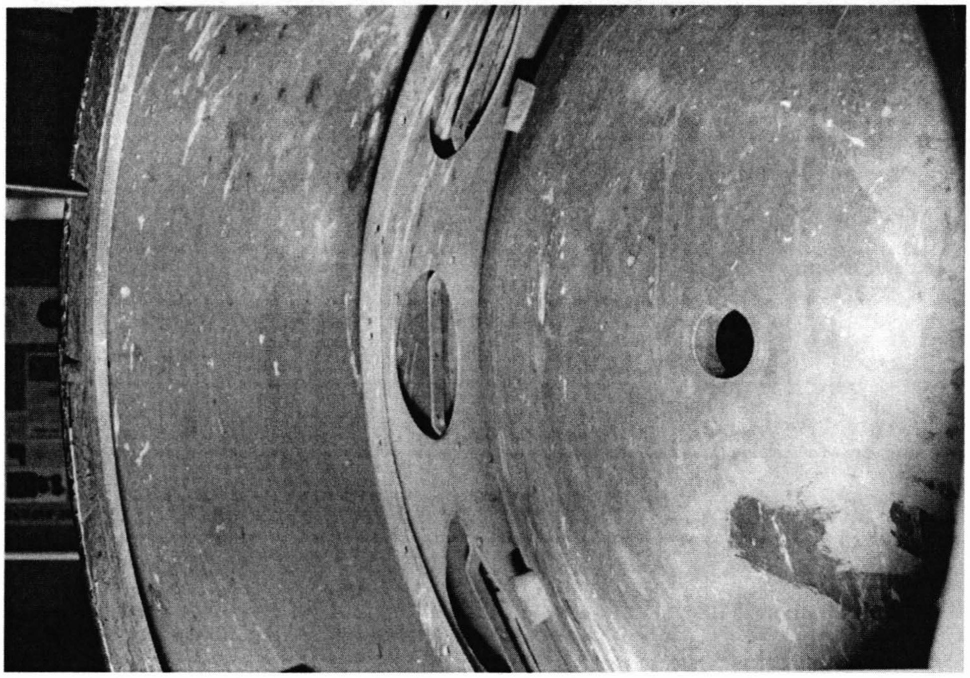
Polar caps with and without cork lining. (LANL)



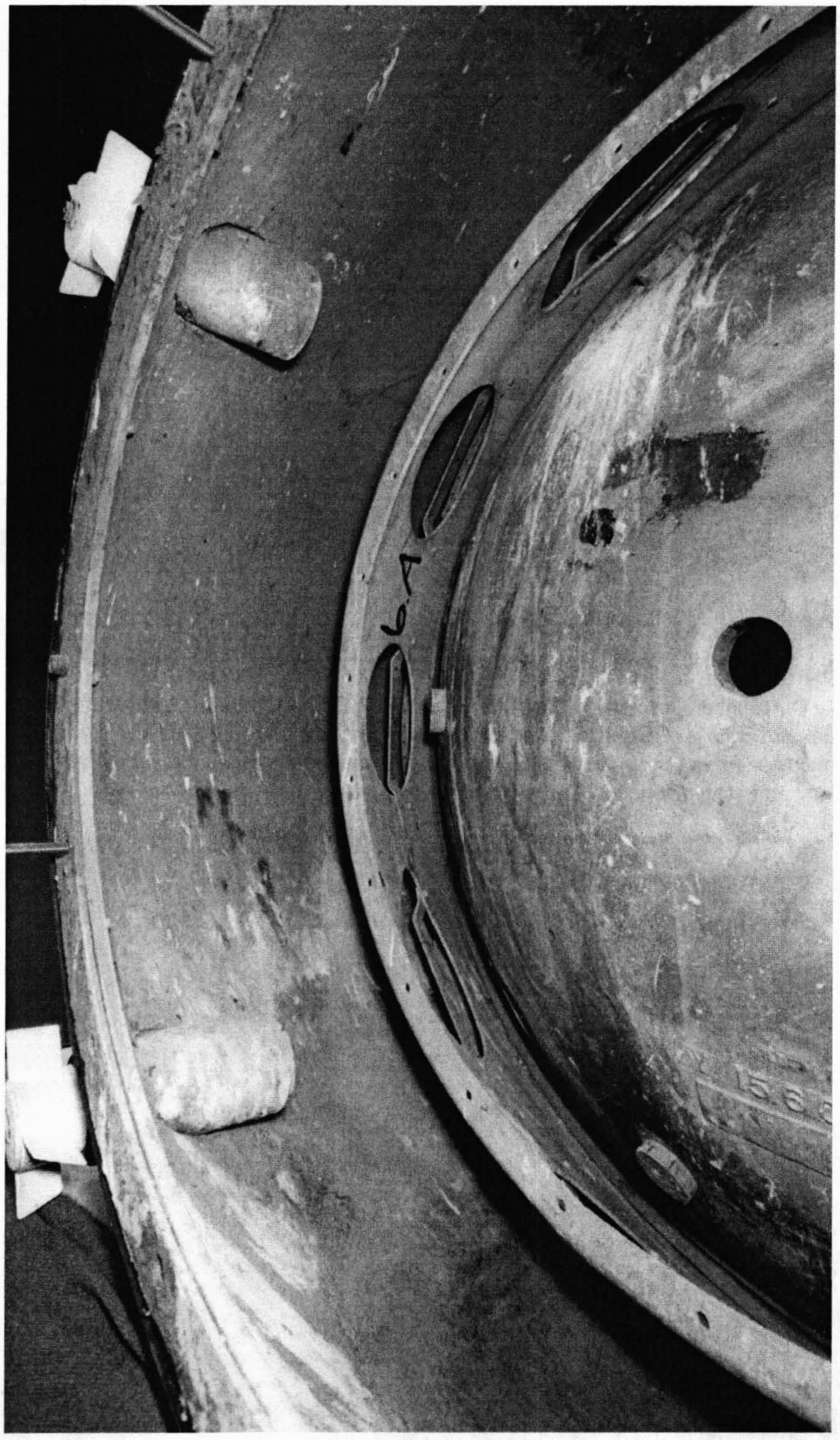
Completed sphere hanging in the assembly building. Lift lug is positioned at the top. (LANL)



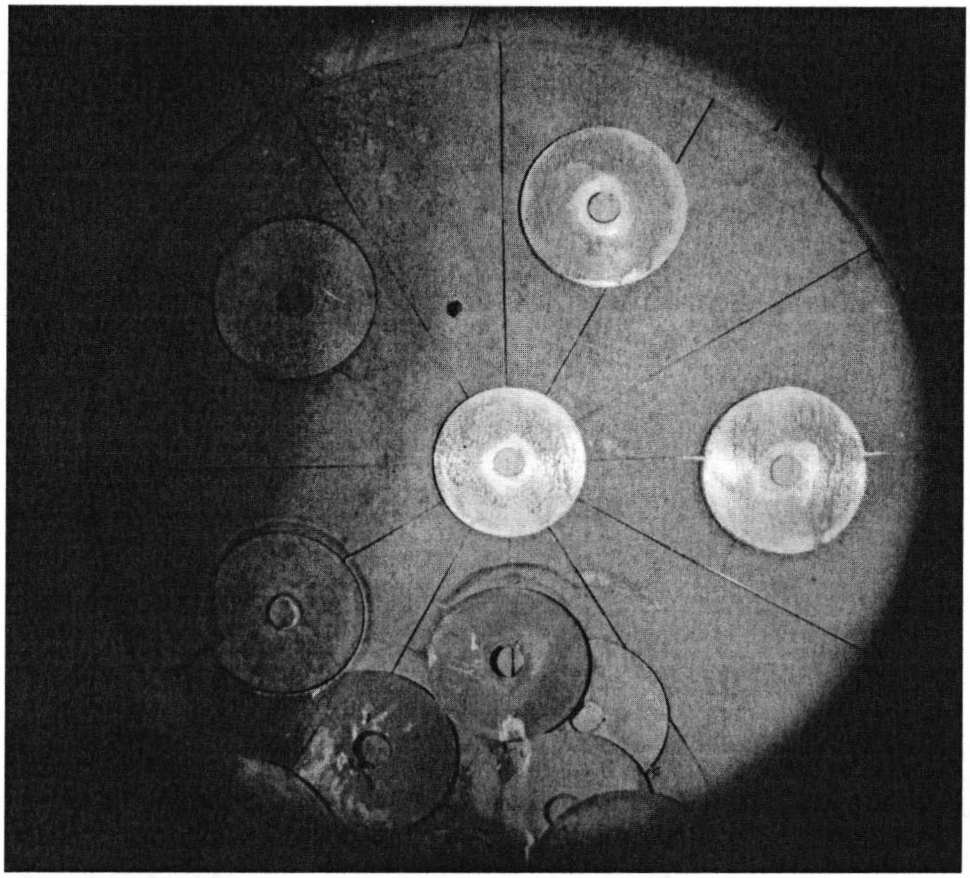
View of the Dural sphere inside a publicly-displayed stockpile unit at the EAA Museum through the open nose. The forward cone is attached to the sphere, but both the "A" and "B" plate are missing. The mounting tubes for the nose fuzes can be seen on the left side. The large hole in the middle of the sphere is for the central polar cap detonator. The other detonator openings are plugged with corks. (Author)



The holes for the detonator cables and detonator cable loom brackets can be seen on the forward cone. The thickness of the sphere can be seen through the detonator opening. (Author)

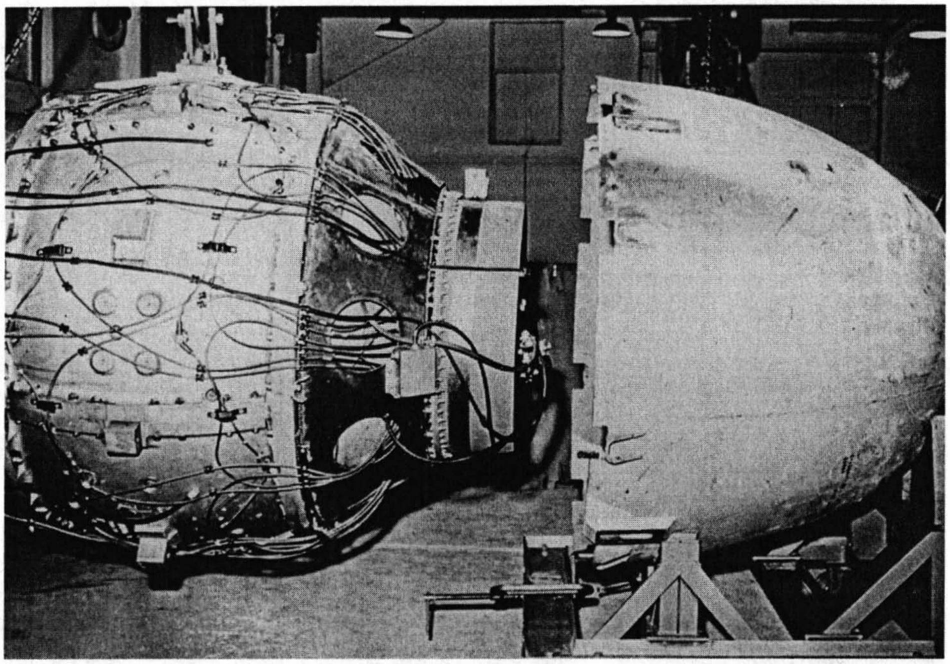


Side view showing nose fuzes, forward cone, and sphere. Since this unit was stored outside for period of time, bird droppings are visible on all the interior surfaces. (Author)

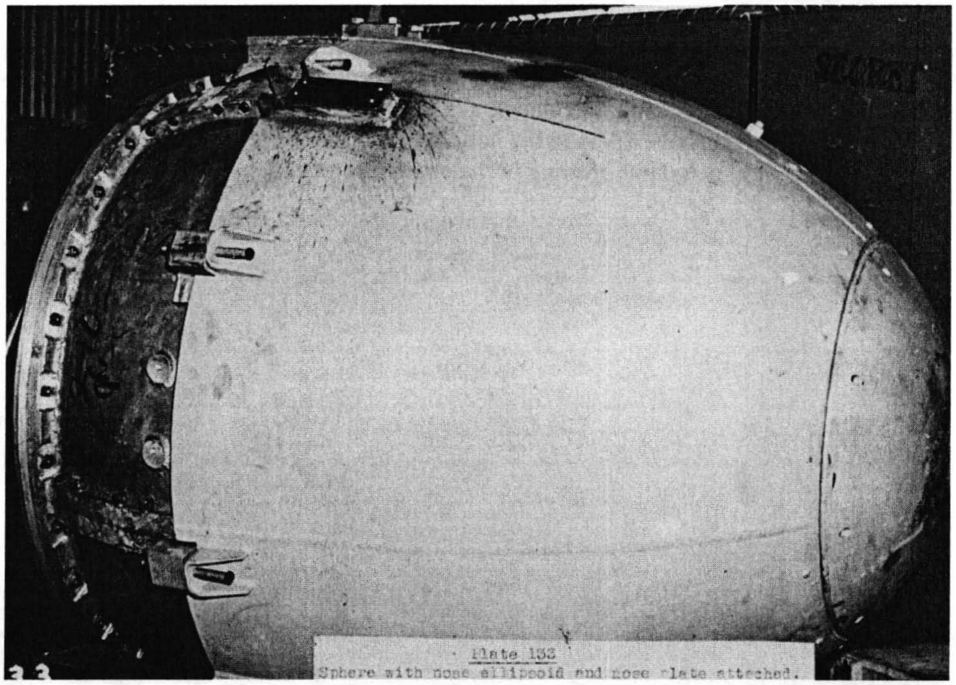


Exclusive view inside the same Dural sphere showing the cork lining and the circular cork pads used to secure the detonator chimney pads. The smaller circular openings in the pads are for the detonators. Because this is a postwar stockpile unit, the glue holding the pads to the shiny Dural sphere polar cap has loosened and several of the pads have fallen to the bottom of the sphere. Photograph was taken through the central detonator opening in the opposite polar cap. (Author)

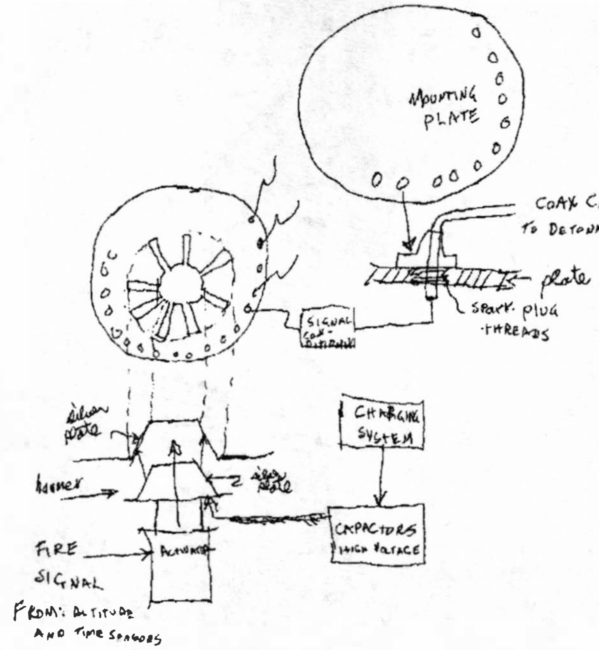
Sphere drawing numbers can be seen cast into the bottom of the polar cap. (Author)



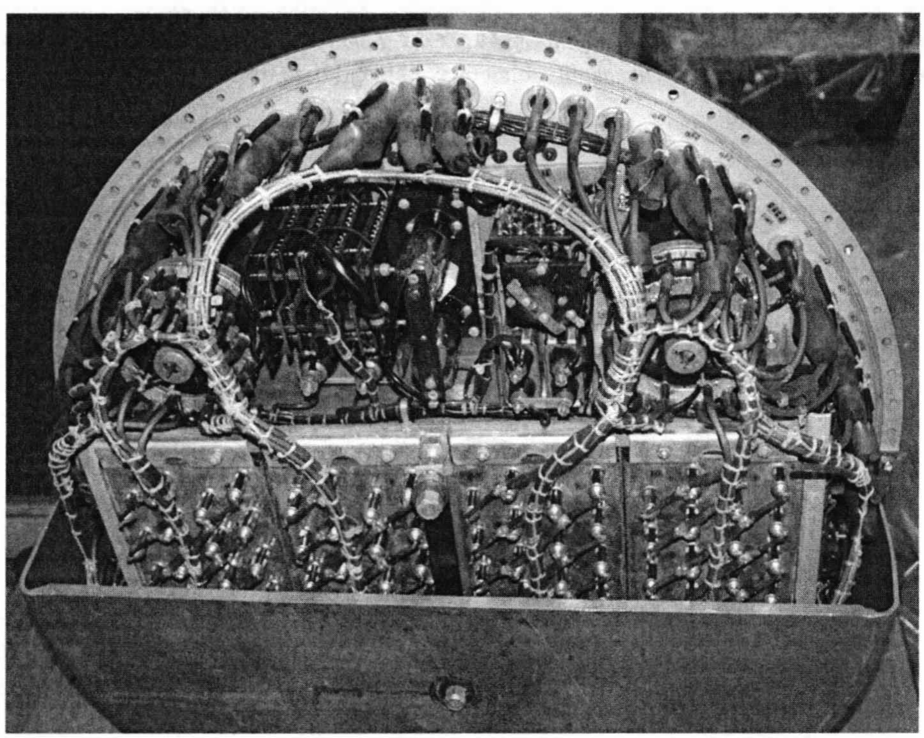
Completed sphere with the ballistic case nose ellipse on its holding fixture awaiting assembly to the sphere. The X-unit can be seen on the right of the sphere attached to the "B" plate on the forward aluminum cone. The detonator coax cables are visible going from each 1773 detonator on the sphere to their attachment points on the aft end of the X-unit inside the cone. (LANL)



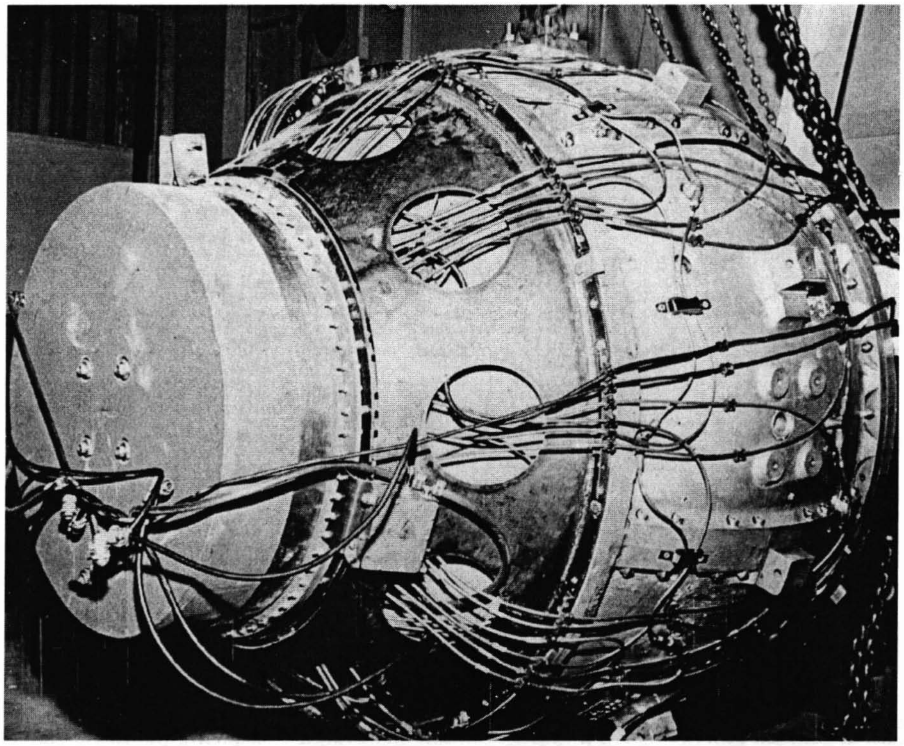
Nose ellipse attached to a completed sphere. The assembly bolts have been placed through the sphere cubes and are awaiting attachment of the rear ellipse before final tightening. Nose plate has also been attached at this point in the assembly. This unit does not have any detonators or electrical cables. (LANL)



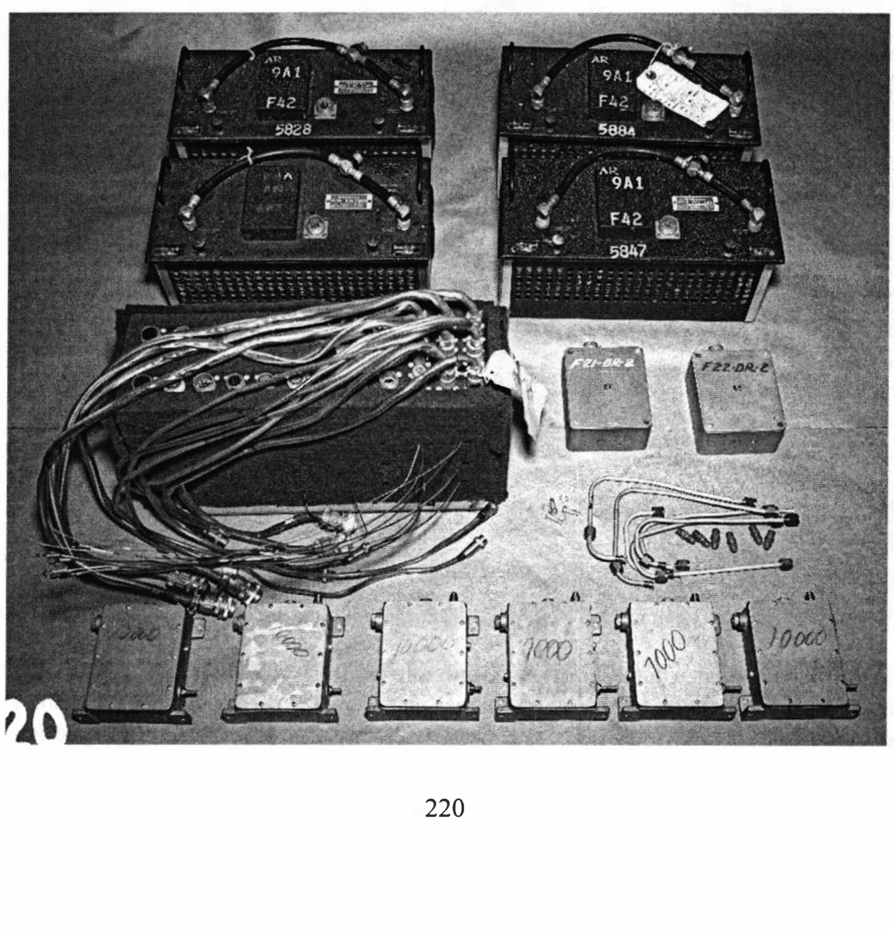
This exclusive sketch of part of the interior layout of the X-unit by Firing Team member Larry DeCuir shows component placement and the use of modified aircraft sparkplugs to transmit the firing signal from the capacitors to the EBW detonators. Sparkplugs were used because the insulation could withstand the high voltage firing signal and the o-ring at the base provided the requisite pressure seal. (Author)



This exclusive photo shows a cutaway of the X-unit interior. The banks of capacitors can be seen at the bottom with two (of four) circular spark-gap switches just above them with their leads going to the aircraft sparkplugs spread around the rim that, in turn, were connected to each of the 32 EBW detonators. (Glen McDuff)



Good view of the X-unit bolted to the "B" plate on the front cone with coax cables going to the detonators. When the front armored ellipsoid ballistic case was attached, the wires shown on the front of the X-unit were attached to the step-up transformers and the inverter. Ballistic case attachment cubes are visible on sphere. Below is a complete set of Firing and Fuzing components for the FM including a Clock Box with cabling, APS-13 radars (4), 0.38 second delay relay (2), and baro boxes (6) with tubing. (LANL)



United States Patent [19]
Hornig

[11] **3,956,658**
[45] **May 11, 1976**

[54] **LOW IMPEDANCE SWITCH**

[75] Inventor: **Donald F. Hornig**, Milwaukee, Wis.

[73] Assignee: **The United States of America as represented by the United States Energy Research and Development Administration**, Washington, D.C.

[22] Filed: **Nov. 28, 1945**

[21] Appl. No.: **631,419**

[52] **U.S. Cl.** **313/217; 315/73**
[51] **Int. Cl.²** **H01J 17/04; H01J 61/06**
[58] **Field of Search** 315/39, 73, 85; 313/217, 218, 197, 313; 250/27.5

[56] **References Cited**

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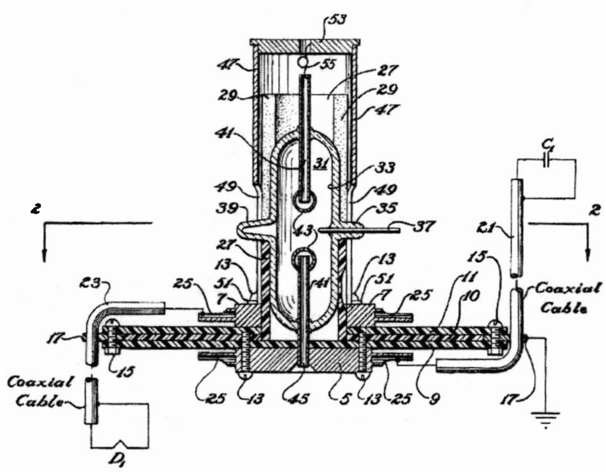
Primary Examiner—Maynard R. Wilbur
Assistant Examiner—T. M. Blum
Attorney, Agent, or Firm—Dean E. Carlson; Paul D. Gaetjens

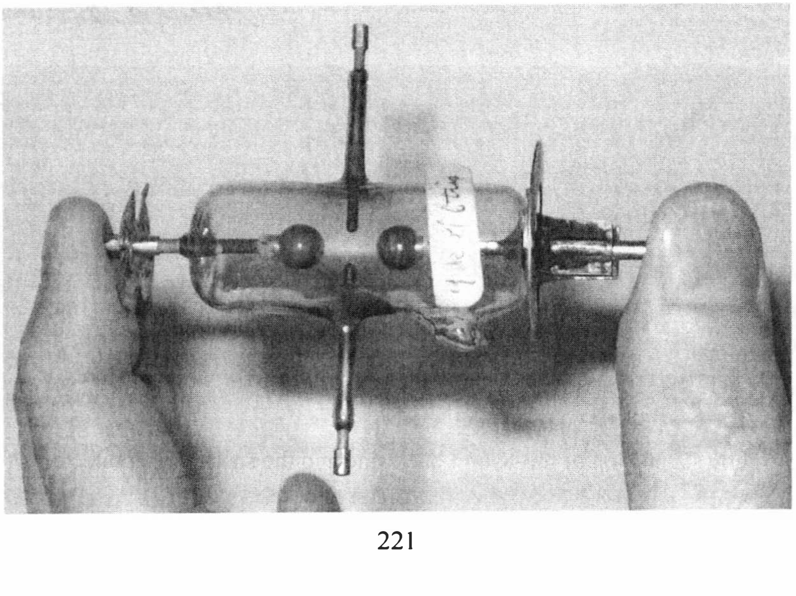
EXEMPLARY CLAIM

1. A low inductance switch comprising a pair of spaced apart, annularly shaped, plate members of conducting material supported in substantially parallel, insulated relationship, said plate members being provided with a plurality of radially extending, spoke-like extensions whereby said members may be connected into a plurality of electrical circuits, and an electrical discharge means connected across said spaced plate members for effecting the simultaneous closing of the electrical circuits connected thereto, said electrical discharge means including an elongated, sealed envelope which contains an ionizable gas and which is supported on one of said plate members with the major axis of said envelope extending generally perpendicular to the plane of said plate members, a pair of elongated, spaced apart, insulated electrodes supported within said envelope and extending axially thereof, one of said electrodes being connected to each of said plate members, and a third, firing or trigger electrode supported within said envelope intermediate said main electrodes and being insulated from said main electrodes.

2 Claims, 3 Drawing Figures



This is the patent awarded to Donald F. Hornig for the X-unit. The vertical column contains the gas-filled, glass tube spark-gap switch held by Glen McDuff that was the heart of the unit. (Courtesy of Alex Wellerstein)



U.S. Patent May 11, 1976 Sheet 1 of 2 3,956,658

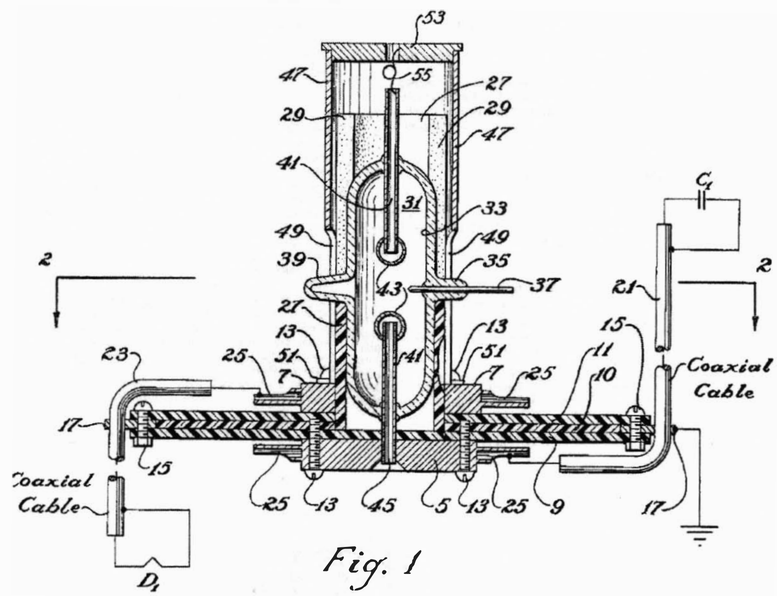


Fig. 1

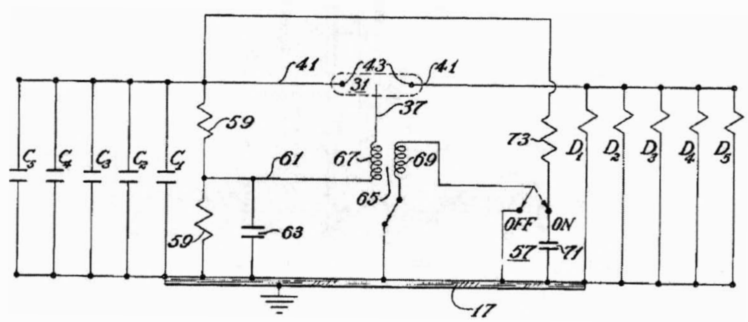
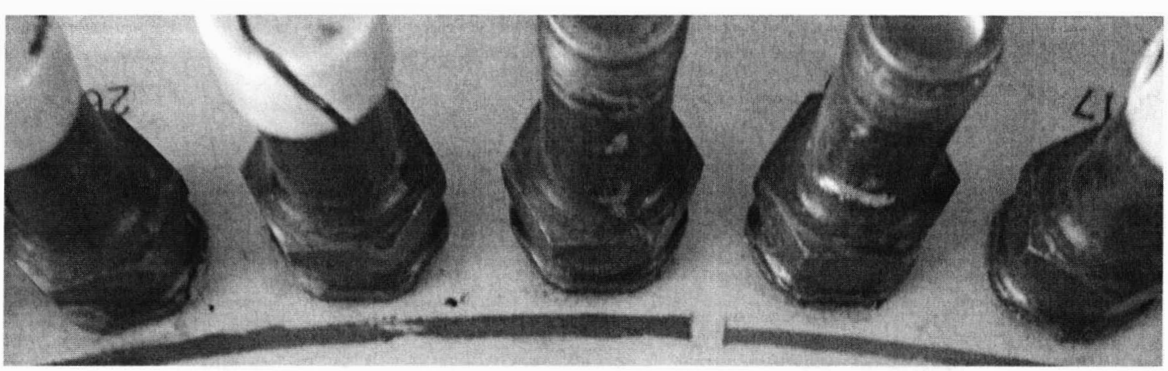


Fig. 3

WITNESSES.

INVENTOR.
DONALD F. HORNIG
BY



Close-up photo shows a portion of the X-unit back side and the sparkplug connectors. (Glen McDuff)

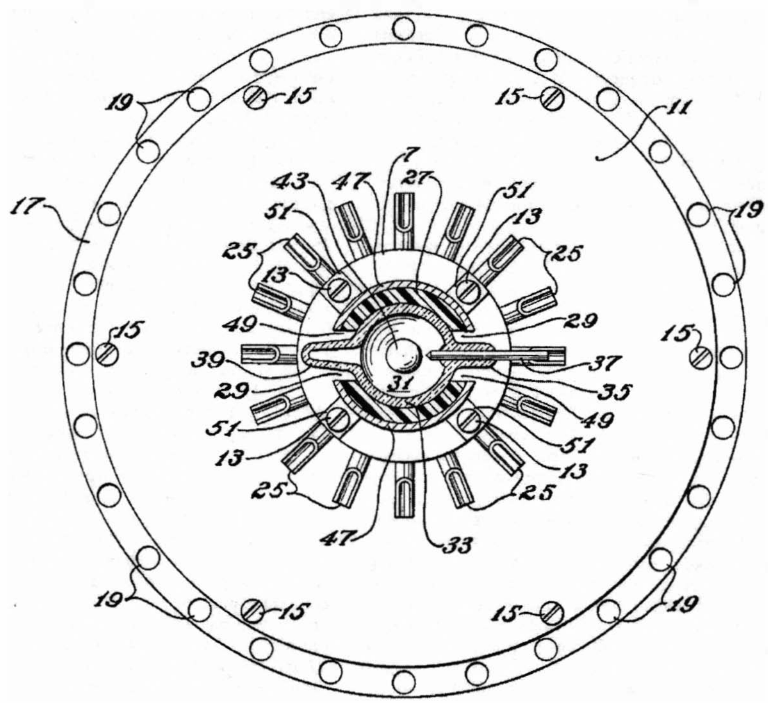


Fig. 2

WITNESSES.
Ralph Carlisle Smith
Paul J. Glaister

INVENTOR.
DONALD F. HORNIG
BY
Robert A. Lavender

LOW IMPEDANCE SWITCH

The present invention relates to electrical switching means, and particularly to electrical switching apparatus adapted for effecting the simultaneous closing of a plurality of electrical circuits within very short intervals of time.

In certain types of ordnance and other equipment, it is necessary to energize a relatively large number of electrical circuits within periods of time of the order of 0.05 to 0.5 microseconds. While it is usually possible to reduce the inductance and capacitance of the various conductor elements of the circuits to be energized to a sufficiently low value to permit operation within time intervals of this very small magnitude, considerable difficulty has been experienced in the provision of satisfactory switching equipment. Most, although not all mechanical devices are inherently too slow to be of value, and in various of the other proposed switching devices, extreme difficulty has been experienced in lowering the inherent inductance of the device to a sufficiently low value to make possible the desired, multiple circuit, switching operation within the required time interval.

The principal object of the present invention therefore, is to provide improved switching apparatus for effecting the simultaneous closing of a plurality of electrical circuits of the type described above. A more specific object of the invention is to provide an improved switching means of sufficiently low inductance and capacitance and having such operational characteristics, that the simultaneous closing of a multiplicity of controlled circuits can be effected within a period of time of the order of 0.05 to 0.5 microseconds.

As will hereinafter appear, these objects are accomplished by the provision of an improved, multiple circuit, electrical switch and switching system which utilizes a single gas discharge device for closing all of the controlled circuits. The system includes means whereby breakdown of the gas discharge switching device and energization of the controlled circuits is effected from a single potential source, despite the fact that the normal breakdown voltage of the gas discharge switching means is normally considerably higher than this potential. The various novel features of the low inductance electrical switch and high speed switching system of the present invention will be made more apparent in the accompanying drawings and the following description of one preferred embodiment thereof.

In the drawings,

FIG. 1 is a sectional view through a low inductance switch embodying principles of the invention. Exemplary circuit connections are illustrated diagrammatically in this Figure;

FIG. 2 is a sectional view on the line 2–2 of FIG. 1; and

FIG. 3 is a diagrammatic view illustrating a switching system in accordance with the invention.

As illustrated, the low inductance switch of the invention includes a pair of annularly shaped plate members 5 and 7 of conducting material which are supported in spaced apart, substantially parallel, insulated relationship by means of three circular discs, 9, 10 and 11, of insulating material and a plurality of angularly displaced screws 13, which engage suitable threaded openings provided within the insulating discs. The edges of the discs 9, 10 and 11 are held together by spaced, peripherilly disposed, screw fastenings 15 which also serve to support a metallic ground ring 17, as illustrated. The ground ring 17 is provided with spaced openings 19 adapted to receive the coaxial cables which are preferably employed in making the electrical connections in the system of which the switch constitutes a part. Two such coaxial cables are shown at 21 and 23 in FIG. 1.

Each of the plate members 5 and 7 is provided with a plurality of radially extending, spoke-like, extensions 25, which may comprise tubular connector lugs, as illustrated, in order that one side of each of the multiplicity of circuits which are to be controlled by the switch may be connected thereto. The plate members 5 and 7 are supported concentrically with respect to each other, and the upper member 7 is provided with a substantially larger central opening than the lower plate member 5 for receiving a cylindrical sleeve 27 of insulating material which is provided with diametrically opposed slots 29 at its upper end, as illustrated.

The gas discharge device 31, which is utilized for electrically connecting the plate members 5 and 7 and thus the plurality of electrical circuits connected thereto, includes a cylindrical glass envelope 33 which is adapted to fit snugly within the insulating sleeve 27. The two slots 29 in the sleeve 27 accommodate a press seal 35, provided at one side of the envelope 33 for supporting a trigger electrode 37 and a tubular extension 39, provided at the other side of the envelope 33 for facilitating the filling of the envelope 33 with a gas. Two axially extending, centrally disposed, main electrodes 41, are sealed into the opposite ends of the envelope 33 by conventional seals, and each of the main electrodes 41 terminates in a ball shaped end portion 43. The trigger electrode 37, which is positioned so as to extend into the envelope 33, intermediate the main electrodes 41, is desirably provided with a pointed end.

The external shank portion 45 of the lower of the main electrodes 41, extends through the central opening provided in the lower connector plate 5 and through an aligning opening in the insulating disc 9. It is electrically and mechanically connected to the lower connector plate 5. A cylindrical sleeve or shield 47 of conducting material, having a pair of diametrically opposed slots 49, is disposed about the insulating sleeve 27 and the gas discharge device 31, which is contained therein. The conducting sleeve 47 is provided with four angularly displaced feet or brackets 51 which are adapted to be engaged by the screw fastenings 13 used for supporting the upper connector plate 7, as illustrated. By this means the conducting sleeve or shield 47 is mechanically supported in place so as to provide a coaxial shield for the gas discharge device 31, and is electrically connected to the upper connector plate 7. The upper end of the shield 47 is closed by a suitable disc 53 and the disc 53 is electrically connected to the upper of the main electrodes 41 by means of a spring wire connection 55.

During use of the device it is contemplated that the envelope 33 shall be filled with an ionizable gas which may be introduced into the envelope 33 through the inlet tube 39 during manufacture. Such gases as nitrogen, argon, neon, hydrogen, krypton and the like are suitable. The selection of the gas and the pressure at which the gas is maintained within the envelope 33 will be determined primarily by the voltage at which the discharge device is to be used, and extensive data concerning gap breakdown voltages is available in the art.

Normally, full circuit potential will be impressed across the main electrodes 41, and as a result, the spacing of the electrodes 41 and the gas pressure must be such that breakdown will not result at the operating potential. At the same time, the device must be capable of breakdown when a voltage pulse of reasonable magnitude is applied between the trigger electrode 37 and one of the main electrodes 41, that method being the preferred firing or circuit closing procedure.

A circuit illustrating one electrical switching system particularly adapted for use with the switch means of the invention is illustrated in FIG. 3.

This system includes a plurality of parallel circuits D1, D2, D3, D4, and D5 which are to be energized simultaneously by operation of the gas discharge switching means 31, and a bank of condensers, C1, C2, C3, C4, and C5, which are also connected in parallel and which, when charged, constitute the single power source of the system. The circuits D1 to D5 may constitute detonators or other circuit elements. One side of each of the paralleled circuits D1 to D5 is connected to the ground ring 17, and the other side is connected to one of the electrodes 41. The condensers C1 to C5 are similarly connected with one side of each of the paralleled units, being connected to the ground ring 17 and the other side to the other electrode 41, as illustrated.

In order to lower the overall inductance of the system to the minimum possible value, the electrical connections to the condensers C1 to C5 and the connections to the paralleled circuits D1 to D5 are desirably made by means of coaxial cables, as illustrated diagrammatically at 21 and 23 in FIG. 1. The outer conductor in each instance extends through one of the openings 19 provided in the ground ring 17, and is electrically connected thereto. It will be apparent that the arrangements provided by the spoke-like, terminals or extensions 25 forming a part of the plate members 5 and 7, greatly facilitate the connecting of the coaxial cables.

The particular system illustrated in the drawings, includes five condenser units, C1 to C5 and five detonator or other circuits to be energized, D1 to D5. It will be understood that any number of circuits or condenser units may be used, within the capacity of the device, although to minimize space requirements it is usually convenient to provide the same number of condensers as there are circuits to be energized. When the system is to be used to simultaneously energize a plurality of detonators, the paralleled condenser units mayconveniently be charged to voltage of the order of 5000 to 15000 volts and should have a total capacity of the order of ½ to 1 micro-farad for each circuit to be energized.

In addition to the circuit elements described, the system includes means for maintaining the trigger electrode 37 at a potential midway between that impressed across the main electrodes 41, and means for providing a high voltage pulse of sufficient magnitude to initiate breakdown within the gas discharge device 31 upon the operation of a suitable control switch which may be of the type indicated at 57. The means for maintaining the trigger electrode 37 at a potential intermediate the potential of the two main electrodes 41, comprises a pair of high ohmage resistance units 59, series connected across the paralleled condenser units C1 to C5 to provide a voltage divider circuit. The trigger electrode 37 is connected to the mid point of the series connected resistors 59 by a suitable conductor as shown at 61. For voltages of the order desirably employed in circuits of this type, that is 5000 to 15000 volts, the resistances 59 should be of the order of 20 to 50 megohms. To prevent any transient voltage or charge induced in the voltage divider circuit from producing accidental sparkover between the trigger electrode 37 and one of the main electrodes 41, a by-pass condenser 63, which may have a capacity of the order of 0.1 to 0.01 micro-farads, is connected across the active section of the voltage divider resistances 59. Due to the relative positioning of the trigger and main electrodes 37 and 41, the breakdown potential between the trigger electrode 37 and either of the main electrodes is considerably lower than the breakdown potential between the main electrodes. This aids in assuring positive and reliable operation of the gas discharge device 31.

The means for producing a high voltage peak between the trigger electrode 37 and one of the main electrodes 41, when it is desired to energize circuits D1 to D5, includes a transformer 65 which may be a Tesla coil or the like, having a secondary winding 67, which is connected in series with the conductor 61 from the voltage divider resistances 59 to the trigger electrode 37, and a primary winding 69 which is connected so as to receive the charge of a small condenser 71 when the control switch 57 is moved from the position shown in full in FIG. 3 to the position shown in dotted in that Figure. One side of the condenser 71 is connected to the ground ring 17, and the other side is connected to the high side of the paralleled condenser units C1 to C5 through a suitable charging resistance 73, which may be of the order of ten megohms.

The control switch 57 is a single pole, double throw switch which is connected so as to short-circuit the primary 69 of the transformer unit 65 when in the off position and is operable to connect the pulsing condenser 71 so as to discharge the charge accumulated therein when moved to the on position. When readying the system for operation, the control switch 57 will be placed in the off position, the main condenser bank C1 to C5 will be charged to the desired voltage, and simultaneously the pulsing condenser 71 will also be charged. The electrical characteristics of the system components are such that all of the condensers will hold their charges for as long a period as may be expected to elapse prior to the operation of the system.

When operation of the system and energization of the various parallel circuits D1 to D5 is to be effected, the control switch 57 will be moved to the dotted position of FIG. 3, thereby discharging the pulsing condenser 71 through the primary 69 of the high voltage transformer 65. This discharge will impress a high voltage pulse between the trigger electrode 37 and one of the main electrodes 41 of sufficient magnitude to produce ionization and insulation breakdown across the main electrodes 41 within the envelope 33. The main condenser bank will then discharge through the various paralleled circuits which are to be energized. By virtue of the low inductance of the gas discharge switching means 31 and the associated circuit connections, it is possible to effect simultaneous energization of all of the various connected circuits D1 to D5 within periods of time of the order of 0.05 to 0.5 microseconds, following the closing of the main control switch 57. It will be understood that the main control switch may be of an automatic or any other desired type. In ordnance application it will conveniently comprise a fuse type switch. It will also be understood that the usual safety and arming switches can be introduced into the system for added safety and to prevent premature operation of the system. The electrical switch of the invention and the switching systems which are made possible by the use of that switch are much more reliable and positive in operation than the previously known devices, and are completely free from the various defects of those devices. The extremely short period of operation which is an inherent feature of the switch is due in large part to its low inherent inductance and capacitance which characteristics result from the particular structural arrangements disclosed, included among which are the annularly shaped main connector elements and the co-axial shielding provided for the current carrying electrode. The features of the invention which are believed to be new are expressly pointed out in the appended claims.

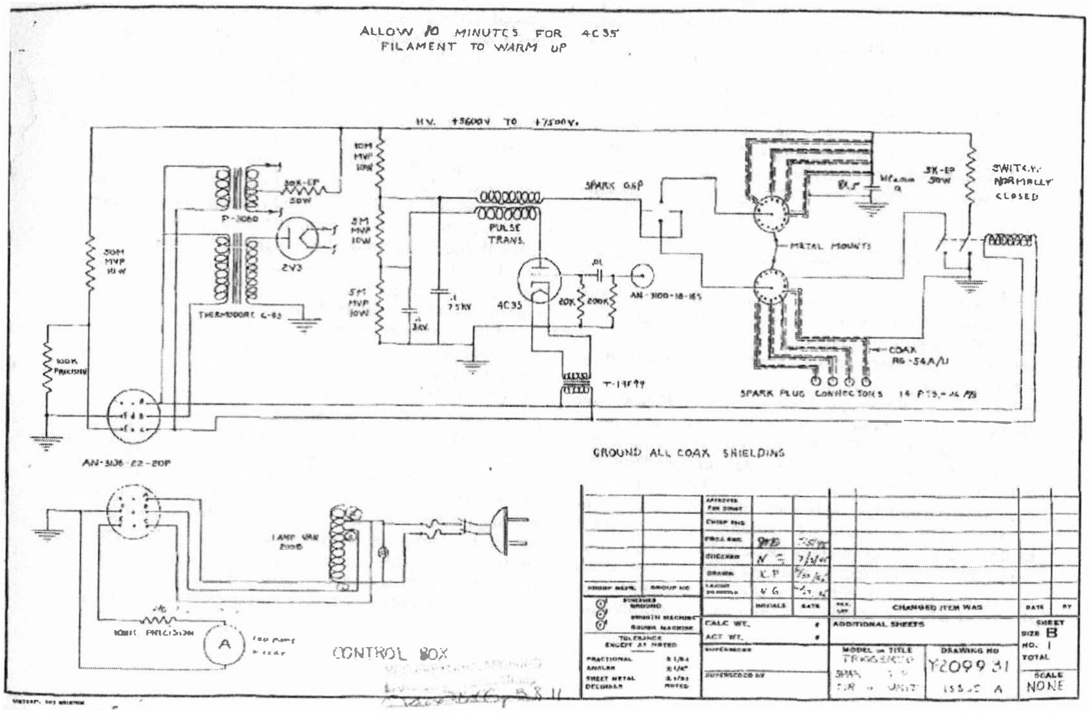
We claim:

1. A low inductance switch comprising a pair of spaced apart, annularly shaped, plate members of conducting material supported in substantially parallel, insulated relationship, said plate members being provided with a plurality of radially extending, spoke-like extensions whereby said members may be connected into a plurality of electrical circuits, and an electrical discharge means connected across said spaced plate members for effecting the simultaneous closing of the electrical circuits connected thereto, said electrical discharge means including an elongated, sealed envelope which contains an ionizable gas and which is supported on one of said plate members with the major axis of said envelope extending generally perpendicular to the plane of said plate members, a pair of elongated, spaced apart, insulated electrodes supported within

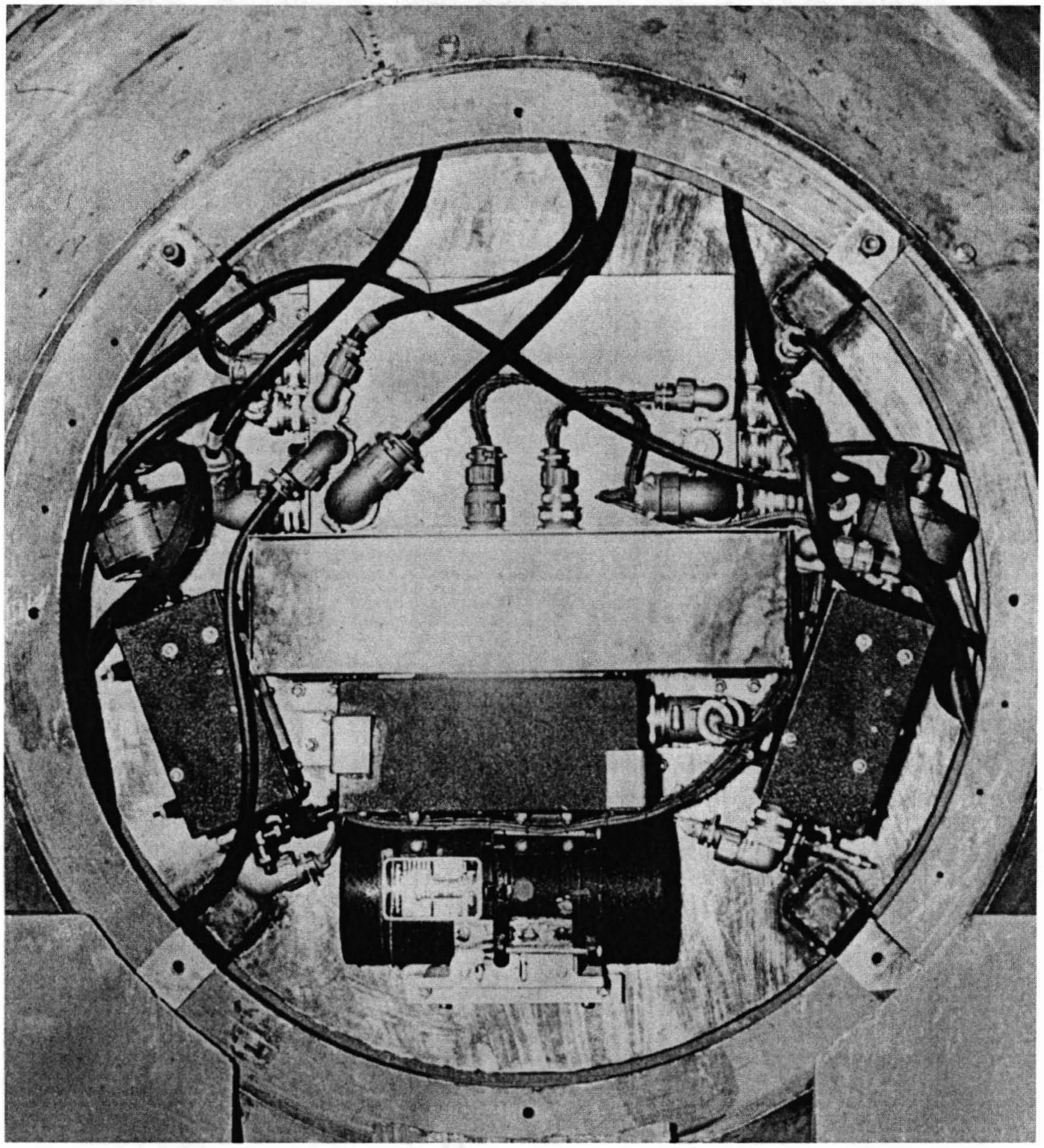
said envelope and extending axially thereof, one of said electrodes being connected to each of said plate members, and a third, firing or trigger electrode supported within said envelope intermediate said main electrodes and being insulated from said main electrodes.

2. A low inductance switch comprising a pair of spaced apart, annularly shaped, plate members of conducting material supported in substantially parallel, insulated relationship, said plate members being provided with a plurality of radially extending, spoke-like extensions whereby said members may be connected into a plurality of electrical circuits, an electrical discharge means connected across said spaced plate members for effecting the simultaneous closing of the electrical circuits connected thereto, said electrical discharge means including an elongated, sealed, cylindrically shaped, glass envelope which contains an ionizable gas and which is supported on one of said plate members with the major axis of said envelope extending generally perpendicular to the plane of said plate members, a pair of elongated, spaced apart, electrodes, each of which terminates in a ball shaped end portion, supported centrally within said envelope and extending coaxially therewith, said main electrodes being insulated from each other and each of said main electrodes being connected to one of said plate members, and a third, firing or trigger, electrode, having a pointed end, which is supported so as to extend into said envelope intermediate said main electrodes, said third electrode being insulated from said main electrodes, and a cylindrical shield member of conducting material which is connected to one of said plate members and which extends about said envelope coaxially therewith.

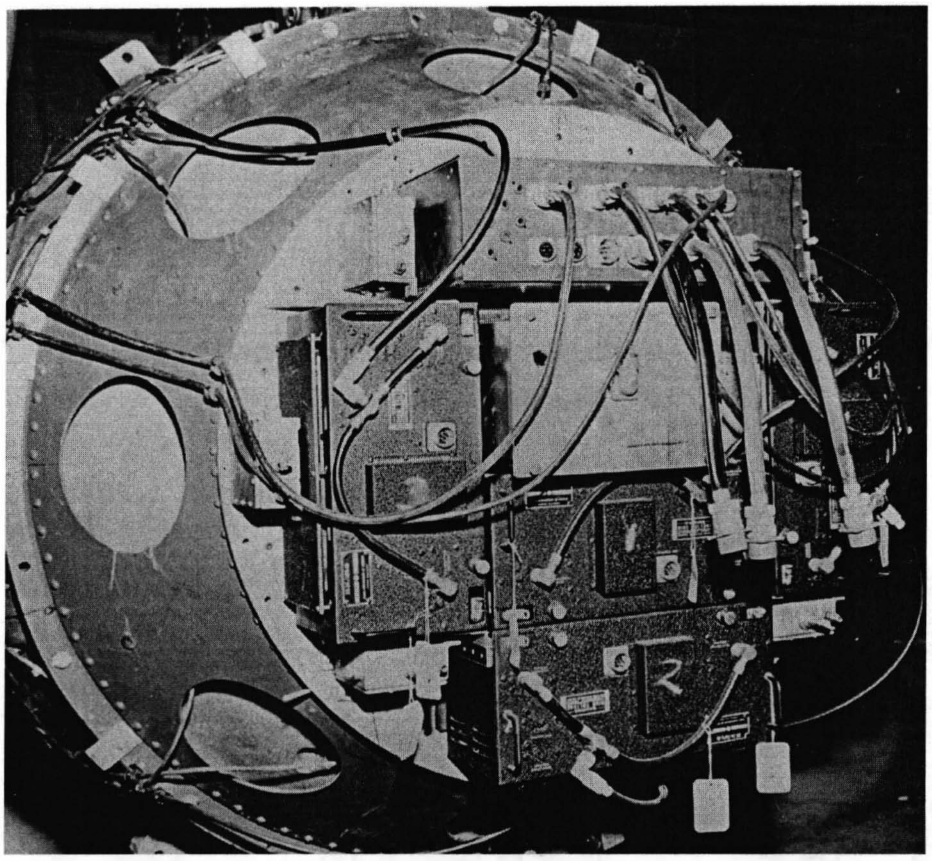
* * * * *



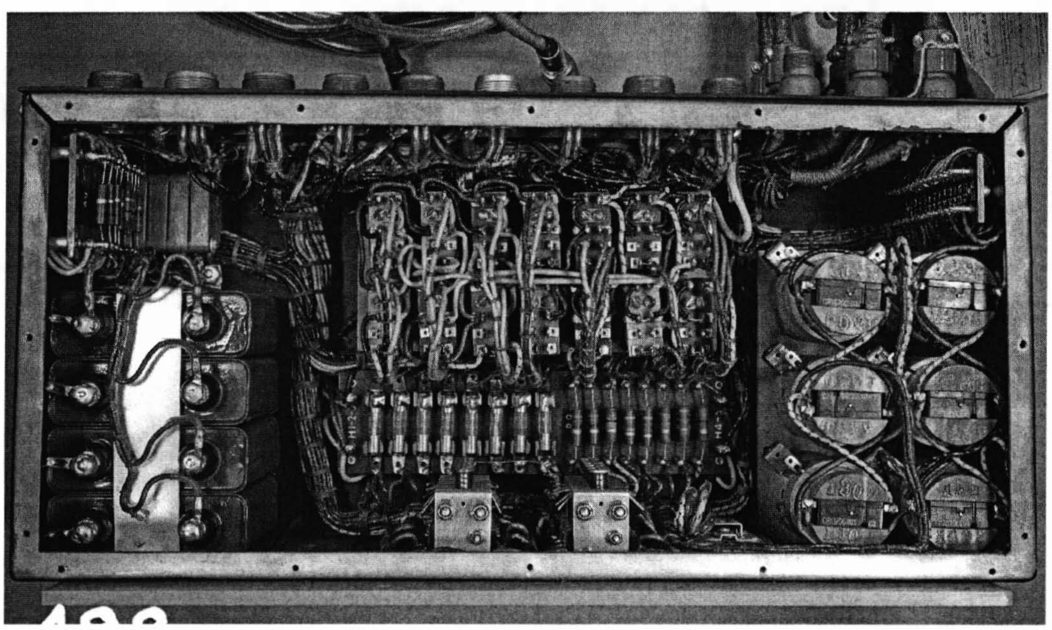
X-Unit circuit diagram including the spark-gap switches. (Glen McDuff)



"A" plate attached to the front armored ellipsoid case shown here with the batteries, pump, inverter, battery box relay, and junction box containing step-up transformers. Nose plate has not been secured. (LANL)



This view shows the "C" plate attached to the aft cone. The clock box is shown at the top (without pullout wires). The four black APS-13 radar boxes and large white battery box are shown just below the clock box. Several of the small white baro switch boxes are also visible adjacent to the APS-13 units, but the large stainless steel baro tube manifold ring has not been attached along with none of the detonator cables. Below is the FM Clock Box. Except for a mounting plate on the back, this was identical to the LB Clock Box. (LANL)



Dec. 19, 1967 A. N. AYERS **3,358,605**

PRESSURE SENSITIVE SWITCH

Filed Jan. 4, 1946 3 Sheets-Sheet 1

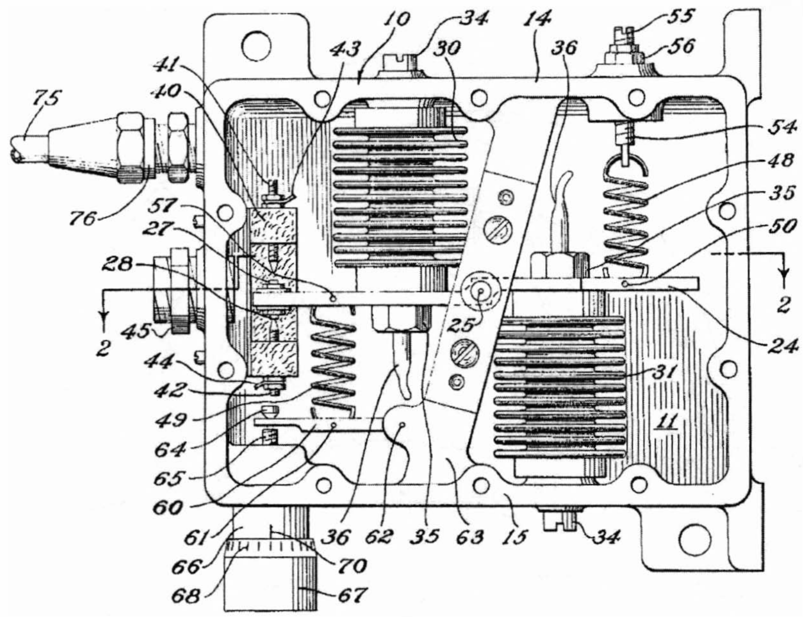


Fig. 1

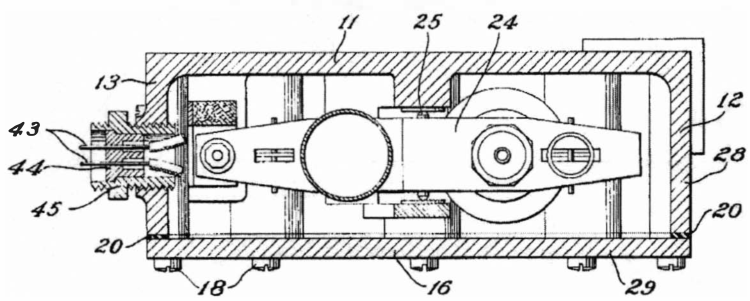


Fig. 2

WITNESSES.

INVENTOR.
Alan N. Ayers
BY

These are drawings from the patent awarded to Alan N. Ayers for the Barometric Switch used on both *Little Boy* and *Fat Man*. The tubing (75) ran from each baro switch to the large stainless steel manifold ring while the pairs of wires (43) from each went directly to the clock box as part of the firing circuit. The adjustment vernier knob (67) was used to tune each hermetically-sealed switch so these would activate at the proper firing altitude. These switches could be mounted either on end (FM) or flat (LB). (Courtesy of Alex Wellerstein)

Dec. 19, 1967 A. N. AYERS **3,358,605**

PRESSURE SENSITIVE SWITCH

Filed Jan. 4, 1946 3 Sheets-Sheet 3

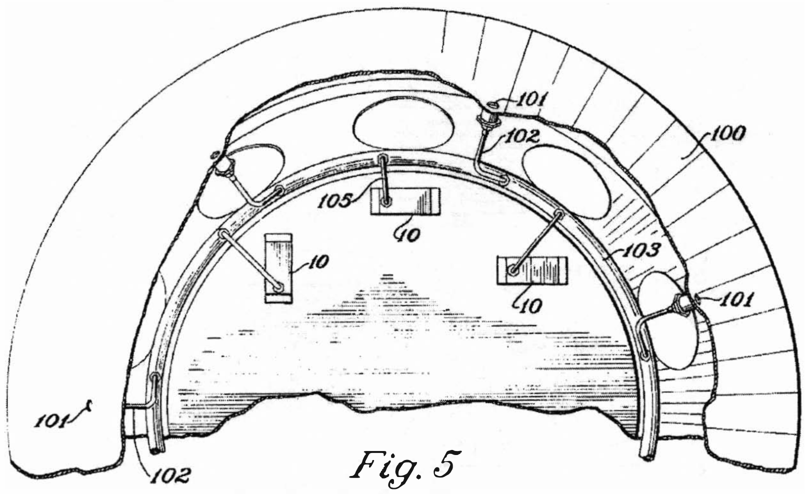


Fig. 5

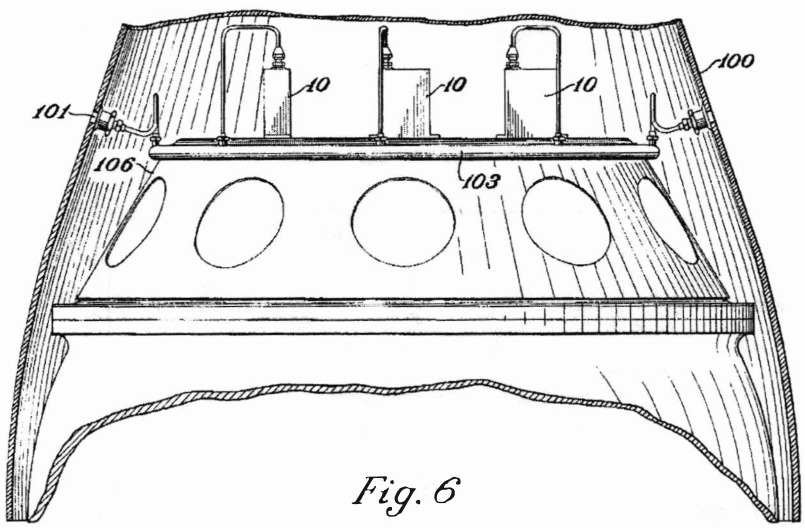


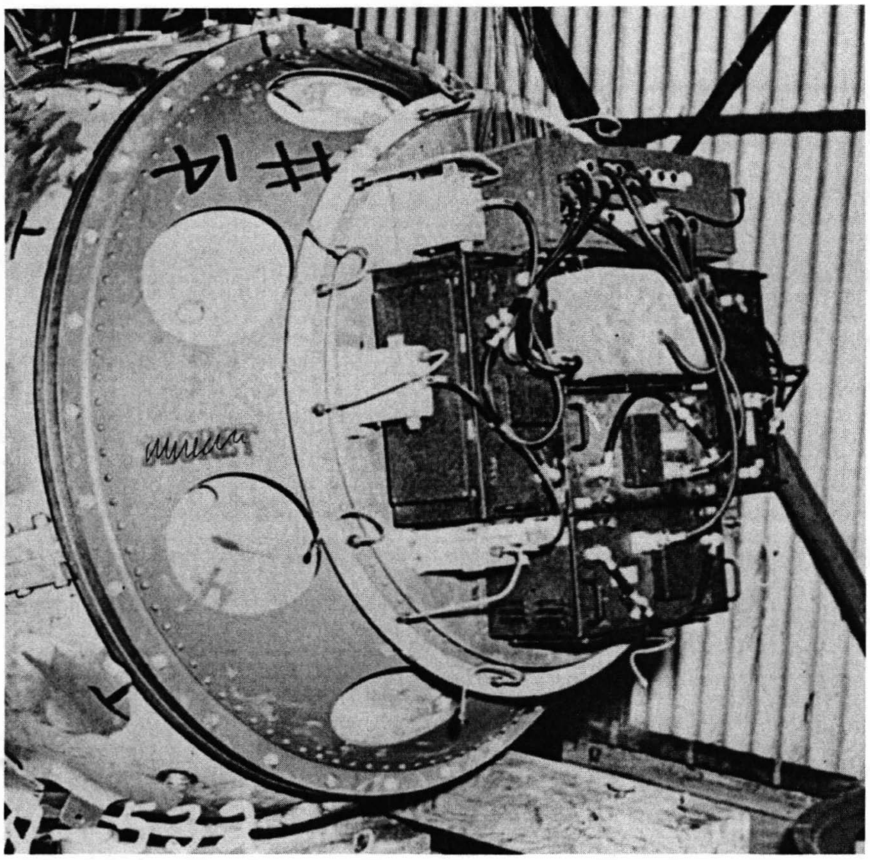
Fig. 6

WITNESSES.

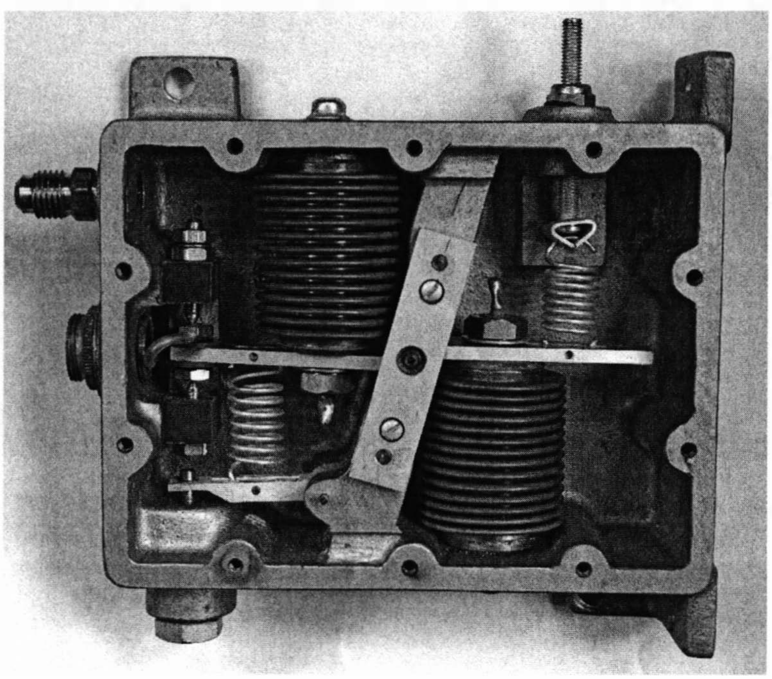
Ralph Carlisle Smith
Ralph D Miller

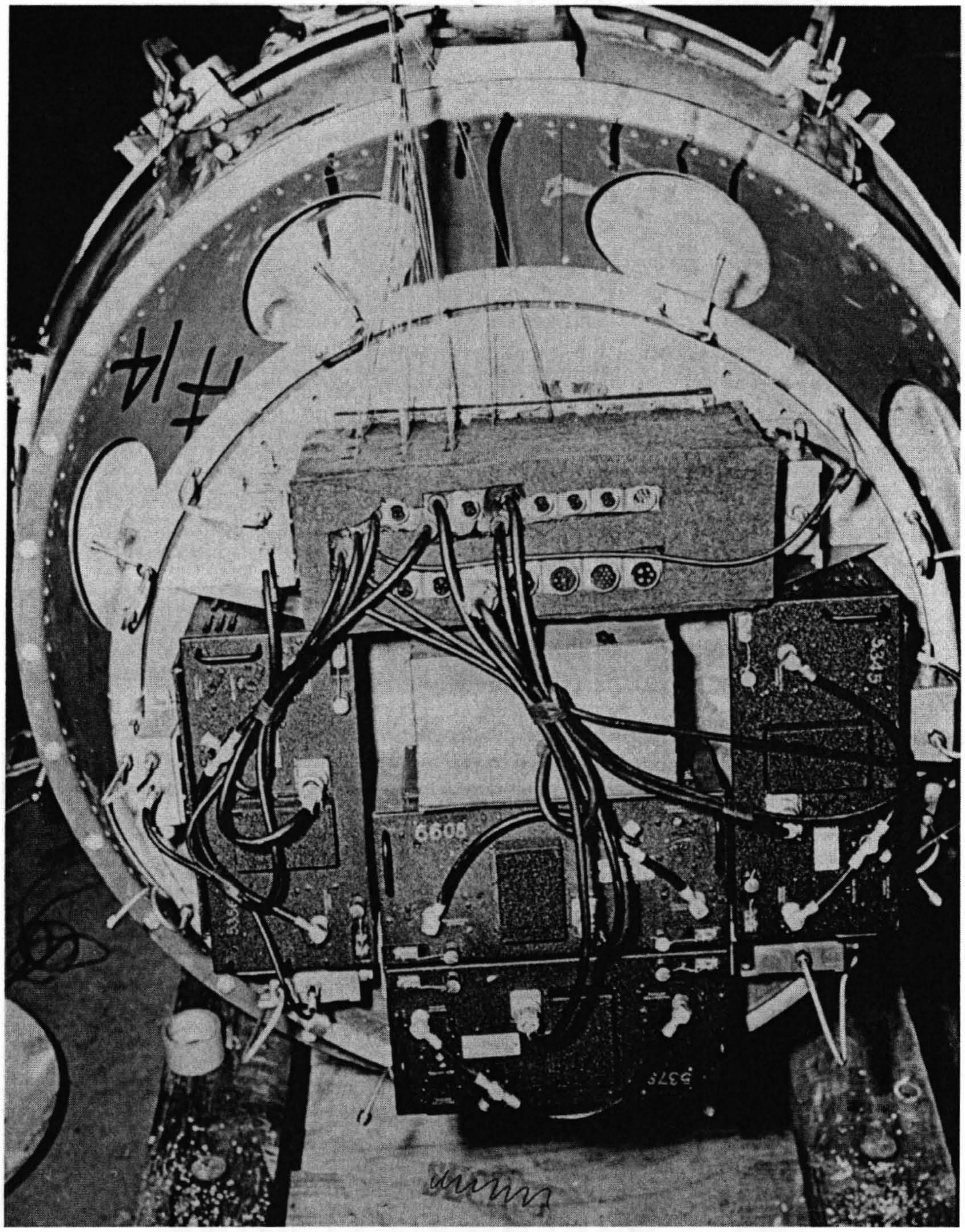
INVENTOR.
Alon N. Ayers
BY

This shows the placement of these baro switches (10) relative to the Dural sphere, the aft cone (106), the "C" plate with the stainless steel baro tube manifold ring (103), and the tubing (102) that ran from this ring to the openings (101) in the aft ballistic case (100). (Courtesy of Alex Wellerstein)

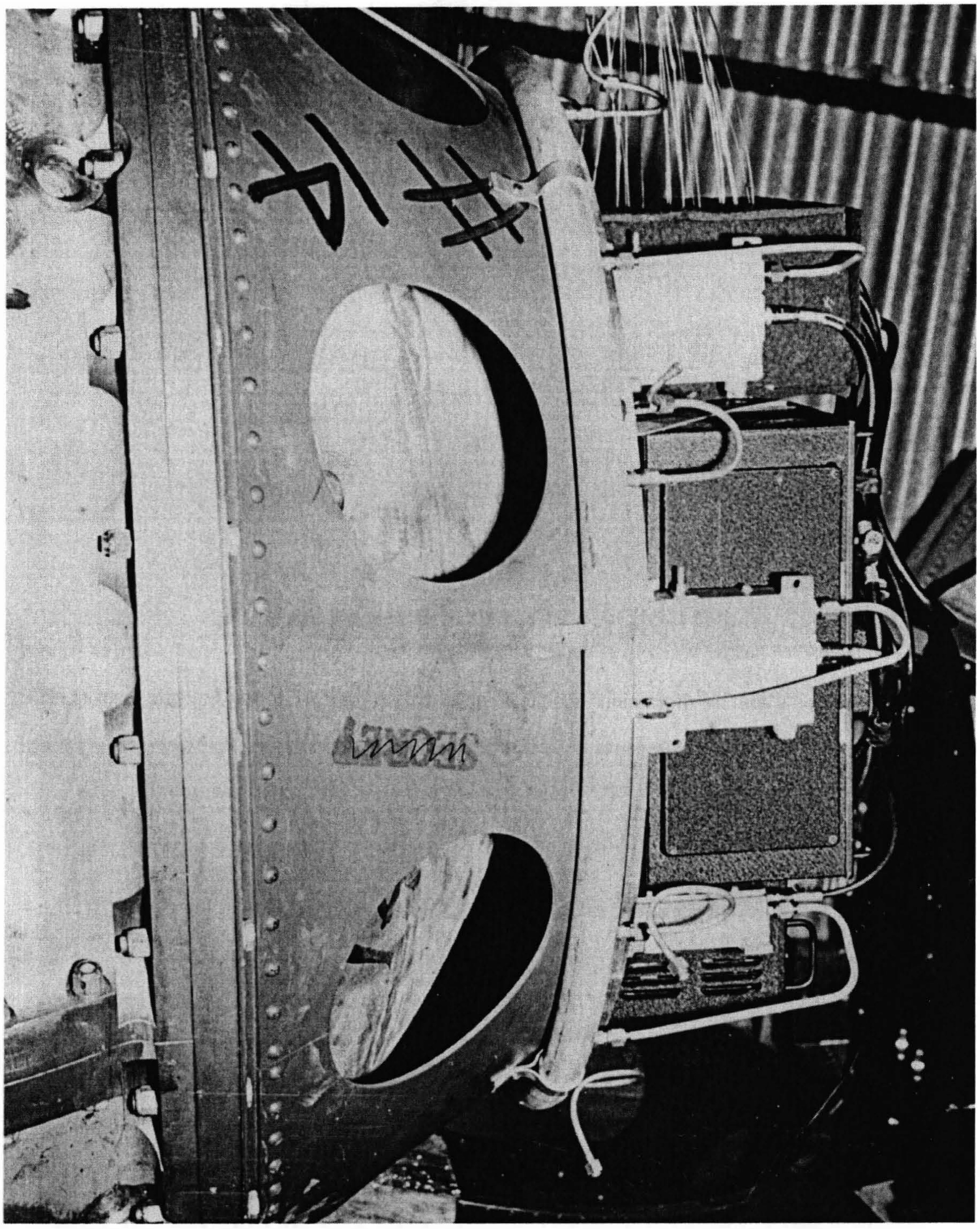


Rear view of sphere showing the large diameter circular stainless steel baro tube manifold ring next to the "C" plate, three of the six small white baro switch boxes, four black APS-13 radar units, large white battery box, and the felt-covered clock box (with pullout wires) at top. Below is an actual baro switch. (LANL)

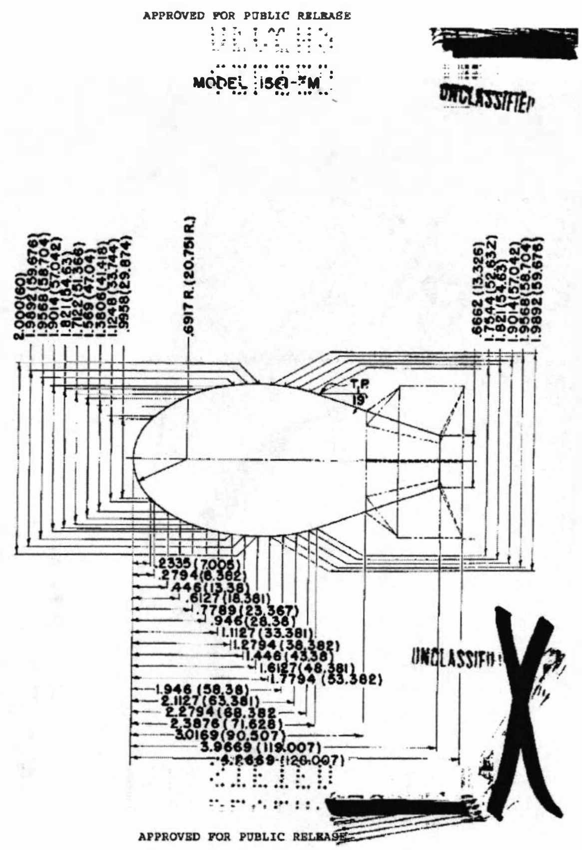




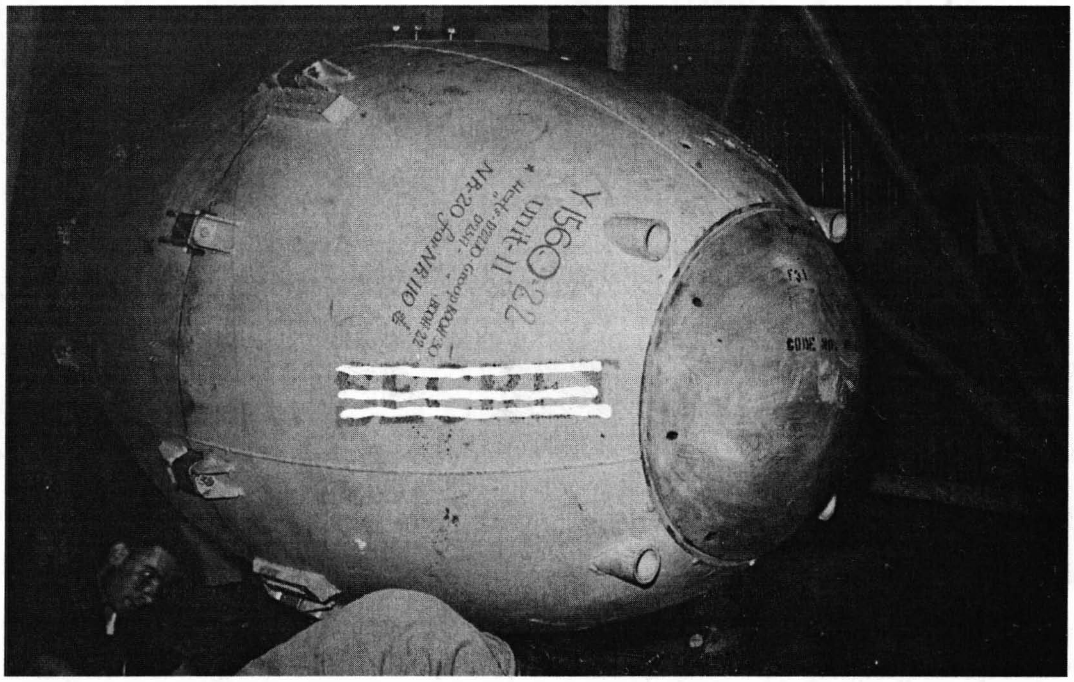
Rear view showing the large diameter circular stainless steel manifold ring with small white baro switch boxes connected by smaller diameter stainless steel tubes. (LANL)



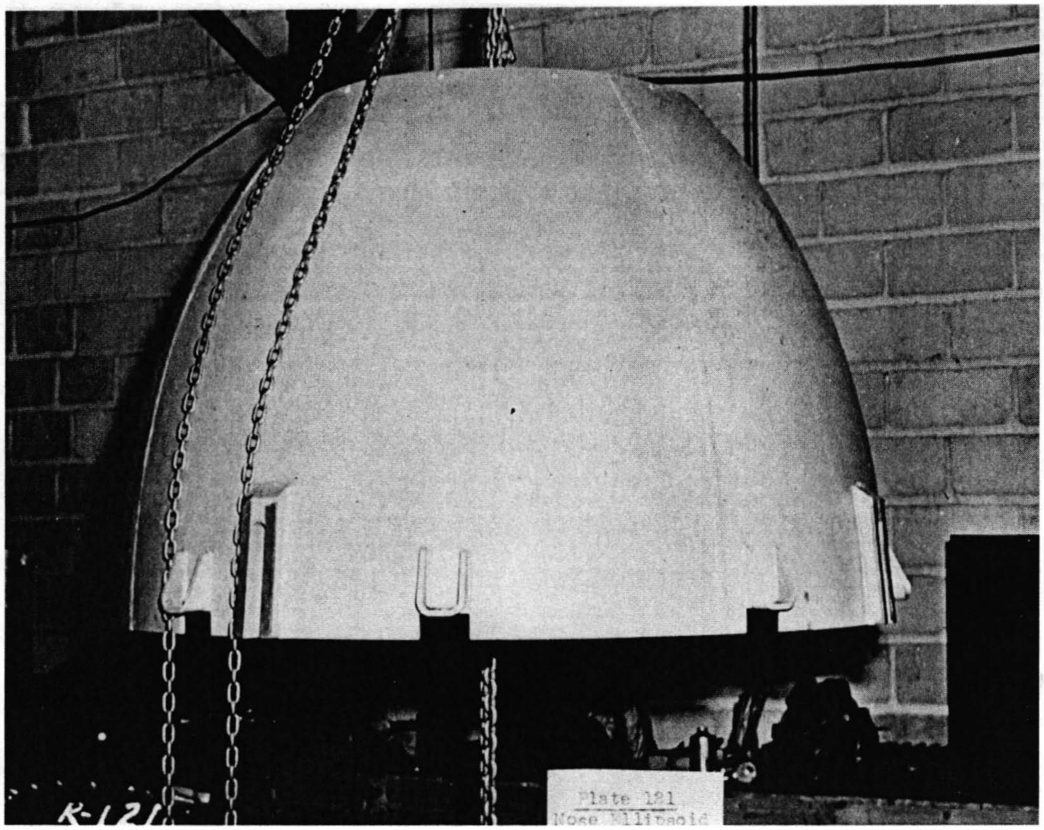
Side view of the aft cone bolted to the sphere with the large diameter stainless steel baro tube manifold ring shown with the tubing attached to the small white baro switch boxes. When the aft ballistic case was finally attached, the small coils of tubing attached to the large baro tube were attached to the baro holes in the case. (LANL)



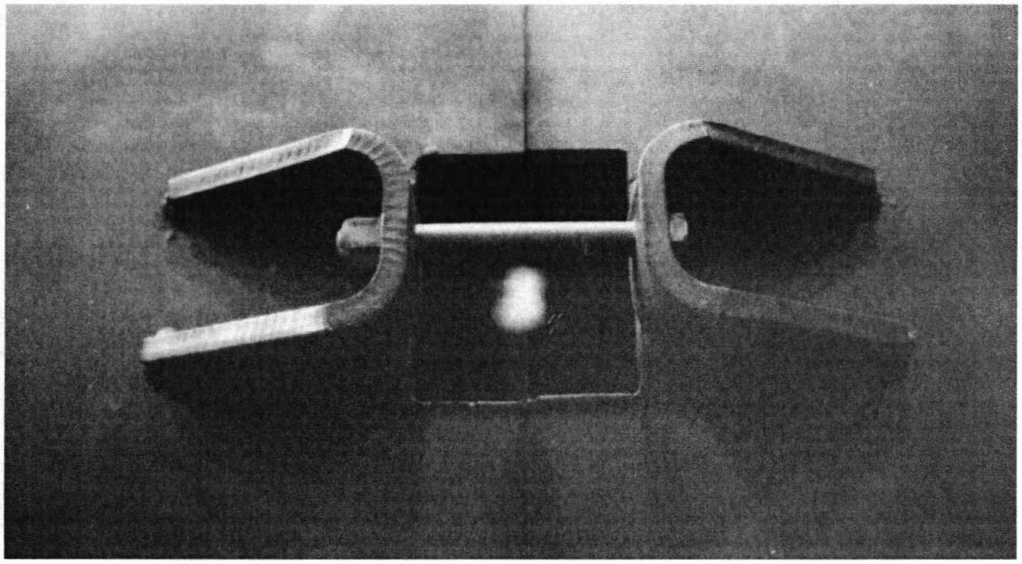
This drawing shows both the dimensions and the complex curves for the *Fat Man* ballistic case. (LANL)



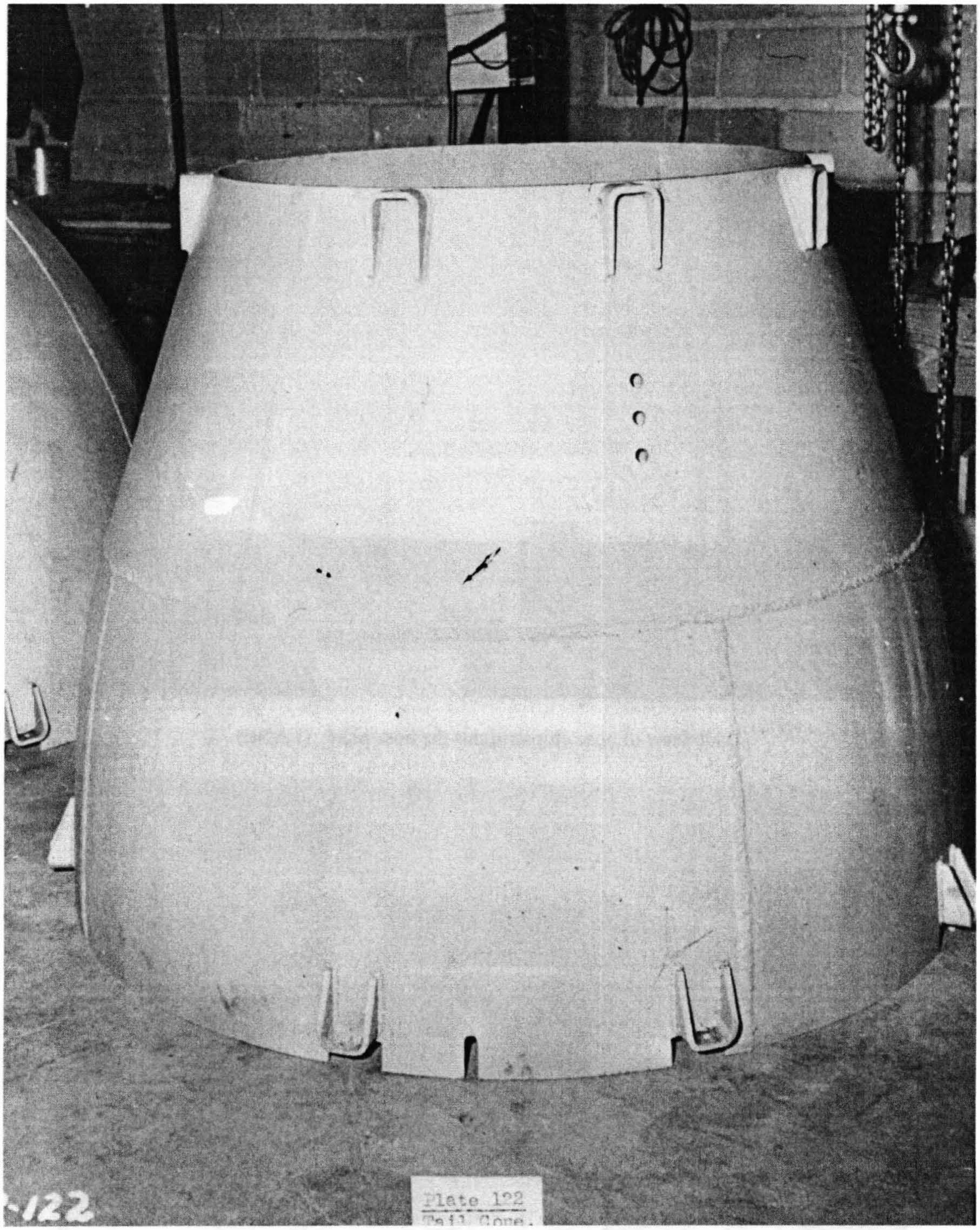
This exclusive photo shows the completed F-31 unit being readied at Los Alamos. (Glen McDuff)



Side view of nose ellipse minus the nose plate. (LANL)

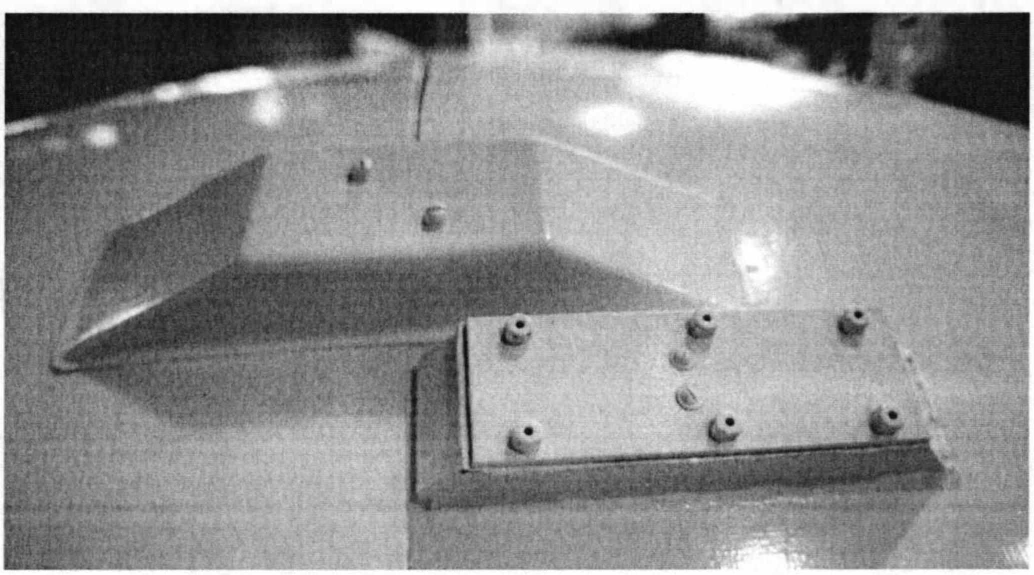


Close-up view shows how the bathtub fittings were used to attach front and rear ellipses. This stockpile unit does not have a sphere inside so no cubes are shown here. (Author)

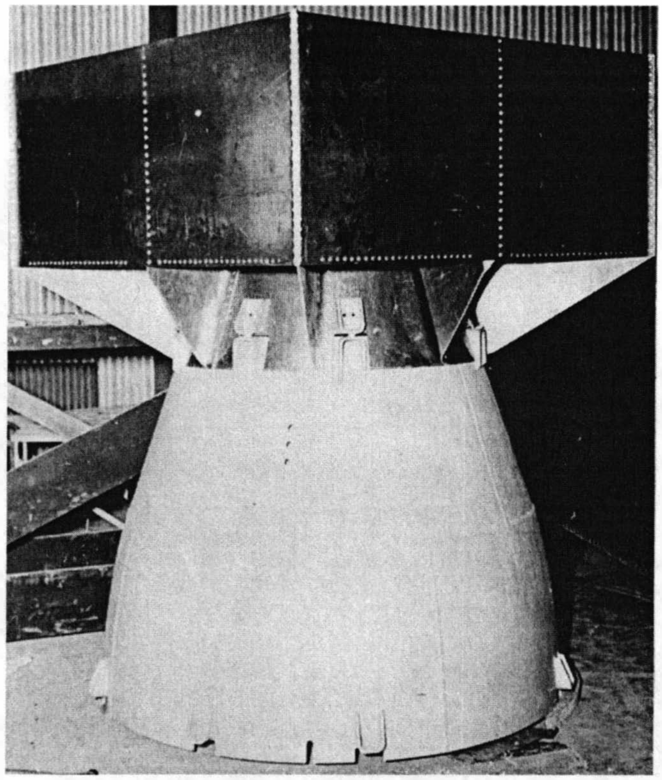


Tail ellipse case. There are no baro openings in this case. (LANL)

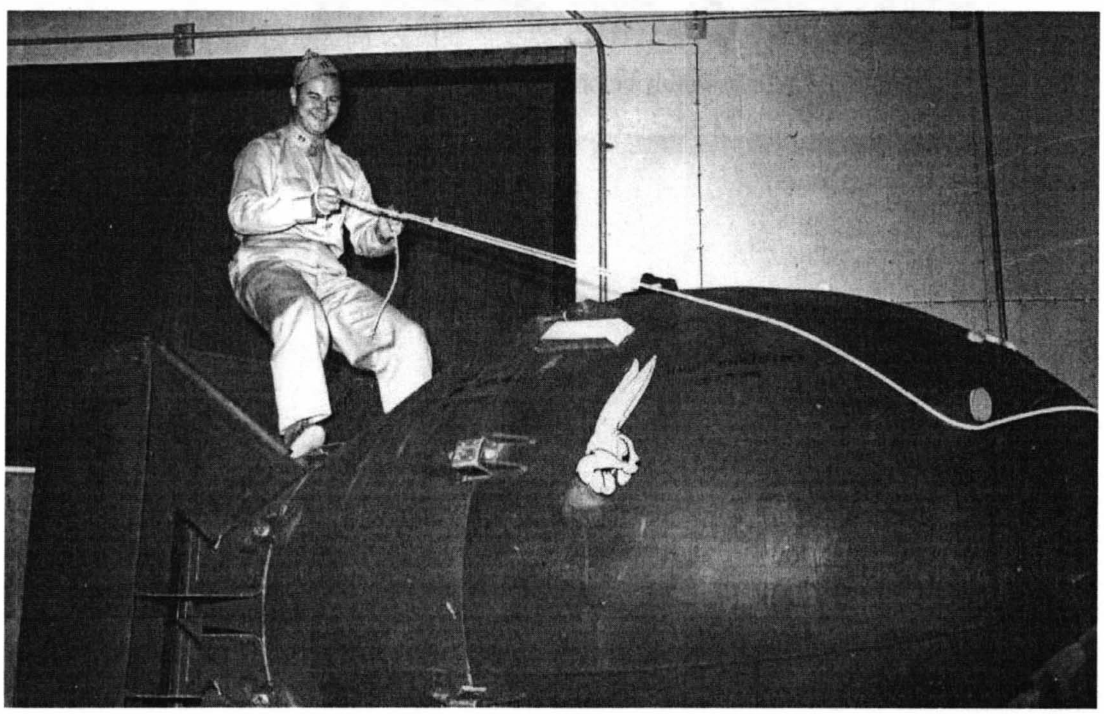
Completed tail fin assembly before attachment to the tail ellipse. (LANL)



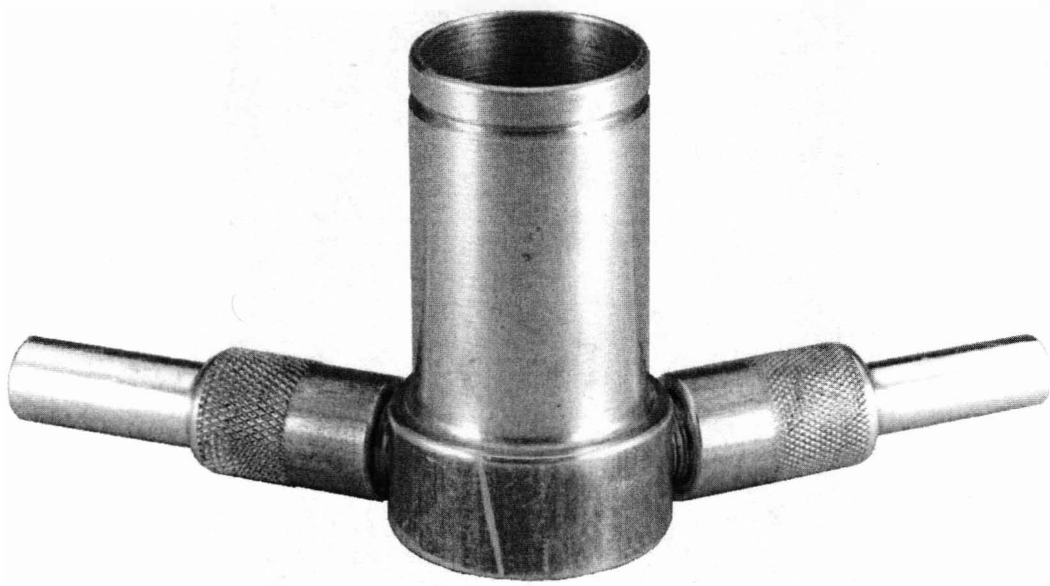
Completed case protective "Bathtub" cover with covered radar plate below. (Author)



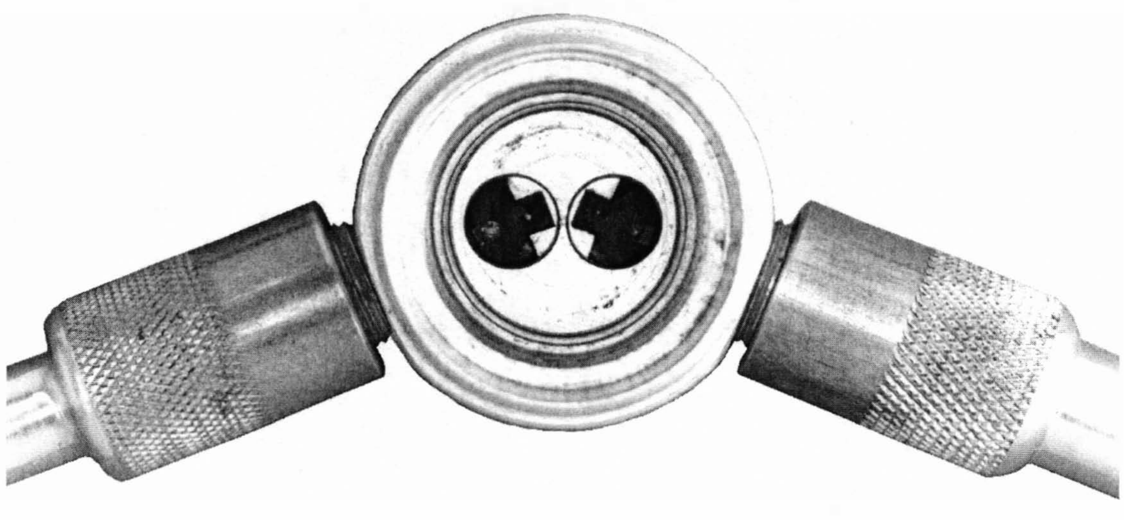
Tail ellipse with tail assembly attached. This shows how the bathtub fittings were used to attach the tail. (LANL)



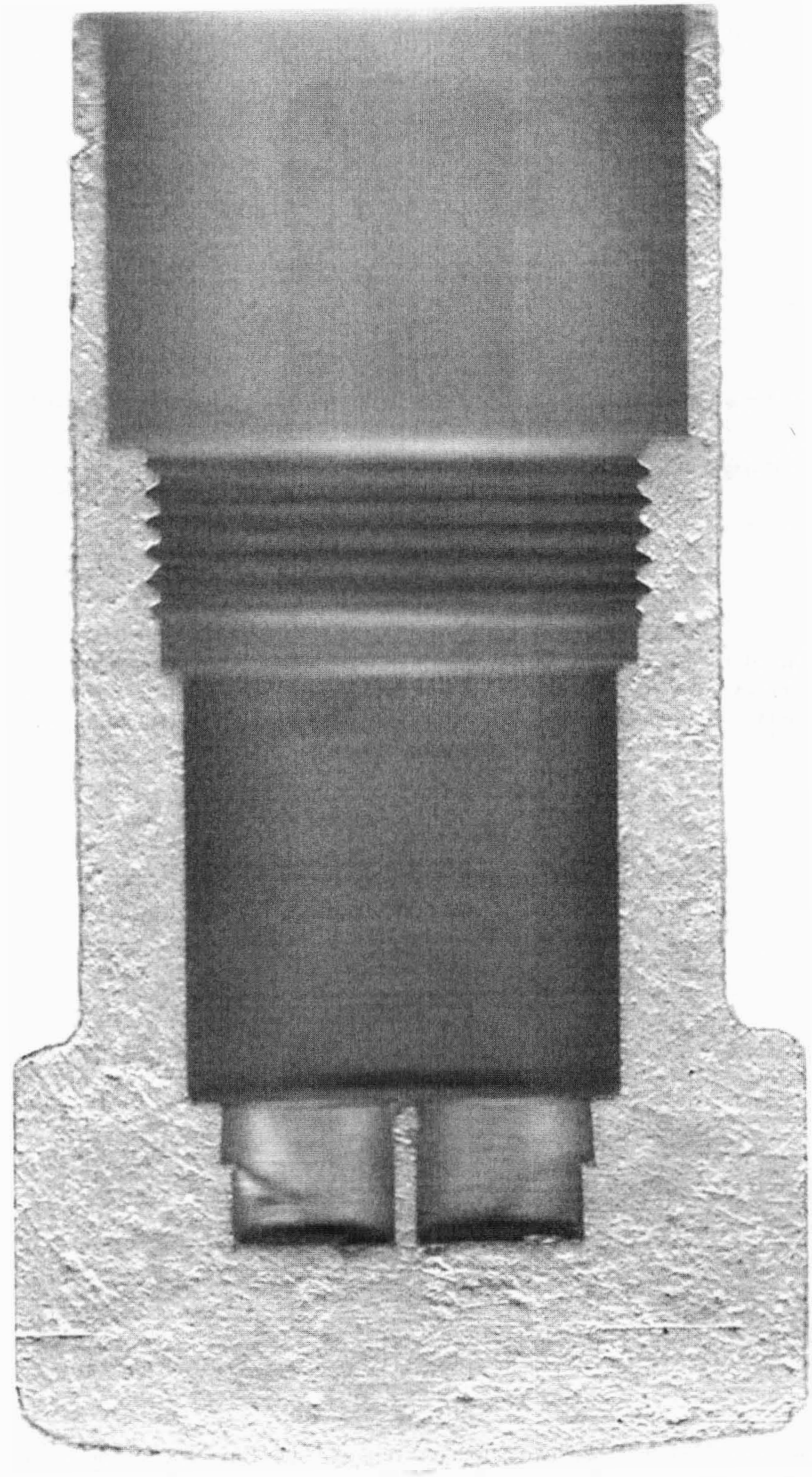
Capt. Wilbur Schaffer the day they assembled the first *Fat Man* at Los Alamos. Above Bugs Bunny it reads "High Explosives Dangerous." (Jon Schaffer)



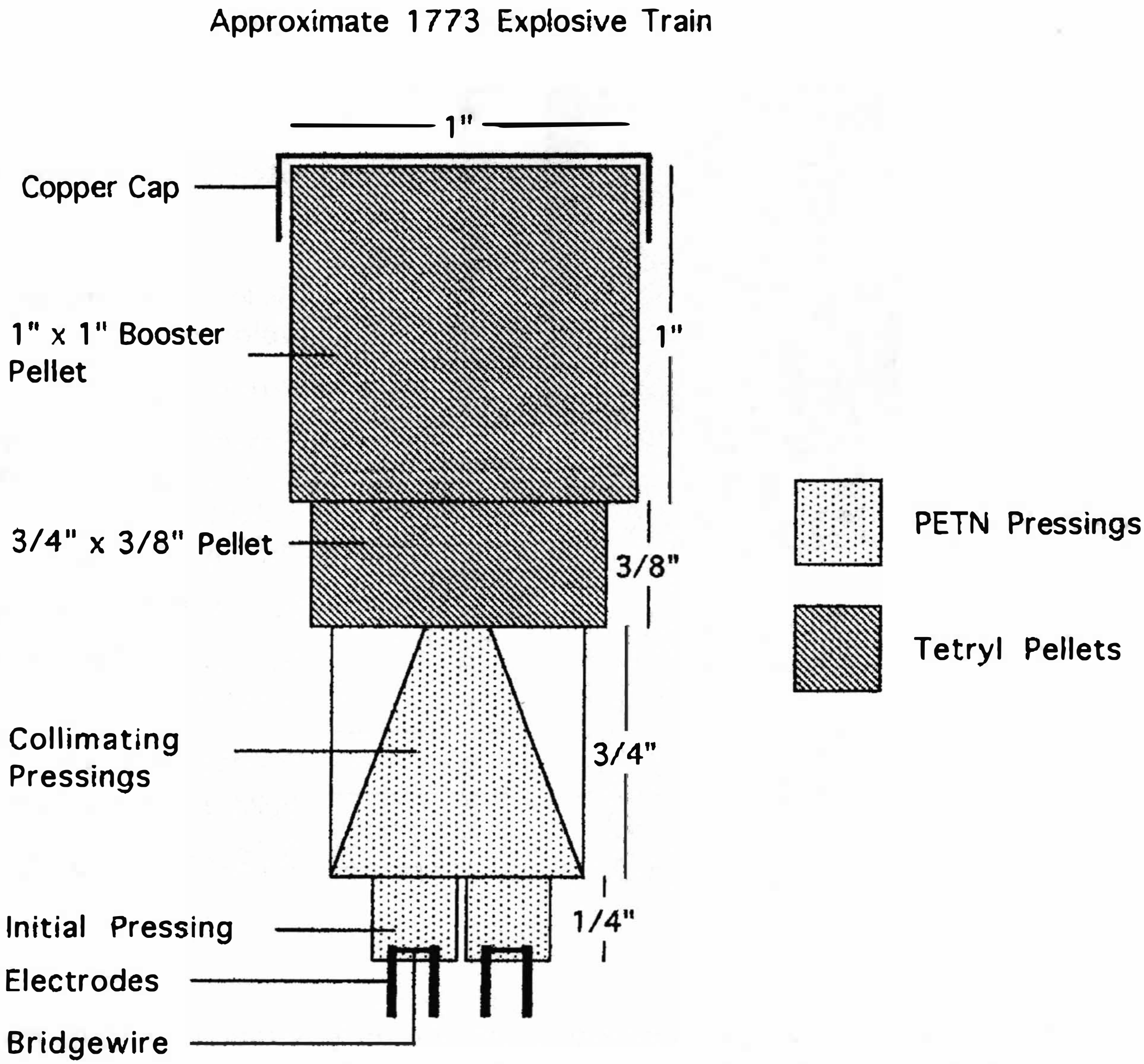
1773 EBW detonator with sidearms. This was an inert test unit loaned to the author in 1995 so there is no Tetryl and PETN explosive or copper nose cap on this detonator. The notched area around the top was to help secure the crimped copper cap. The detonator cables were attached to both sidearms on each detonator. (Author)

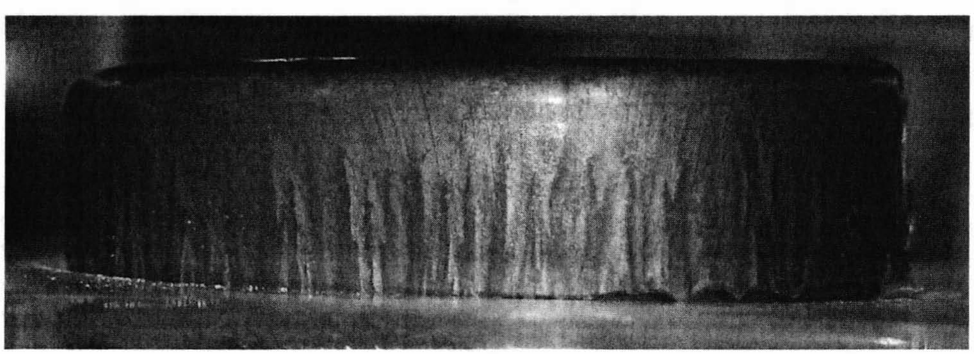


Looking inside the 1773 showing the two detonator wells and sidearms. The two dots visible in the black areas at the bottom of the wells were the attachment points for the bridgewires. The angle of attachment for the sidearms clearly illustrate why it was nicknamed the "handlebar" detonator. (Author)

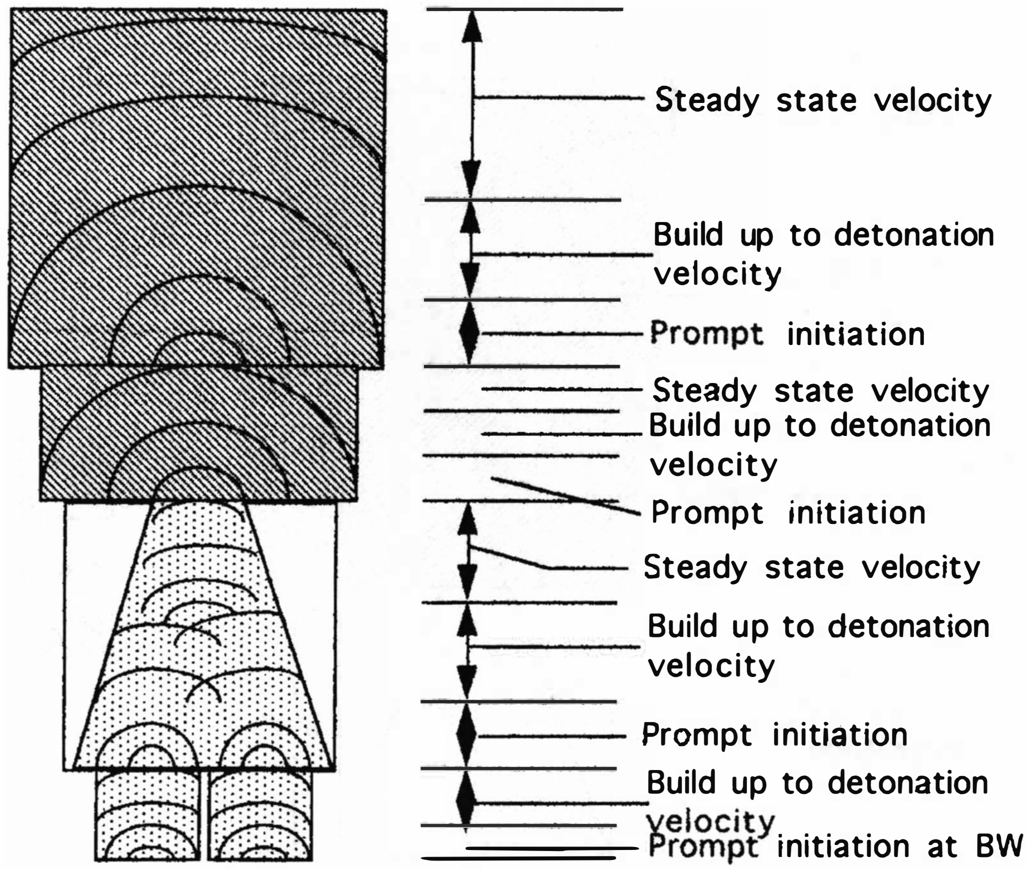


1773 cross-section cutaway showing two PETN cavities at bottom. (Author)



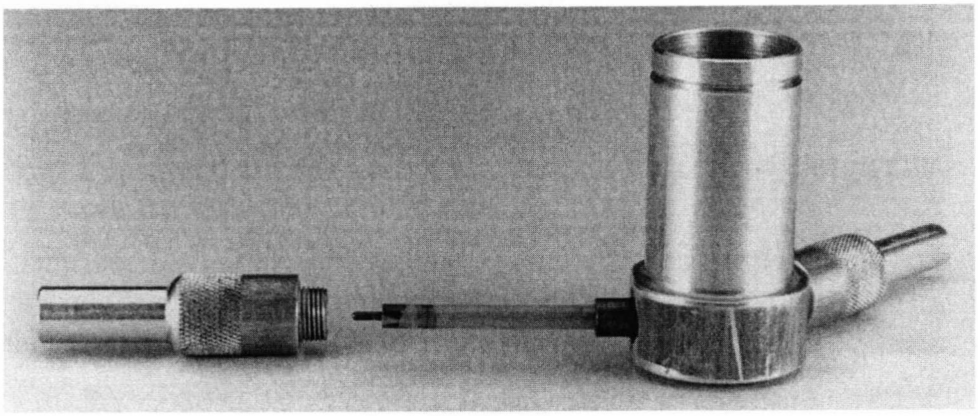


These two exclusive drawings furnished to the author by John Tucker (Ensign Tucker) based on the preceding cross-section cutaway show the interior of the 1773 EBW detonator and depict the explosive components consisting of the Bridgewires, the PETN Initial and Collimating Pressings, the Collimating Spacer, the Tetryl Pellet and Tetryl Booster Pellet, and the crimped Copper Cap (shown above). (Author)

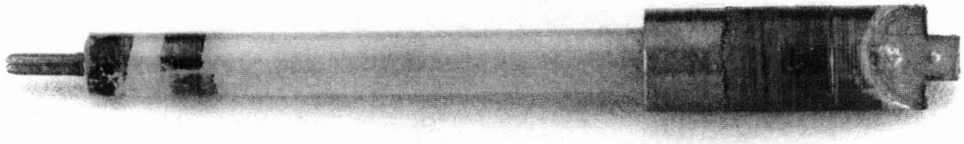


Note: The various zones indicated above are for illustration purposes only. The length of each explosive component must be long enough to reach full detonation, steady state, velocity at its output end. This is necessary to promptly initiate the next component in the explosive train. If this and prompt initiation at the bridgewire is not achieved, timing errors will result.

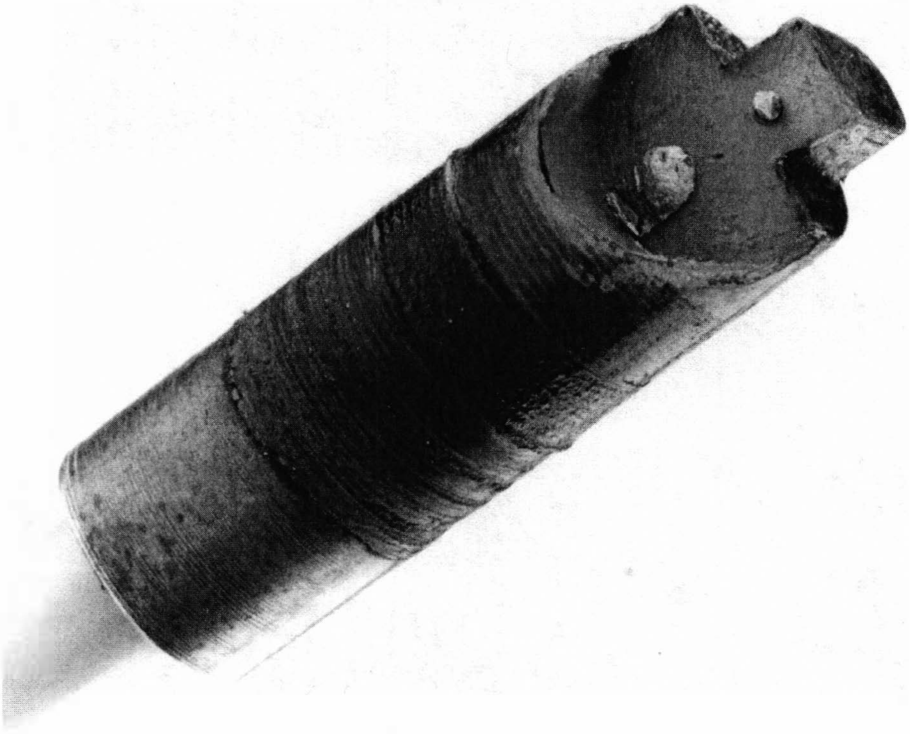
Here John Tucker depicts the "Explosive Train" process that went on inside the 1773 EBW detonator from the beginning "Prompt Initiation" induced by the vaporization of the two Bridgewires (BW) at the bottom under the PETN "Initial Pressings" up to the emergence of the "Steady State Velocity" wave at the very top that pushed against the copper cap which, in turn, "slapped" into the outer Comp B explosive lens. This went on simultaneously throughout all 32 EBW detonators that resulted in the completely spherical implosion sequence.
(Author)



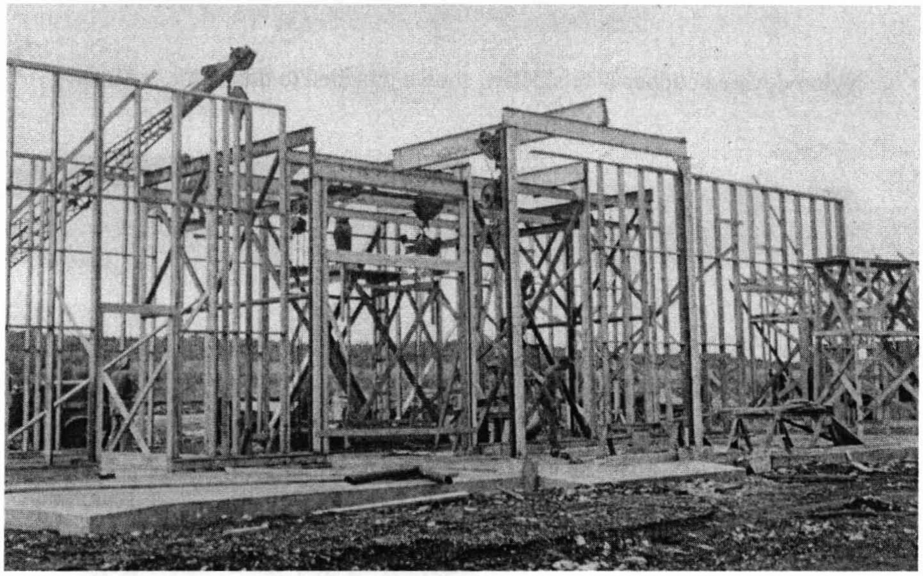
Nylon covered copper wire sidearm shown attached to detonator. (Author)

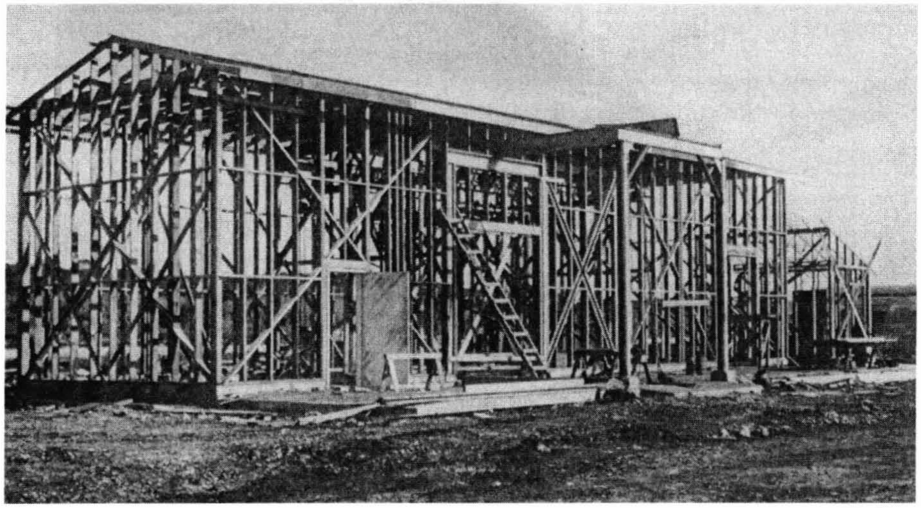


Detail of sidearm. Bridgewire was soldered between two solder points on the right. (Author)

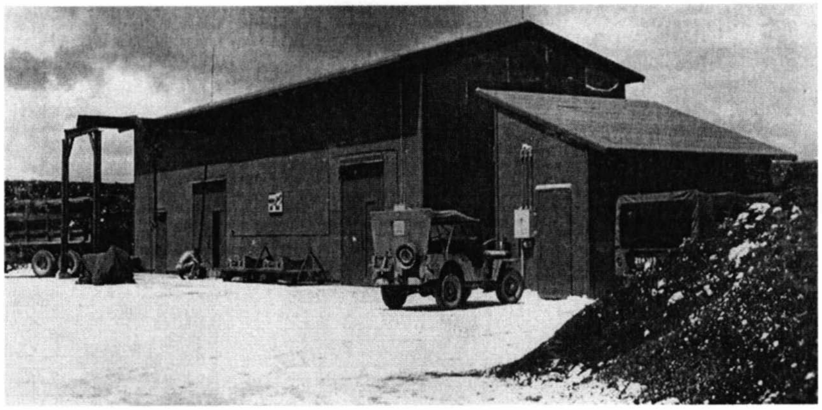


Extreme close-up of sidearm showing solder points where the bridgewire was attached. Since this was a test unit, the bridgewire has already been vaporized. The dark portion on the exterior was the copper covered electrical ground and was connected to the smaller solder dot. The larger point was soldered directly to the central copper wire in the nylon sidearm. (Author)

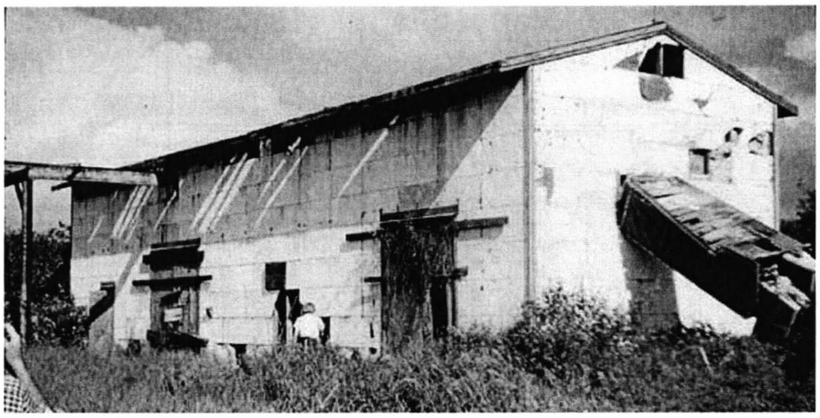




These three views show the construction of Assembly Building #3 on Tinian where the F-31 *Fat Man* was constructed. The top view was taken from the transport road that ran along the east side of all three assembly buildings while the remaining two show the front of the building. The internal steel beam structure used to support the numerous overhead hoists is clearly visible surrounded by the wood frame structure. Note that the building exterior panels and protective earthen berms are not yet in place. (National Archives/Courtesy of Steve Bice)

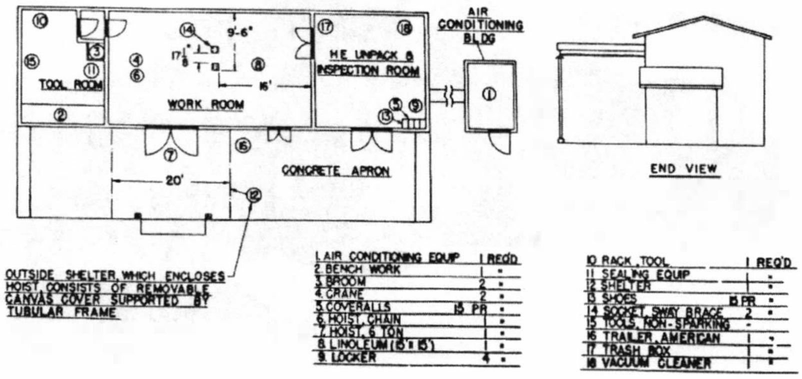


Tinian *Fat Man* Assembly Building #3. Steel beams salvaged from the Japanese occupation of Tinian were used in constructing special facilities for bomb assembly, storage, etc. (USAF)

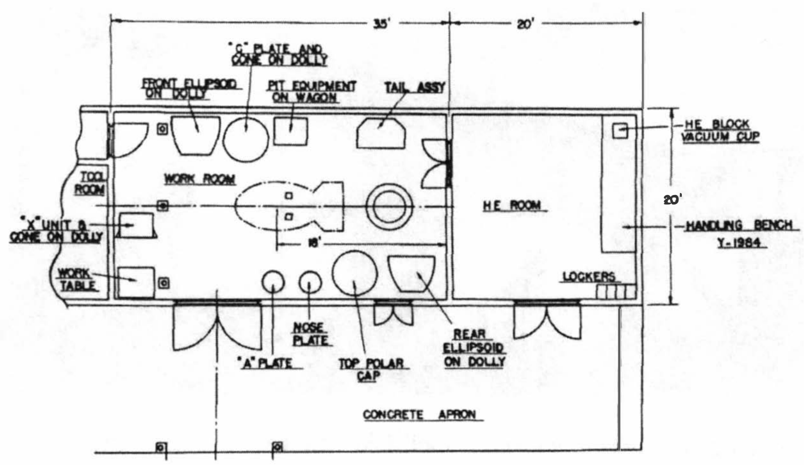


The same building in 1959 before it was demolished. (Lowell Boothe/Courtesy of Gary Boothe)

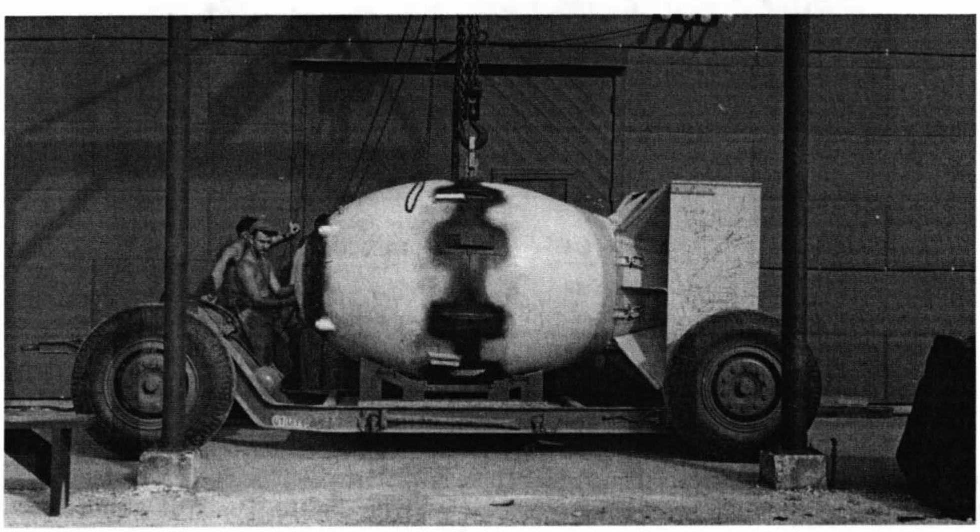
Professor Anderson Giles and the author are shown here in 2010 standing on the center of the concrete floor of what remained of #3. It is now completely covered by jungle growth. For those wishing to explore in person or through satellite maps, the GPS coordinates for this assembly site are 15° 05' 38.65" N, 145° 38' 17.50" E. (Author)



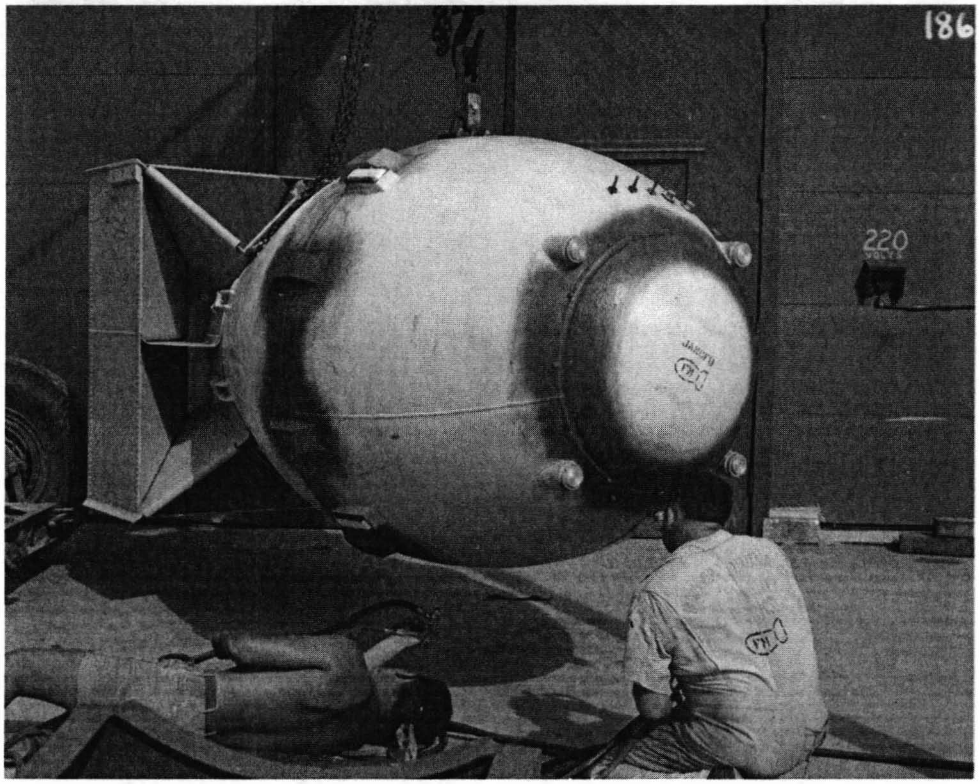
Detail showing interior layout. Note the differences in the exterior door placements between this preliminary drawing and the actual building shown in the photos. (LANL)



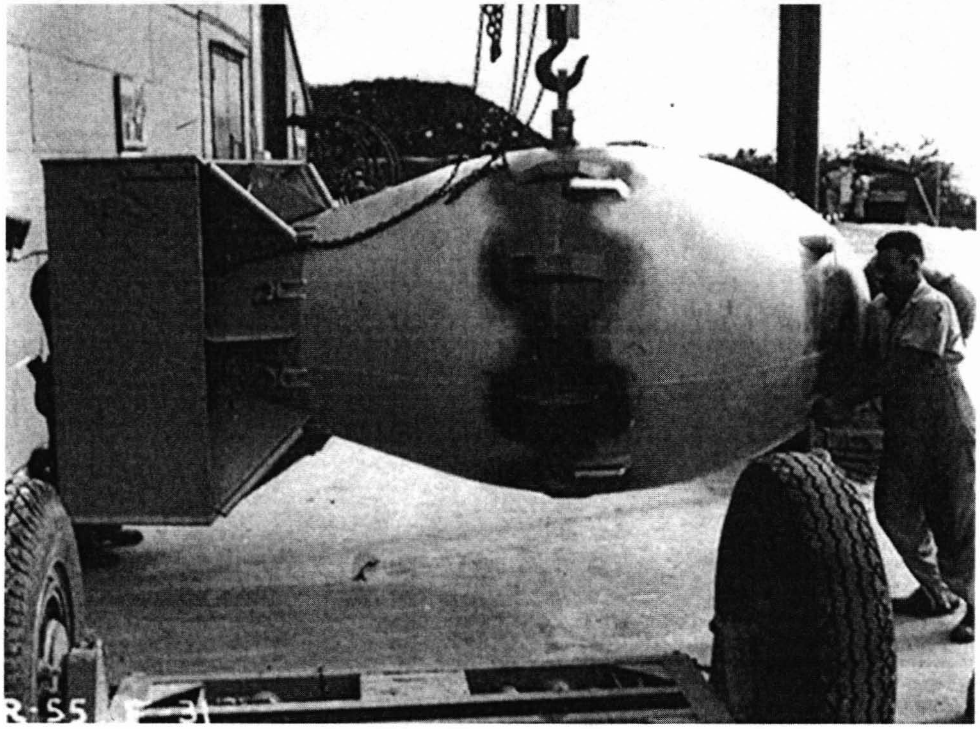
Detail of work room showing layout of *Fat Man* parts. (LANL)



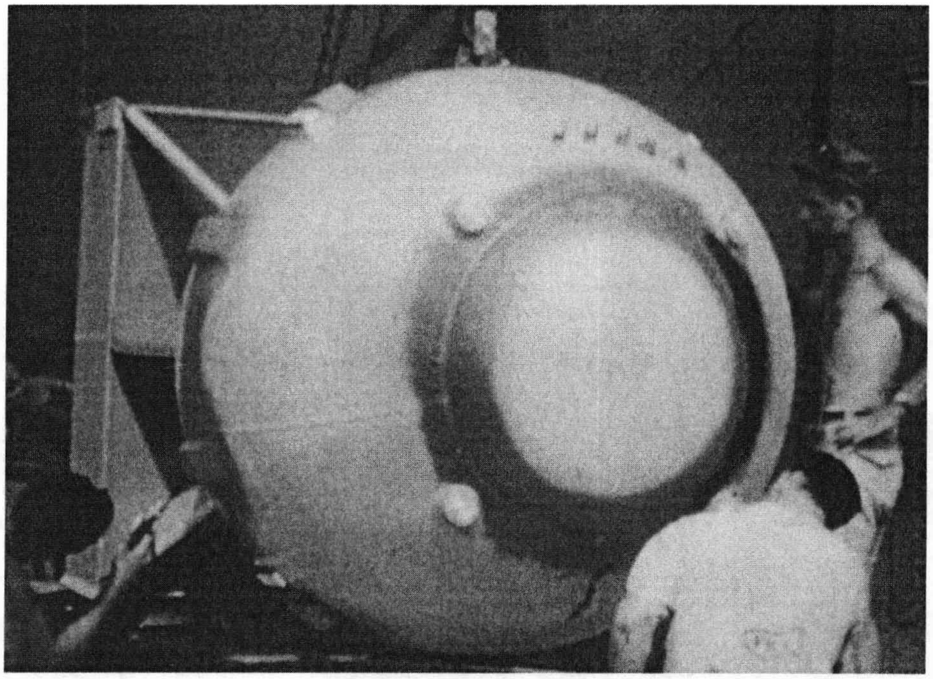
Unit F-31 outside assembly building on transport carriage. (National Archives)



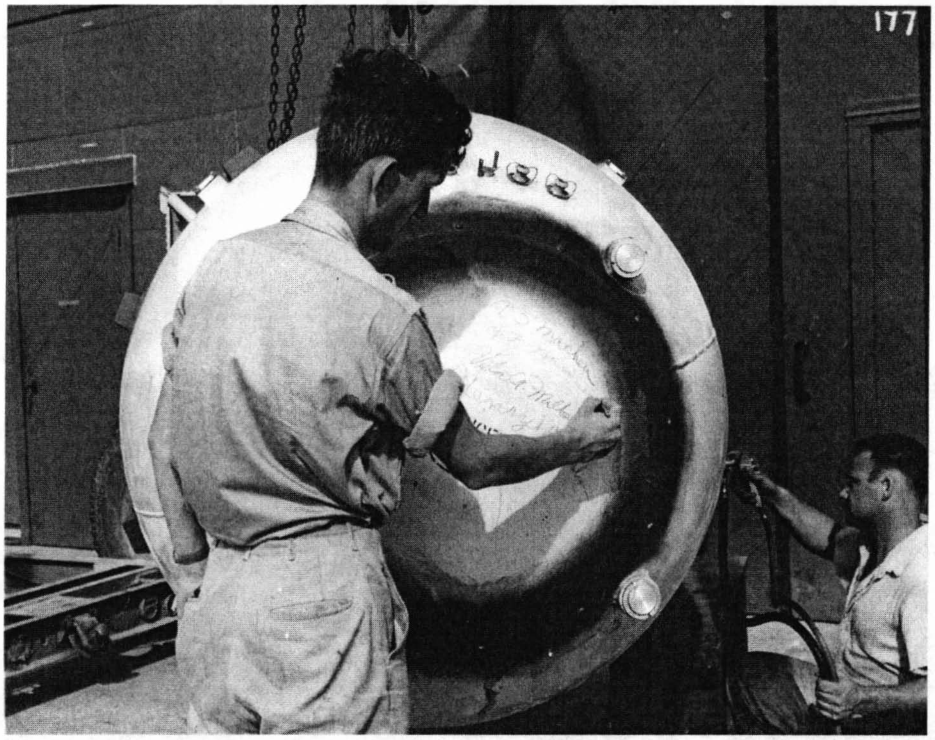
Cocooning process outside assembly building. (National Archives)



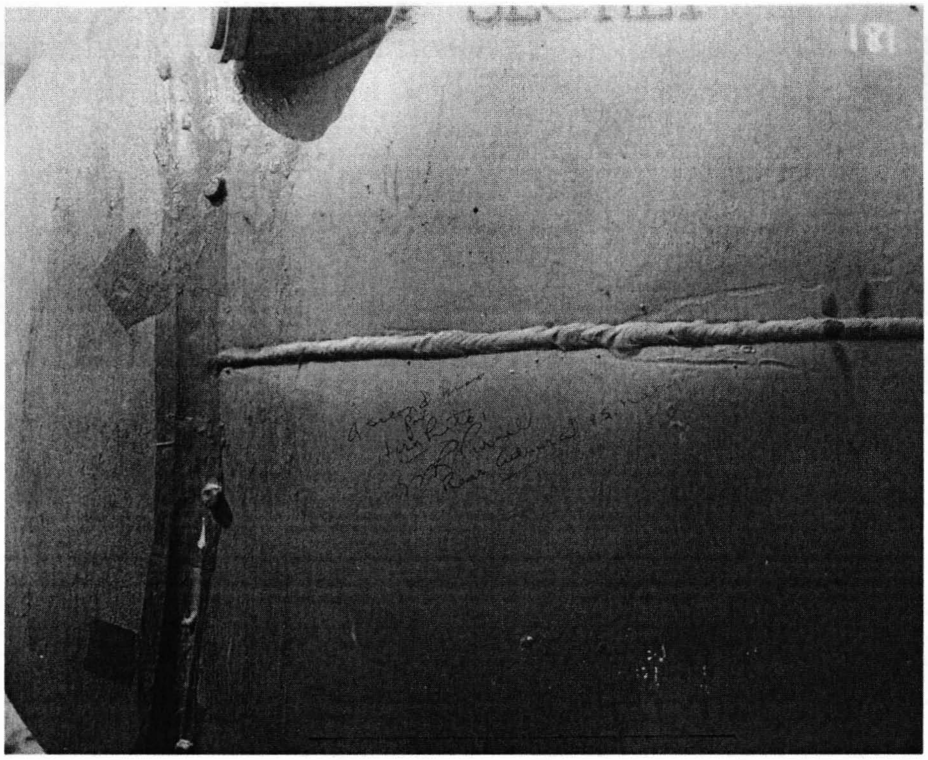
Side view of F-31. (National Archives)



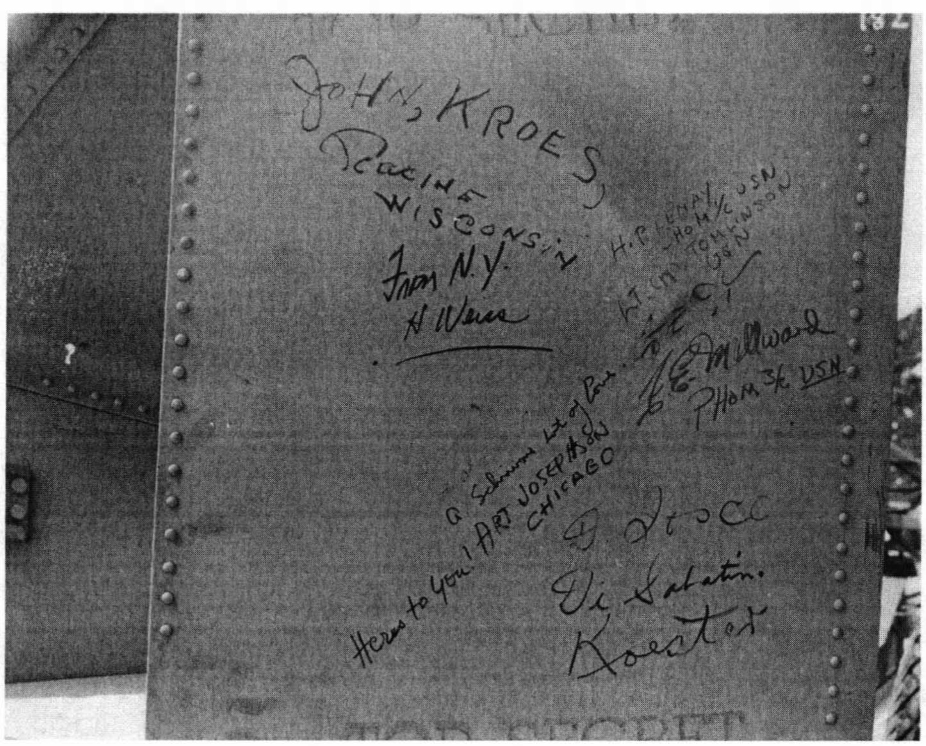
Another view of the cocooning process. (National Archives)



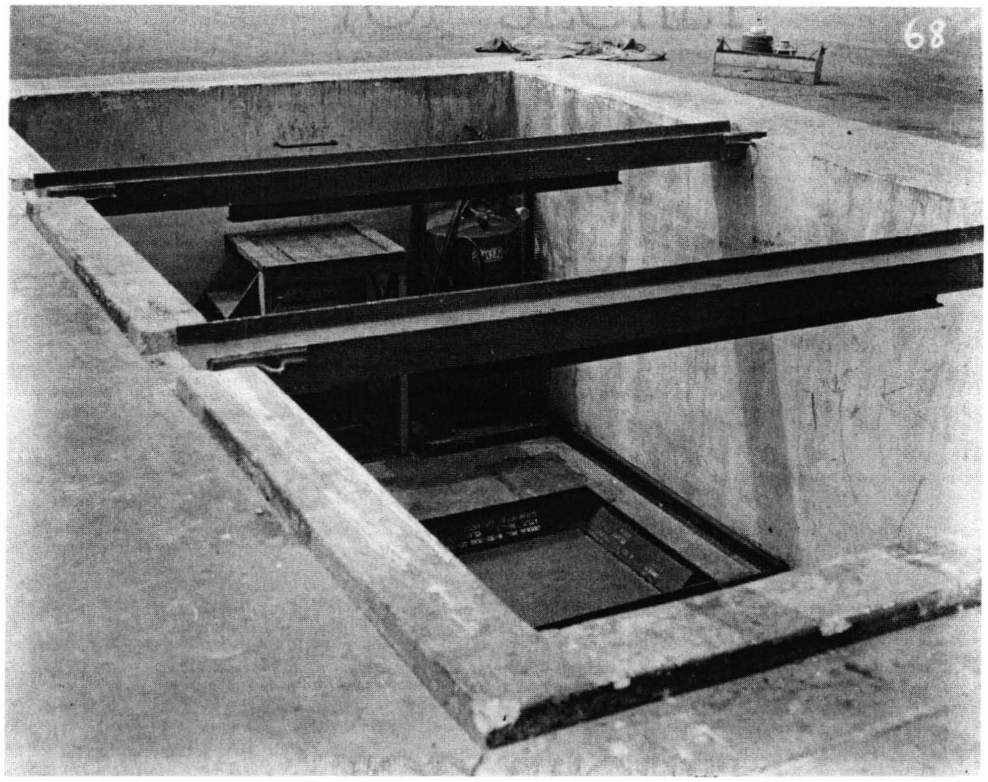
Norman Ramsey is pictured signing the nose of F-31 while the cocooning process was still underway as 1st Ordnance member Joseph Galdarisi, Jr. sprays on the sealant. At this point there were already many signatures on the bomb. Note the clips over the safing plugs on the nose and the dummy plugs covering the nose fuzes. (National Archives)



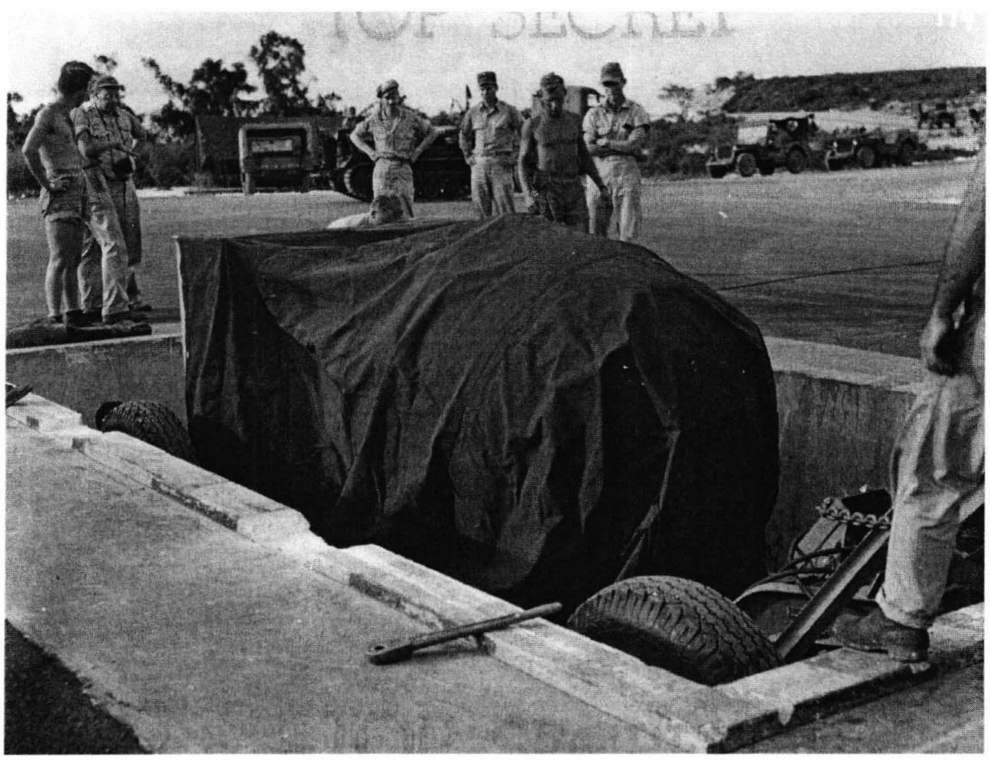
Side view of F-31 showing signatures. Tape had been applied to the nose seam and bolt openings on the nose at this point, but the spray coating of Glyptol had not. (National Archives)



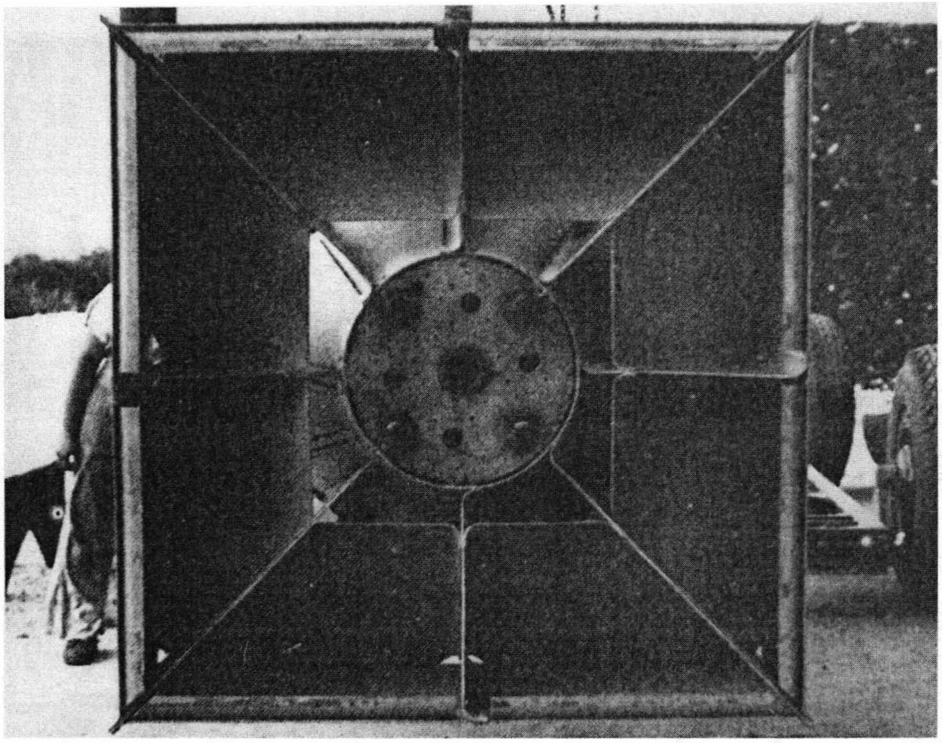
Side view of tail showing signatures. (National Archives)



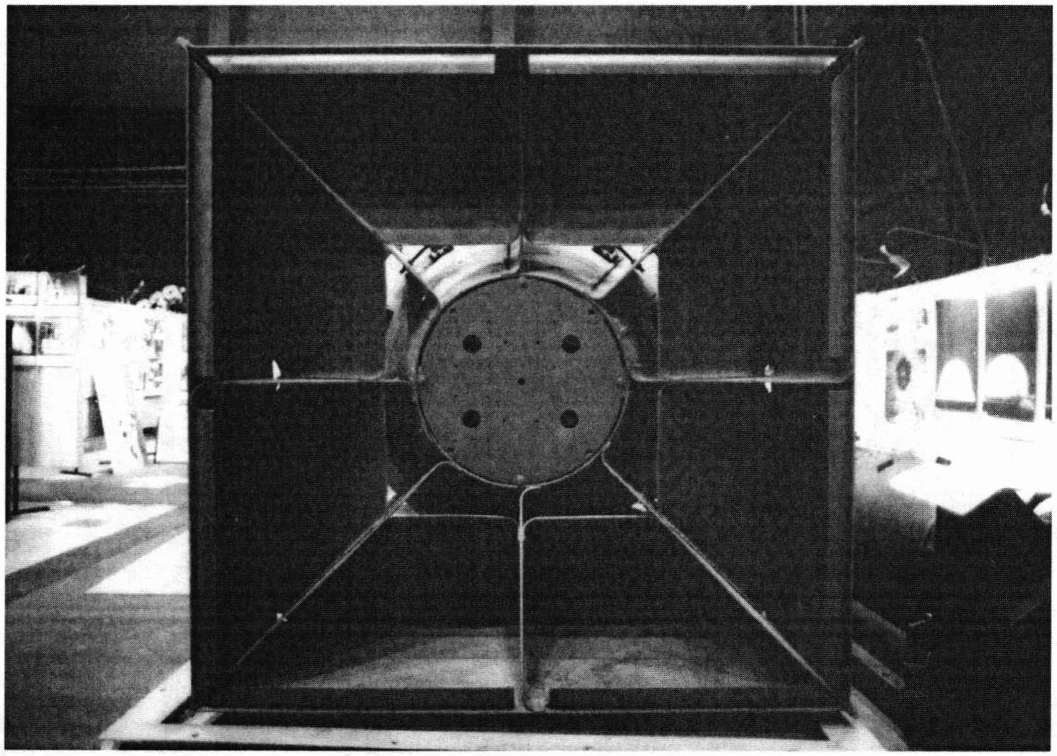
Loading pit before the F-31 was positioned. (National Archives)



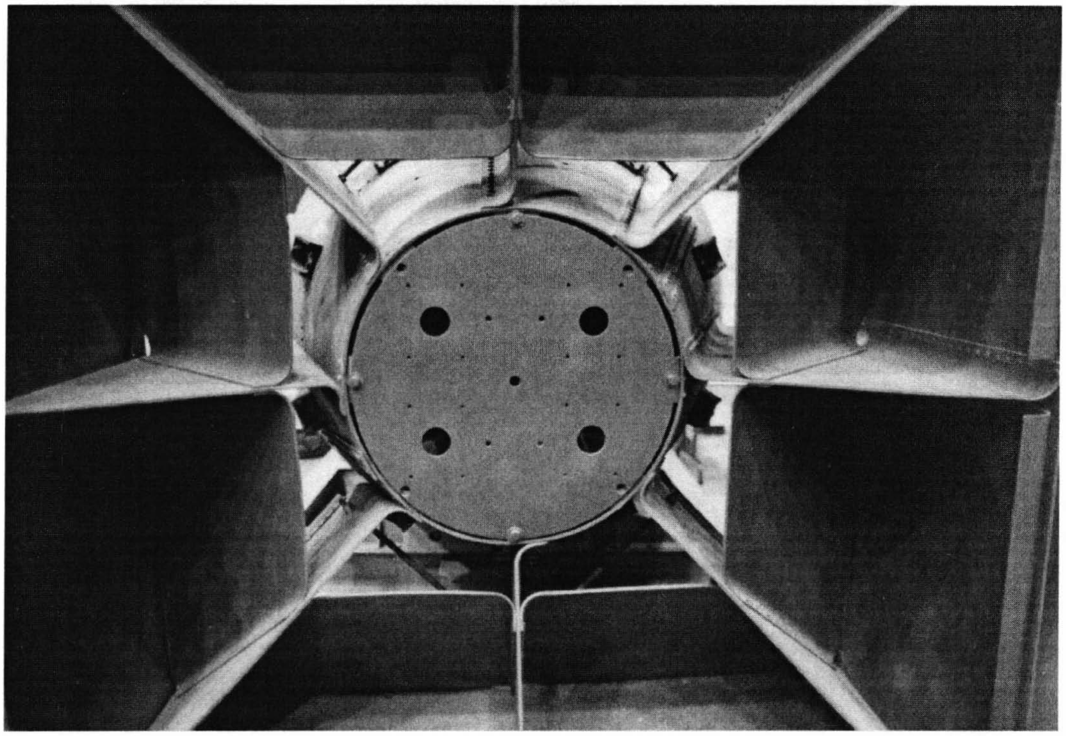
Canvas shrouded F-31 being lowered into pit. (National Archives)



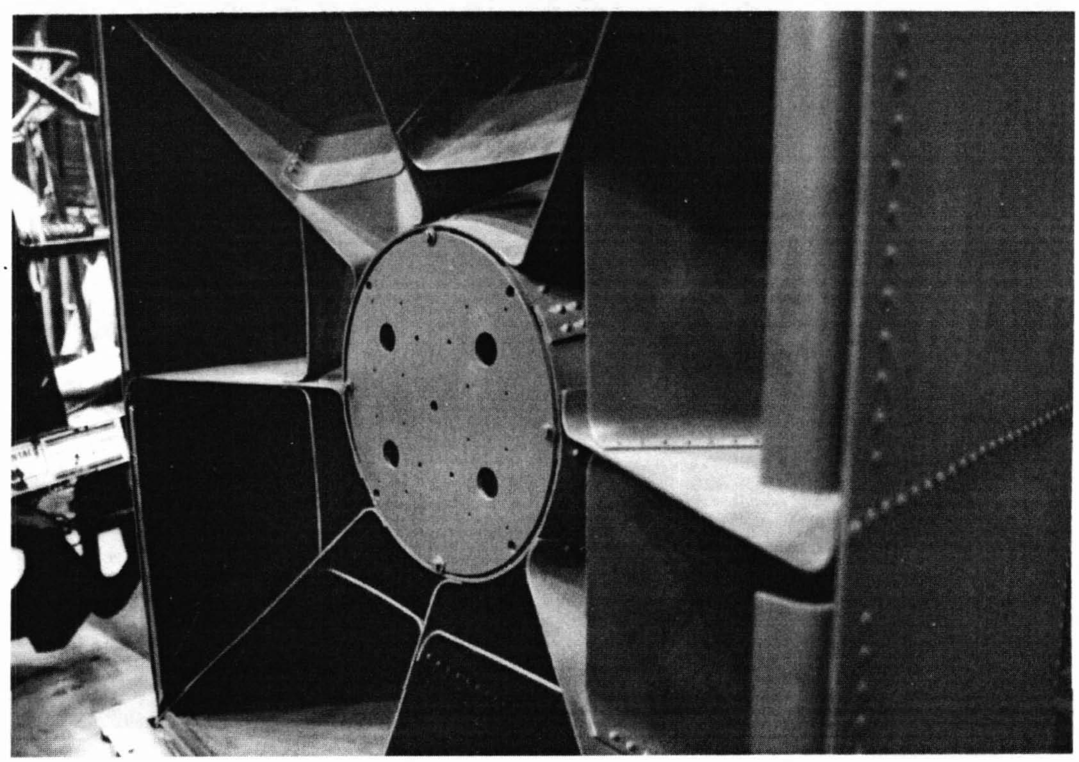
View of the F-31 tail outside the Tinian assembly building. (National Archives)



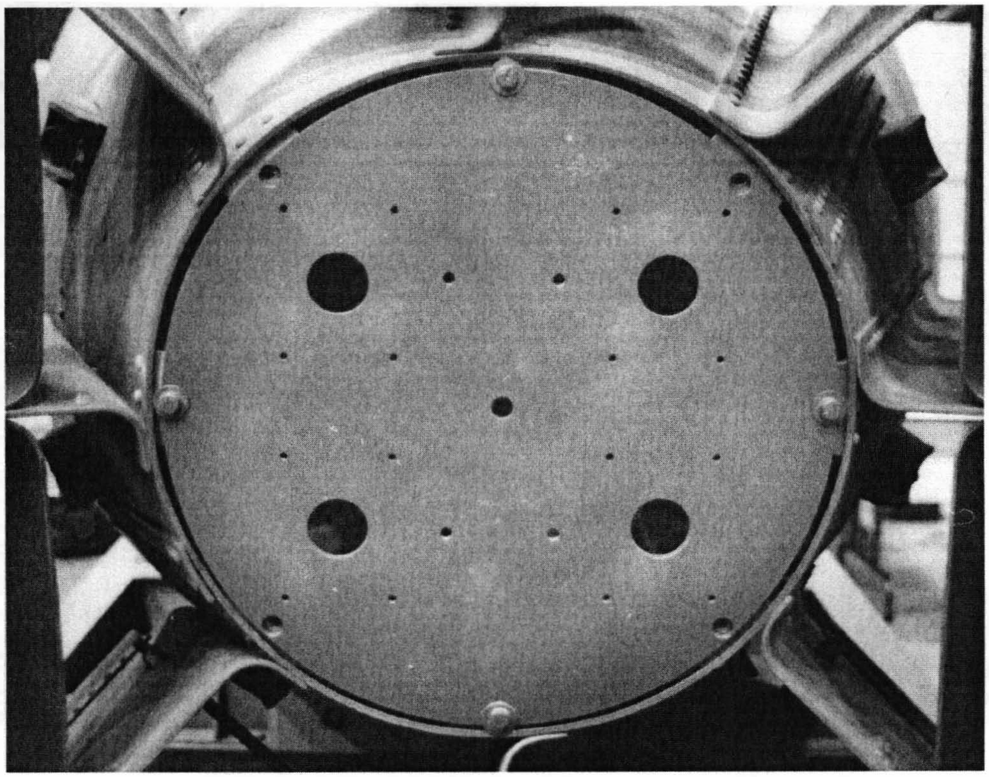
Same tail on stockpile unit at The National Museum of Nuclear Science and History. Note orientation of "E" plate on both. (Author)



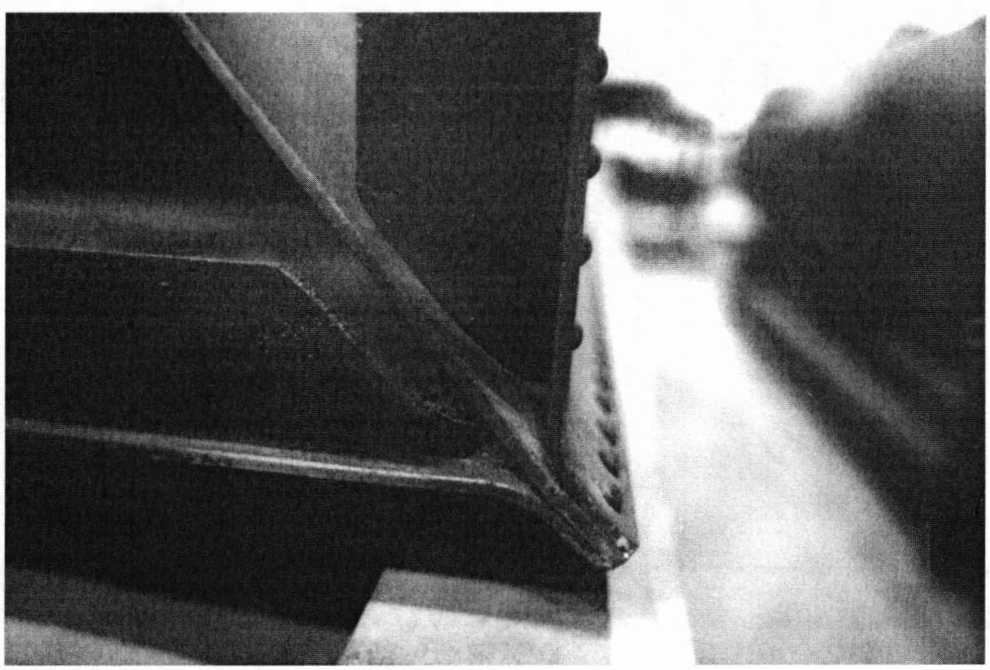
Enlarged view of tail on stockpile unit at The National Museum of Nuclear Science and History. (Author)



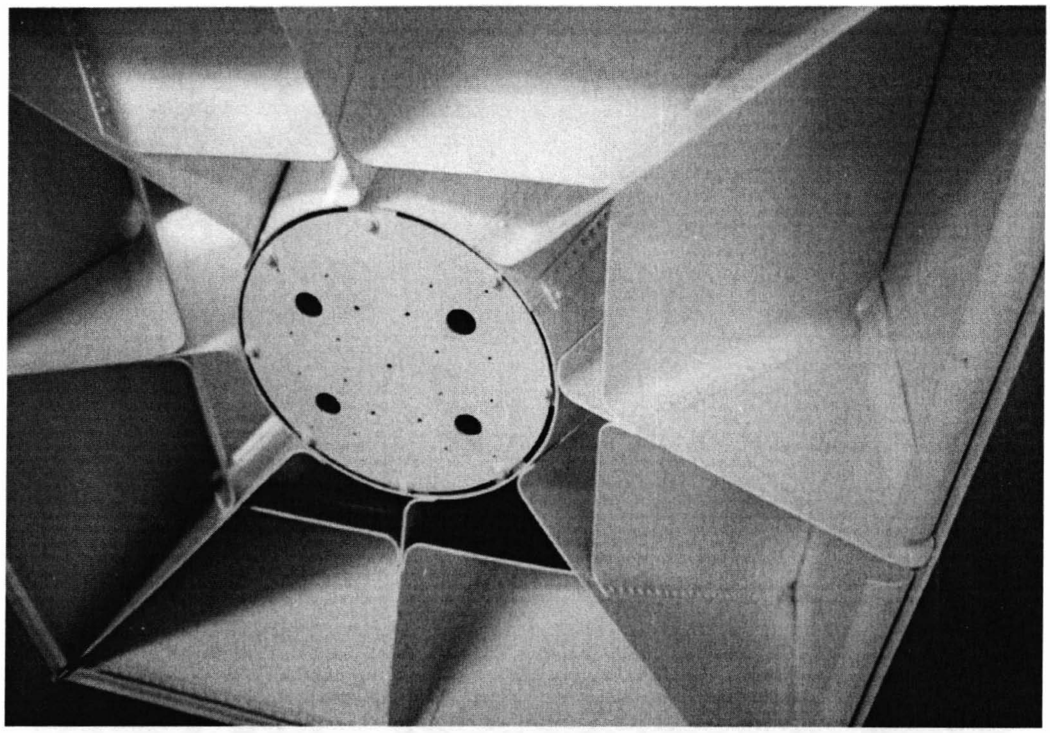
Side view of the tail section. (Author)



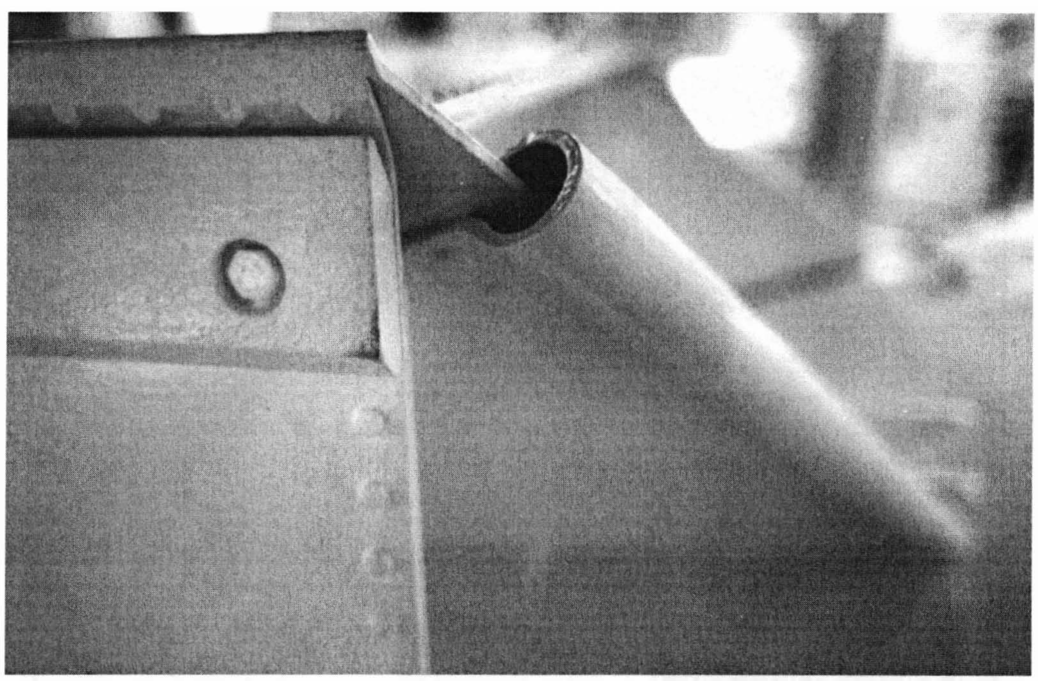
Close-up of "E" plate. (Author)



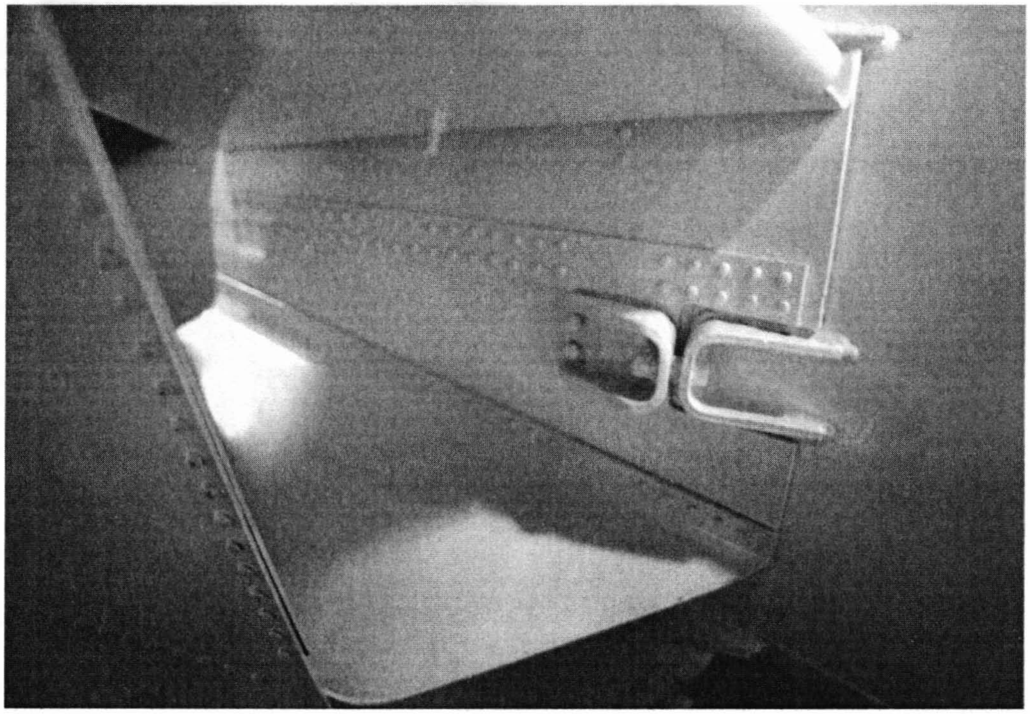
Tail corner detail. (Author)



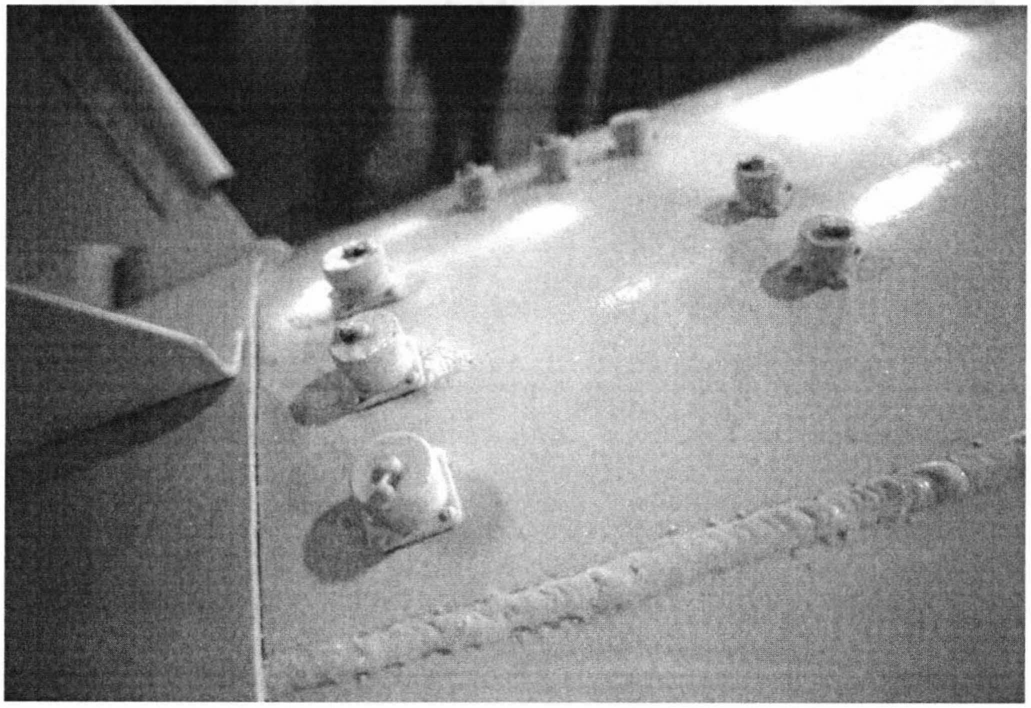
Tail on LANL Bradbury Museum *Fat Man*. (Author)



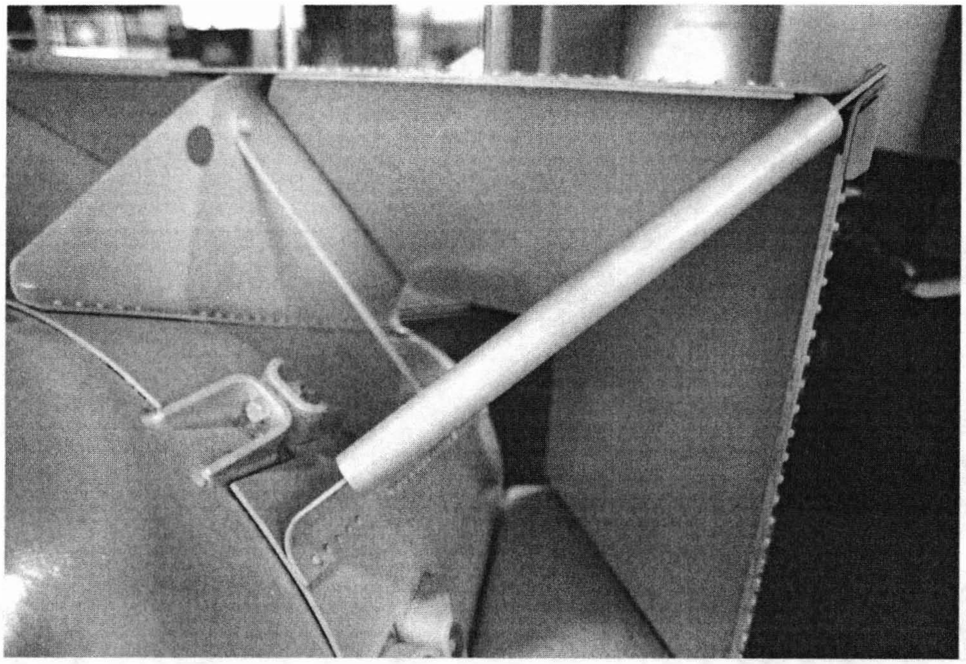
Detail of tail section showing Micarta rubbing block (l) at top of tail and cylindrical stiffener tube. (Author)



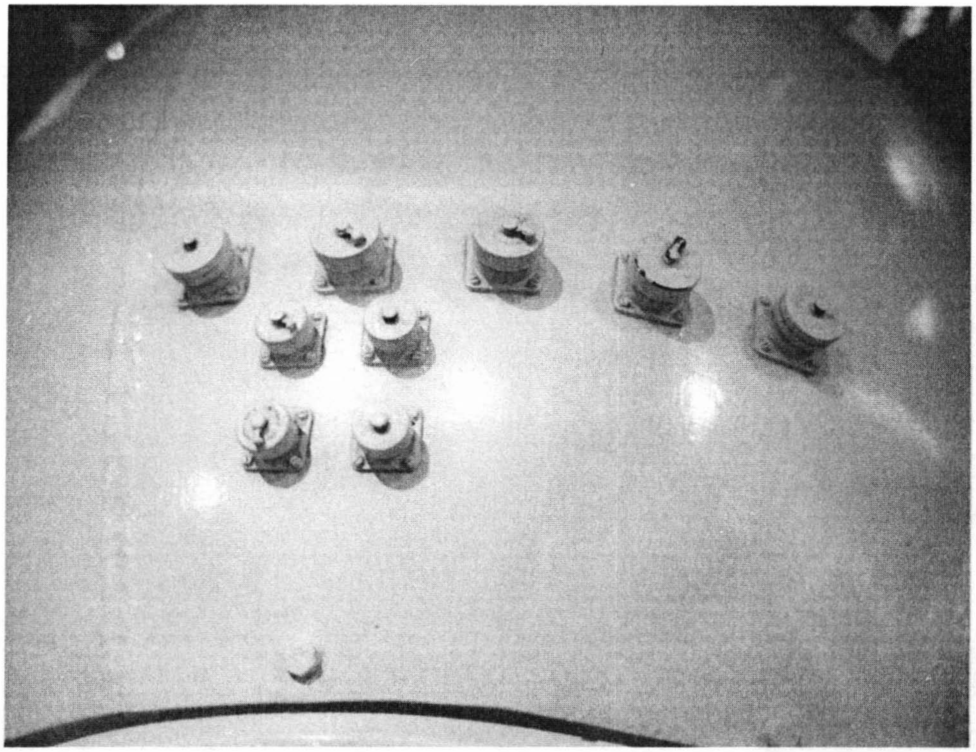
Detail showing tail area bathtub fitting. (Author)



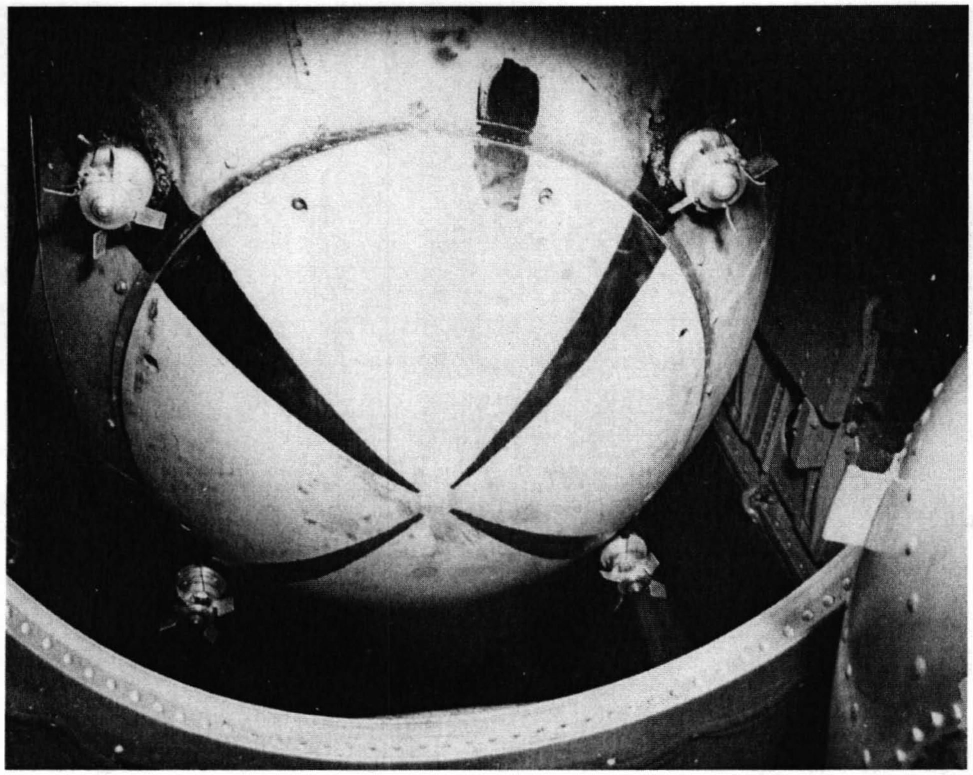
Detail of electrical plugs on upper tail section of stockpile unit. (Author)



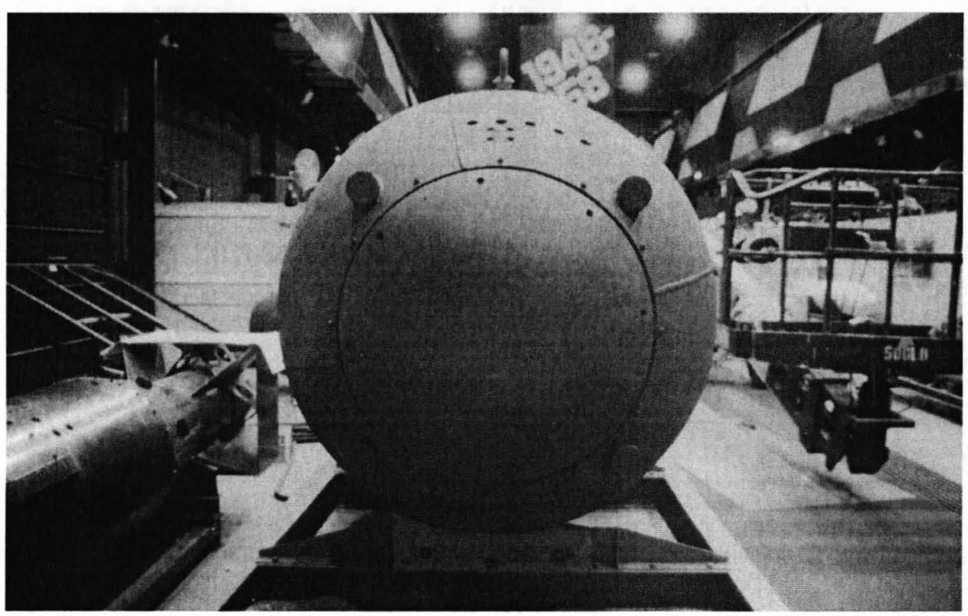
Detail view of tail front showing stiffener tube and Micarta block on upper right corner. (Author)



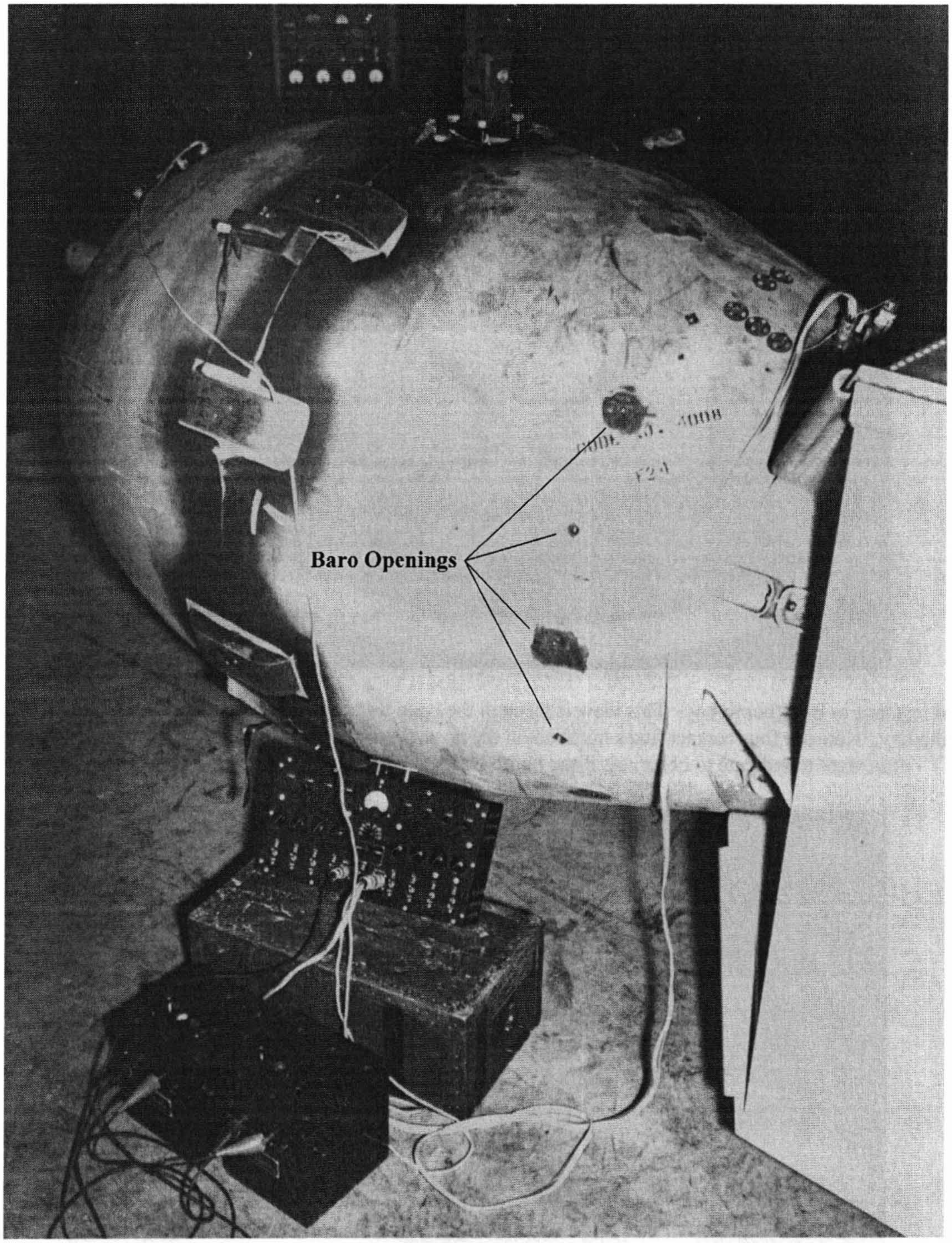
Detail showing nose plugs on stockpile unit. Only the top three large plugs on the left were used on the F-31 combat unit. The other two in the top row were for the safing/arming plugs. (Author)



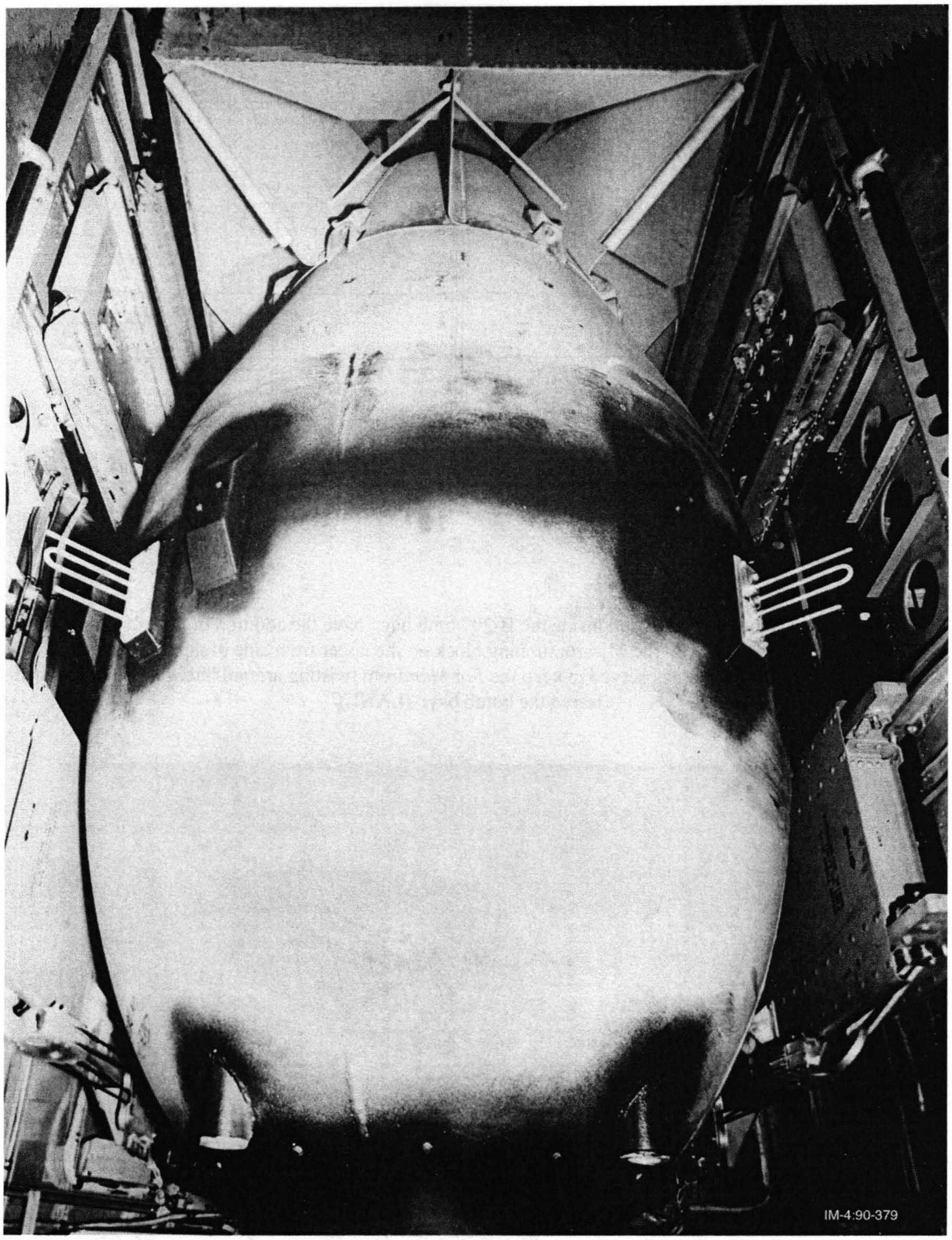
FM test unit in B-29 bomb bay. This view is through the open door in the aft cockpit leading to the forward bomb bay. Note the four contact fuzes installed on the nose. Pressure door is on the right. The stripes on the nose were to indicate to observers if the bomb was spinning during the descent phase. (LANL)



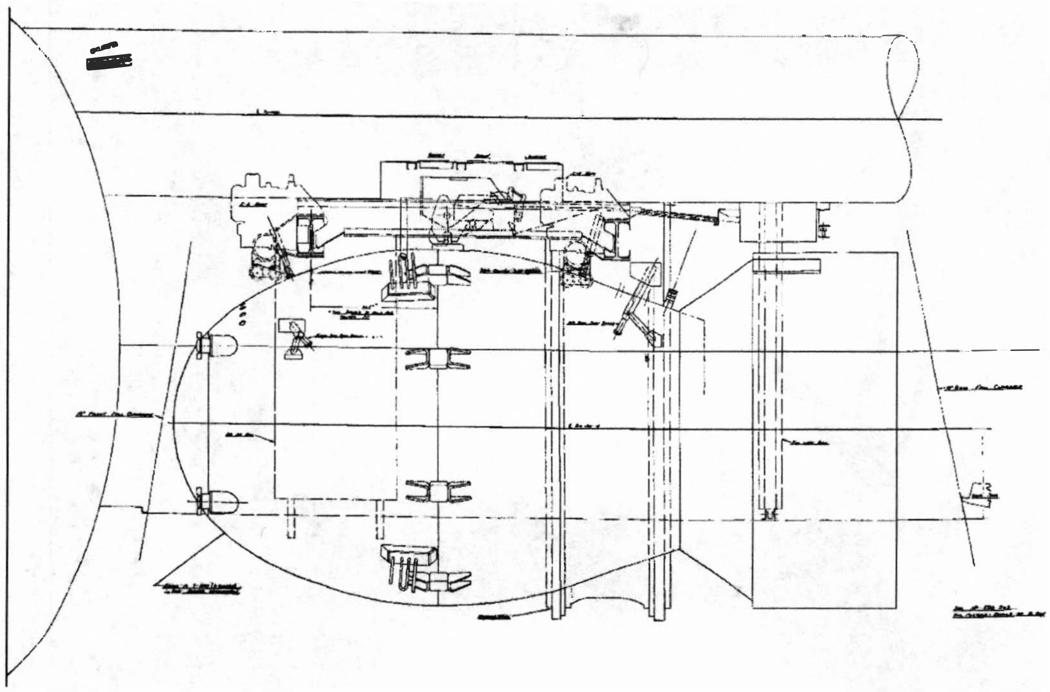
Nose on stockpile unit at The National Museum of Nuclear Science and History. *Little Boy* is visible on the left. Photos were taken during museum remodeling in 1993 so a man lift is visible on the right. (Author)



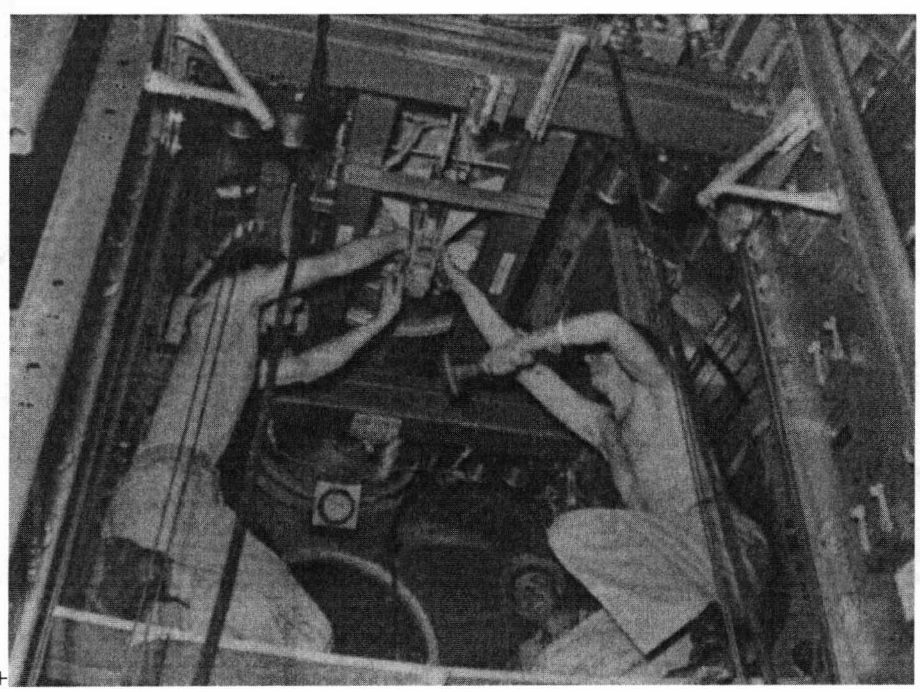
Test unit F-24 inside Tinian assembly building. Note baro holes in aft case and FTB field test box hooked up to electrical connections on F-24. (LANL)



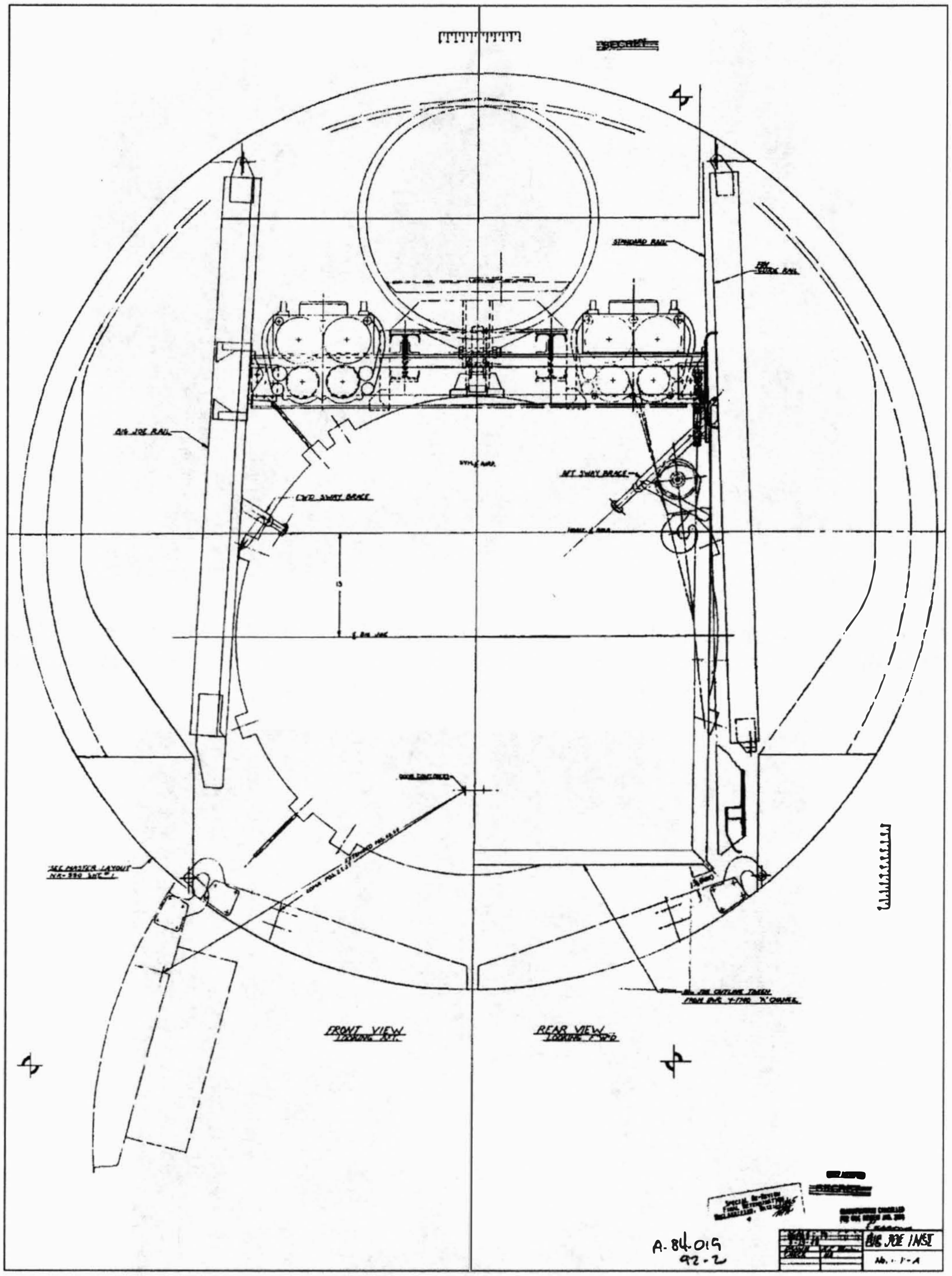
This view looking up shows a *Fat Man* test unit inside the bomb bay. (LANL)



This side-view drawing shows *Fat Man* inside the B-29 bomb bay. Note the addition of the Fin Guide Rail on the right specifically for use with the Micarta rubbing block on the upper front side of the tail. Because it was such a tight fit, the rubbing block served to keep the *Fat Man* from twisting around after release until it had cleared the bomb bay. (LANL)

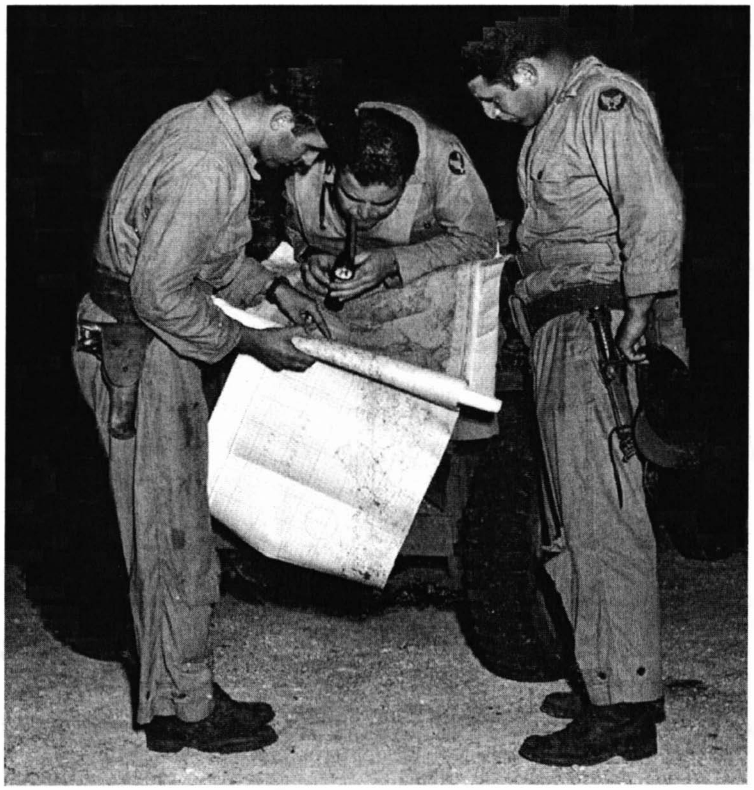


Technicians are shown changing the bomb shackle inside the B-29 bomb bay. (National Archives/Courtesy of Steve Bice)



This 4/13/45 cross-section drawing of the B-29 shows the front and rear views of *Fat Man* (Big Joe) in the bomb bay. Note the extremely tight shoehorn fit. (LANL)

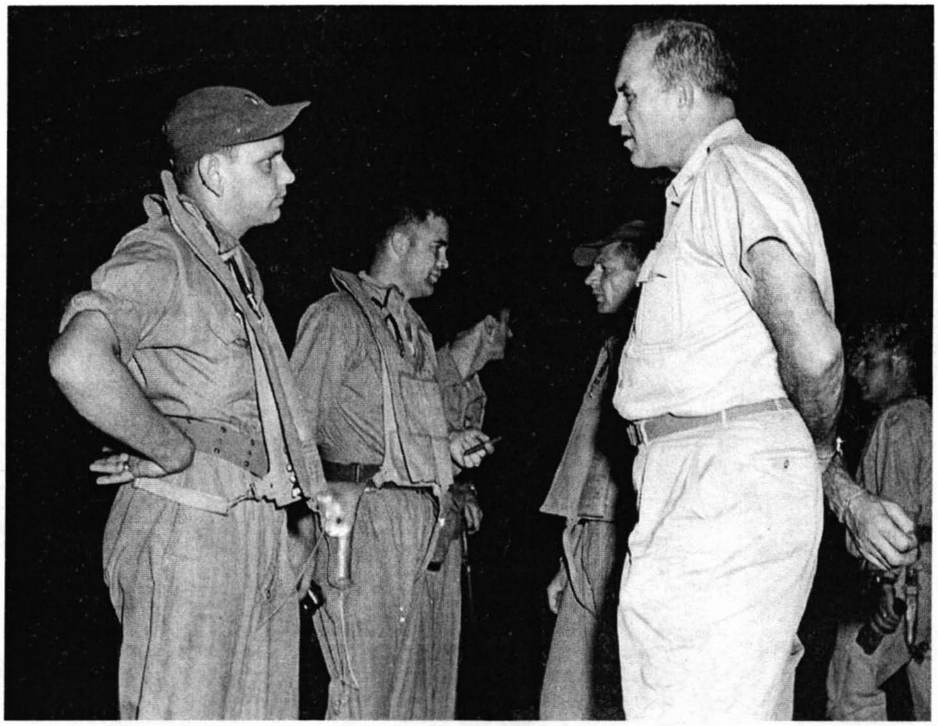
Bockscar crew. Standing: Capt. Beahan, Capt. Van Pelt, Lt. Albury, Lt. Olivi, Maj. Sweeney. Kneeling: S/Sgt. Buckley, M/Sgt. Kuharek, Sgt. Gallagher, S/Sgt. De Hart, Sgt. Spitzer. Not shown are Cdr. Ashworth, Lt. Barnes, and Lt. Beser. (USAF)



Capt. Van Pelt, Maj. Sweeney, and Lt. Olivi studying the map before takeoff. (USAF)

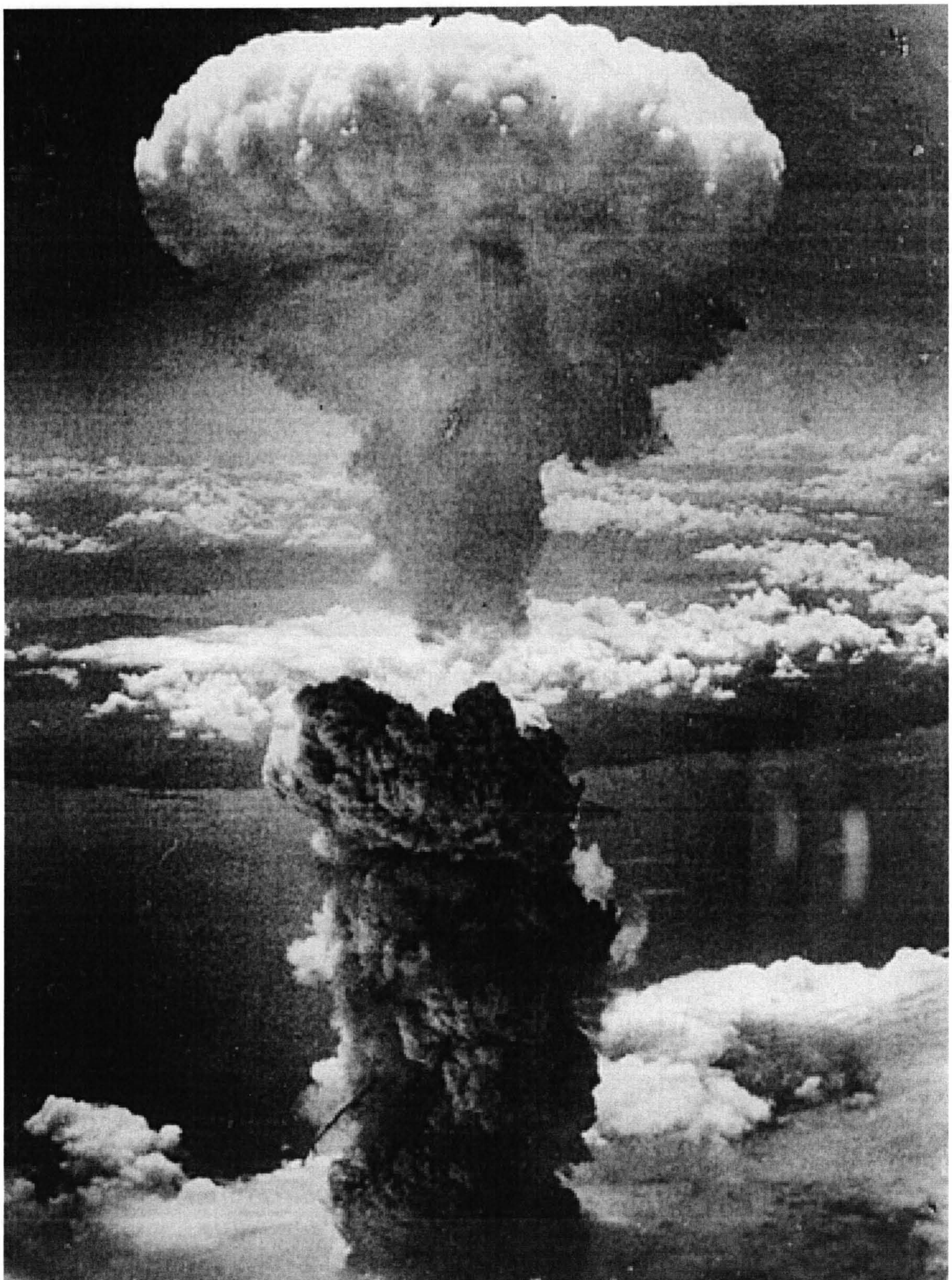
1st Lt. Jacob Beser looks on as Flight Engineer M/Sgt. John D. Kuharek performs his pre-flight checks on *Bockscar* before the mission. (USAF)

Assistant Flight Engineer Sgt. Raymond G. Gallagher checking fuel tank levels in *Bockscar* before takeoff. (USAF)

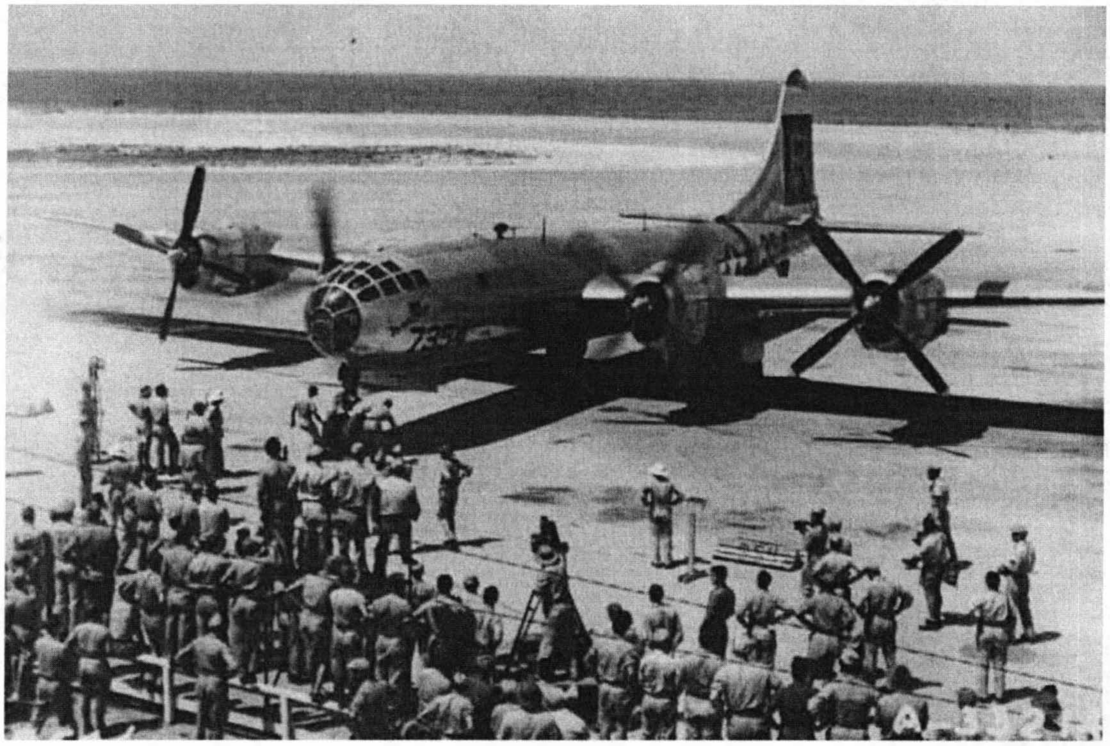


Bockscar Co-Pilot 1st Lt. Charles D. Albury (l) confers with USAAF Intelligence Officer Captain Irwin (r) before take off. Maj. Charles W. Sweeney is seen standing next to Albury. (USAF)

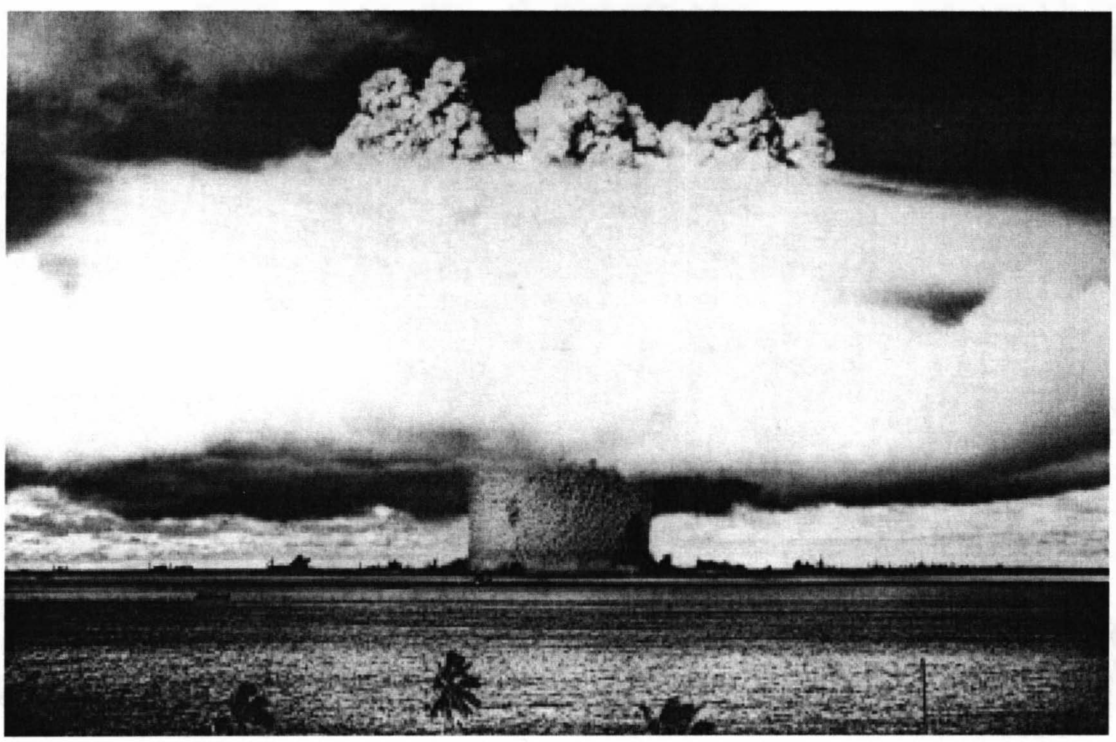
Cdr. Frederick L. Ashworth USN in his TBF-1 Avenger on Guadalcanal in May 1943. (USN)



The now familiar mushroom-shaped cloud over Nagasaki. (USAF)



Dave's Dream before takeoff during the ABLE test of Operation CROSSROADS. (USAF)



Mushroom cloud from BAKER underwater test during Operation CROSSROADS. (LANL)

Documents

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UNCLASSIFIED

[redacted]

A-84-019
41-17
321961

6 July 1944

E. McMillan

F. G. Stroke

Meeting - 5 July 1944 - 3" Target Program

PUBLICLY RELEASABLE
LANL Classification Group

VERIFIED UNCLASSIFIED

The following program has been outlined for the initial work on alloy steel targets:

Diameter of targets - 18 inches
Alloy steel --------- SAE 4340
Details of Design----furnished by Mr. Serduke.

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
FEB 5, 1981

1. **Target Design.**

The following types are to be fired:

Type A - single case - Blind
Type B - single case and one sleeve - Blind
*Type C - open target, single or multiple sleeves with independent rear plug
*Type C may have many modifications, particularly with respect to axial absorbing mechanisms at the rear of the target.

2. **Liners.**

The simple cylindrical type of liner (substitutional tamper) of alloy steel (K-46) is to be used in all of the above designs.

3. **Projectiles.**

a. One series (types A, B, C) shall be fired using copper projectiles with hardened alloy steel backs.

b. Subsequent series to be fired using tuballoy projectiles.

4. **Future Considerations.**

Programs for the future will consider the use of tungsten carbide liners, tuballoy projectiles, and initiators.

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

BEST COPY AVAILABLE

F. G. STROKE

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FGS/evb

Classification changed to ...
by authority of ...
Per ... 4/14/54
(Person authorizing change in classification) (Date)
By Pat McAndrew 11/12/54
(Date)

cc - Capt. Parsons, Critchfield, Wood, Langer, Serduke, file, Cline, C. S. Smith, Kehl, Hirsh, Runyan

[redacted]

UNCLASSIFIED

This report describes components used in the testing of the unsuccessful "Thin Man" plutonium gun program. It mentions the K-46 cylindrical liner that was also used in the later LB design along with the 4340 alloy used for the target case. The exact same alloy was used for the LB target cases. (LANL)

SECRET

2/17/45

To: Comm. F. Birch — 6
N. F. Ramsey — 7

From: Marshall G. Holloway

Subject: Nuclear Safety Tests on Gun Model

It is proposed that G-1 make measurements with large amounts of 25 metal in the hope that these experiments would lead to a better prediction of the performance of the gun model and perhaps lead to some improvement in design of the shapes of the assembly of active material.

It is further proposed that in addition to the above measurements, tests be made which will give to the groups assembling and delivering the gadget some knowledge of the gadgets probable nuclear behavior resulting from any manipulation or accidents which might occur from the beginning of assembly to the time the gadget is delivered to enemy territory. This can be done only to the extent that the conditions of assembly and handling, and of the nature of accidents can be predicted. Discussions with Comm. F. Birch and Mr. A. Folich have brought forth some specific suggestions as to the kind of manipulations and accidents one might expect in connection with the gun. These are listed below together with the test it is proposed be done.

A—During shipment to advanced base:

Two plans of shipping have been suggested as possible. a) One of these would have the active material loaded into both the gun and target, but with the gun and target separate. Each part would be shipped to the advanced base separately and there joined to form a gadget. b) The other would have the complete gun and target assembly shipped without any active material. The active material would be transported separately and inserted into the gun and target at the advanced base.

Comm. F. Birch, in a memorandum to R.F. Bacher, has recommended that plan b) be used if the nuclear properties of the assembly allow. On the assumption that this plan will be used it is proposed that the tests pertinent to the shipment to the advanced base be made on the active material alone with the end in view of ascertaining the necessity and/or usefulness of safety containers. It is very likely that a shipping container which includes appreciable amounts of the enriched B_{10} would make the shipping safe, especially if at least part of the B_{10} were in water soluble form. The tests listed below would be made with and without safety containers. By active material is meant either the target or projectile assembled ready for insertion into the gadget.

1) Many people in close proximity to the active material
Test: Assemble as many people around the active material as possible. Water immersion will probably give upper limit to the danger of assembled people.
2) Active material resting on earth, concrete, thick wood, or thick steel, with perhaps many people around.
Test: Actually rest active material on thick planer of the material in question, assemble people or paraffin equivalents.
3) Complete immersion in
   a) fresh water
   b) salt water
   c) sand, earth, or mud
   d) fuel oil
   e) combinations of above

-1-

Test: With the exception of fuel oil, completely immerse active material in the medium in question. The medium should be essentially infinite on all sides of the active material. A water or paraffin tamper should be a satisfactory substitute for the fuel oil test.

There is an additional hazard connected with long immersions in water or water-bearing solids in that chemical action may disperse the 25 to the extent of making a water boiler. Recovery of the active material under such circumstances might be difficult. It is not proposed that the projectile or target pieces be actually immersed for long times, but rather that the C-M division be asked for information concerning the corrosion of 25 metal in water, both salt and fresh.

4) Fire. There is the possibility that intense heat arising from a fire might ignite the 25 metal and make of it a diffuse mass which would support a nuclear chain reaction. This might be particularly bad if the oxide were mixed with water by fire fighting crews.
Test: No feasible test seems possible at the moment. However, further thought will be given to this problem, with perhaps some help from the T and C-M divisions. Any information concerning this may be of importance in determining the extent to which precautions should be taken against fire hazard. In particular, a container of B_{10} might well eliminate trouble from this hazard as the B_{10} would mix with the oxide and inhibit any chain reaction.

B) Assembling of Active Parts

About one and a half crits will be used for the experiments that will be more directly connected with the physics of the nuclear explosion than the tests made on the gun assembly itself. These experiments will give experience in handling the 25 metal so that a definite plan of assembling the metal can be made.

a) Assembly of 25 metal into target piece and projectile piece. This can be done under laboratory conditions and the safety of the assembly tested as under A, above.

b) Insertion of target and projectile pieces into gun. This must be done under whatever conditions exist at the advanced base. In order that G-1 be able to devise and test a workable method of inserting the active pieces into the gun, close coordination must exist between G-1 and those groupe concerned with the delivery of the gadget. At this time G-1 is ignorant of the problem to be encountered in loading the gadget with active material under field conditions. Information concerning this is requested.

C) During delivery from the advanced base to enemy territory and possible return with the gadget.

In this phase the results of accidents would be much the same, from the viewpoint of the nuclear behavior, as in part A. An accident to the delivering vehicle or jettisoning of the gadget might result in its being immersed in the various media mentioned. The handling of the completely assembled gadget would lead to conditions described under 1) and 2) of A.

By "mock-up" is meant an assembly of steel, carbide and active material as near like the actual gun as possible.

1) Many people in close proximity to gadget, as during loading.
<u>Test:</u> Assemble as many people around mock-up of gun barrel as possible; same for target mock-up.

2) Gadget resting on earth, concrete, thick wood, or thick steel, with perhaps many people around.
<u>Test:</u> Actually rest mock-up of gun barrel on material in question, assemble people or paraffin equivalents; same for target mock-up.

3) Proximity of large tools, such as hoist sling, dolly, spanner wrenches , etc.
<u>Test:</u> Find out, if possible, the amount of steel which must be placed around mock-up of gun barrel to make it unsafe; same for target mock-up. In any event, ascertain safety of large pieces of steel close to mock-ups.

4) Complete immersion in

a) fresh water
b) salt wat r
c) sand, earth, or mud
d) combinations of above

<u>Test:</u> Complete immersion of gun barrel mock-up in medium in question. The remarks under A-3) apply. Same for target mock-up.

5) Fire. The comments under A-4) apply. There is the additional hazard of having <u>both</u> target and projectile oxidized and <u>mixed</u>.

6) Target or projectile coming loose. Since war is a violent business it is possible that either the target or projectile might be torn loose from its fastenings. If interest in this connection is the critical separation of the target and projectile, since this information might allow the design to include some safety device.

The critical separation is also of interest to the problem of predetonation.

<u>Test:</u> With finished 25 metal gun parts, measure critical separation in mock-up or finished gun, preferably the latter.

This memorandum is intended to give in some detail the work which G-1 proposes to carry out in connection with the problems of assembling and delivering the gun model gadget. Undoubtedly some possibilities have been overlooked and others over emphasized, since G-1 is not at all familiar with the problems of assembly and delivery. Comments and suggestions are sincerely requested.

cc/ Oppenheimer —1
Parsons — 2
Allison — 3
Bacher — 4
Frisch — 5

2197 1018

Admin Files, Gen Corres, 319.1 (Reports) (TS), Rpt, Dr. J. B. Conant to Gen Groves, On Visit to Los Alamos on August 17, 1944.

Bomb Design and Testing

Report to Gen.Groves on Visit to Los Alamos on August 17, 1944

1. The latest values for critical size are as follows defining a "crit" as the critical size for a fast neutron chain in the most favorable tamper:

"25"	13 ± 2 kg.	"49"	4.5 kg.	limits of uncertainty not set but probably less than with "25"

2. The development of Mark I bomb (the "25" gun) seems well in hand. I was impressed with the stage of development and the very high chances for success but above all with the fact that every aspect of the weapon except the final nuclear reaction can be tested and retested in advance using straight tube alloy in the dummy. Present estimates are that for 10,000 - 20,000 tons TNT equivalent 3-4 crits of "25" will be required. This means 39-60 kilos of "25" (as effective product). Less than 3 crits, it is predicted will give very much less than 10,000 tons equivalent, the energy falling off rapidly as the amount is lowered below 3 crits. There are clearly uncertainties still here as to amounts which would affect the use of this weapon considerably in view of the production schedule. If the future "breaks" are in the right direction the low figure 39 kilos might prove right. The value of the critical mass will be determined by direct experiment it is hoped long before enough material is on hand for the gun. In fact as little as half a crit may be sufficient for this very important measurement.

3. The second possible weapon we might designate Mark II. It would consist of an implosion bomb with the sort of detonation now available (no explosive lenses), the center filled with hydrogen and either the metal or hydride suspended in the very center. There seems to be a very good chance that such a bomb would give an atomic explosion in spite of the lack of symmetry inherent in the present method of detonating the H.E. The energy release, however, would be very inefficient. The bomb would give 100-500 tons TNT equivalent. It would require 1 crit of "25" and 2 crits of "49." Because of the nuclear properties of "49" this is a peculiarly inefficient way of using "49".

It is agreed that Mark II should be put on the shelf for the present. If all other implosion methods fail, it could be taken off the shelf and developed for combat use in 3 or 4 months time. It represents an almost sure thing which we may have to fall backon for using "49".

4. Mark III bomb would be a "no lens" implosion bomb using no hydrogen. The material would probably be in the center. The x detonation techniques would be essentially as now at hand. The chances that such a bomb will work are probably slim. If it would 1/2 to 2/3 of a crit of "25" or 1 crit of "49" could be employed and yield 1,000-2,000 tons TNT equivalent (or somewhat less for "49"). Various minor changes in explosive technique might make this feasible but there is not too much optimism as to this possibility. When the Ra-La is available and the experiments using this material have been made in sufficient number (perhaps a month) the possibility of doing

something along the line of a practical Mark III bomb can be settled with considerable certainty. <u>If</u> it could be developed with only minor changes the development could be completed by February 1. The estimated date for /1/
the completion of the first round of Ra-La experiments is October 15 provided the material arrives as now scheduled. This appears to be the next significant date on the schedule.

5. Mark IV represents the bomb in which the explosion wave is to be given the correct form by means of explosive lenses. This is a tough problem in the explosive field. If it can be made to work it should produce a very effective bomb, $\frac{1}{2}$ a crit of "25" yielding 3,000 tons TNT equivalent and $\frac{1}{2}$ a crit of "49" - 1,000 tons TNT equivalent. The most optimistic development schedule would have the first bomb ready for the trial shot on February 1. But no one believes this possible. A more likely schedule would put the first shot on April 15; if it can be done at all it should at the worst be ready June 15. "Informal opinion" puts the betting on April 15 as 50:50. My own estimate is less favorable. I think it is not more than a 50:50 bet that Mark IV can be developed at all before the summer of 1945. But every effort must be made to do so and every effort is being made.

I was very favorably impressed by the new organizational set up and the caliber of men now involved. If explosive lenses can be developed inside of a year the present group should do it. Much more information should be available on this point about January 1. If the explosive lens development then looks very bad it may be necessary to work on improving Mark II to see if at least the upper limit of effectiveness (500 tons) cannot be raised somewhat. Until about this date, I think, the feelings about the whole implosion program will rise and fall month by month but no sure conclusions as to ultimate success or failure will be reached.

6. <u>Note on Explosive Damage</u>. It was agreed that Class B damage was damage beyond repair. For the phrase to be of signficance the type of structure must also be named. It was agreed that for <u>dwelling houses</u> the area of Class B damage was about as follows for 1,000 tons TNT:

90% Class B damage equals 0.5 mile radius equals	.75	square mile area
50% Class B damage equals	1.5	square mile area
10% Class B damage equals	7.5	square mile area

For 10,000 tons TNT these figures are to be multiplied by 4.

/s/ J. B. Conant

This document refers to the weapons under consideration a full year before the final designs for each were actually completed. The plutonium gun "Thin Man" design had been abandoned the previous month due to predetonation problems. The Mark II concept was dropped in light of the progress of both the uranium gun and plutonium implosion programs. When this happened, the Mark III "no lens" implosion design mentioned here automatically became the Mark II and the Mark IV became the Mark III which was used at Trinity and Nagasaki. When this memo was written, barely a kilogram of enriched uranium had been produced by Oak Ridge so the actual amount of a "crit" for the uranium gun had yet to be determined with any degree of accuracy. The scientists ended up using a little over four "crits" in the final design. (National Archives/Courtesy of Robert Norris)

A-84-019
1-2

UNCLASSIFIED

3 April 1945

471.6

M. Shapiro

E. Di Sabatino

MODEL NUMBERS AND EXPLANATION OF MODEL NUMBERS

The following is the list of Model numbers of the test units which you requested. A brief explanation of each model number is listed beside the number.

MODEL	DESCRIPTION
1222	Original Fat Man. Cast iron hemisphere construction. (Obsolete)
1560	Ellipsoidal Fat Man. Production model.
1418	Little Boy Dummy. No gun or breech block.
1491	Little Boy Dummy. With gun and breech block.
1721	Little Boy Dummy. Modification of 1491.
1791	Little Boy Dummy. Modification of 1721.
1792) 1793)	Same Models as 1791 with different targets.

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
NOV 3, 1980

E. Di Sabatino

VERIFIED UNCLASSIFIED
NOV - 2 1980
1/2/87

EDS:fs

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(LANL)

A-84-019
41-1

UNCLASSIFIED

315414

16 Apr
W.P.

11 April 1945

O. W. Calloway
F. Birch
Catalogue (Y-1791-1792 Little Boy Assembly)

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

PUBLICLY RELEASABLE
LANL Classification Group

1. Please add on Sheet No. 3, Item No. 40

Part No. Y-1904 Lug Assembly - 1 required per box, consisting of

1 - Lug Y-1904-1

1 - Insert Y-1904-2

2 - Soc.Hd.Screws #8-36 x 3/8

2. We understand these lugs are being procured in sufficient quantities and will be available at W-47.

F. Birch

cc: Lockridge
Ramsey
Parsons ✓
File

2225U902

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
FEB 4, 1981

VERIFIED UNCLASSIFIED
AUG 06 1997

UNCLASSIFIED [redacted]

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

(LANL)

[redacted] UNCLASSIFIED THIS DOCUMENT CONSISTS OF 1 PAGE(S)

INTER-OFFICE MEMORANDUM NO. 1 OF 6 COPIES, SERIES A

DATE 17 July 1945

TO: Captain W. S. Parsons

FROM: F. Birch

SUBJECT: Vent Seals for LB

CLASSIFICATION CANCELLED PER DOC REVIEW JAN. 1973

315411

PUBLICLY RELEASABLE LANL Classification Group

1. Static immersion tests performed on modified vent seals indicate satisfactory performance. Without facilities for recovering units dropped into water, however, there can be no assurance that the seals will be tight after impact; and there remains the possibility that a leak may by-pass the seals through the interrupted threads of the adapter.

2. It is my intention to install these seals, but I would not wish to rely upon them alone to safeguard the unit in case of accidental impact on water.

F. Birch

F. Birch

cc: Oppenheimer
Ramsey
G. Fowler
File - 2

FINAL DETERMINATION UNCLASSIFIED L. M. Redman FEB 4, 1981

2225 : 0954

VERIFIED UNCLASSIFIED AUG 06 1997

CLASSIFICATION CANCELLED PER DOC REVIEW JAN. 1973

Form 25

UNCLASSIFIED

The "interrupted threads of the adapter" referred to in this document are the vent slots that had been machined along the sides of the adapter. These vent slots were cut through the Acme threads around the perimeter of the adapter where it screwed into the aft end of the target case. (LANL)

25 May 1945

Captain W. S. Parsons

F. Birch

Breech removal, etc.

1. Without some modifications, it is exceedingly difficult, if not impossible, for one man to remove the complete breech plug assembly in flight. Two men can probably accomplish the removal with present equipment. With the construction of special tools, and a slight modification of the present breech plug, the removal can be done by one man, after a little practice. A time of perhaps 15 to 30 minutes should be allowed for the operation. In addition to special tools which we shall supply, it is very desirable if not absolutely necessary, to have the platform which I have requested Mr. Dike to supply. This platform should be available for trial during the June test period. The required tools, exclusive of the platform, will weigh about 50 pounds.

2. An alternative to this plan, which we are also developing, is the construction of a special breech plug, from which an inner plug of about 4" diameter, can be unscrewed. This inner plug would contain the 3 primers, and weigh about 15-20 pounds. With this plug it would be possible to load or to unload in flight with confidence. Loading could of course be accomplished on the ground in the usual manner. Special tools and a platform are also required for this operation.

F. Birch

cc: Oppenheimer ✓
Ramsey
File

THIS DOCUMENT CONSISTS OF 2 PAGE(S)
NO. 2 OF 6 COPIES, SERIES A

17 July 1945

PL 4-3-87

Captain W. S. Parsons

F. Birch

Considerations affecting use of impact switch for LB.

1. Status of tests.

No test has been made of a complete installation combining Archies and the impact switch. A high altitude drop (T 138) into water gave no indication either of performance or non-performance; on a high altitude drop on land (T 141) no puff was o served and one of the smoke puffs was recovered unfired. On a drop (T 140) from 5000 feet on land, the smoke puffs did not fire; it is not yet known whether the projectile seated. The switch functioned and fired a smoke puff in a drop on land from 650 feet, (T 152) which did not move the projectile.

2. Installation.

Several methods of connecting the impact switch are conceivable:

A. The switch by-passes the Archies, but is armed by the regular clock-box. This requires a release altitude of >3600 feet for arming (15 sec.).

B. The switch by-passes Archies and clock-box; arming is by pullout wires alone.

C. The switch has an independent battery, line, arming wire and primer.

In either case A or B, there seem to be possibilities that trouble in the switch circuit may influence the behavior of the Archies, and vice versa. Case C sacrifices some of the security of normal operation by preempting 1 primer for an improbable use.

3. Region of usefulness:

The switch appears to be of value only in the following combination of circumstances:

A. A target is reached;

B. The bomb is released at an altitude of less than some 13000 feet over water or less than 6000 feet over land; and

C. Normal firing fails, for reasons which do not impair action of the impact switch.

Under these conditions, the impact switch may prevent delivering a dud, but almost certainly at the cost of the plane and crew. If proper altitude cannot be reached, the circumstances should be known well in advance of arrival at a target, and a return to the nearest base would seem to be indicated rather than continuation to a suicidal mission. In other words, the combination A & B should not occur; that it should occur with C seems extremely remote. If release is from higher than 15,000 to 20,000 feet, the impact switch is almost certainly unnecessary, as well as useless: the projectile will seat before firing can take place.

4. Recommendation.

In my opinion, since the usefulness of this switch is limited to remote contingencies, and since its presence can scarcely fail to affect the normal fuse functioning adversely to some degree, the impact switch should be omitted from the LB.

F. Birch

cc: Oppenheimer
Ramsey
Brode
File - 2

P. O. BOX 1663,
SANTA FE, NEW MEXICO

110935

[redacted]

23 July 1945

MEMORANDUM FOR Brigadier General T. F. Farrell
and
Captain W. S. Parsons, USN

It may be helpful for you to have a few notes covering some points in the initial combat operations:

1. As a result of the Trinity shot we are led to expect a very similar performance from the first Little Boy and the first plutonium Fat Man. The energy release of both of these units should lie in the range of 12,000 to 20,000 tons, and the blast should be equivalent to that from 8,000 to 15,000 tons of TNT. It will take a long time to obtain and analyse the relevant information from Trinity. Any changes in the anticipations here indicated will be communicated to you at once. It is of the utmost importance that blast measurements be made during combat delivery to confirm or disprove these anticipations.

2. Tentative fuse settings have been established to fire the units at points 1850 feet above terrain. It is possible that further Trinity information may cause us to revise these firing heights. It is essential that the nature of the target be taken into account in determining these firing heights. The figures given above are appropriate for the maximum demolition of light structures. Should the target include important heavy structions, the fusing heights should be revised downward. It is suggested that Drs. Ramsay, Penney, and Serber be consulted on this matter and that, if at all possible, the problem be referred back to Site Y.

3. With such high firing heights it is not expected that radioactive contamination will reach the ground. The Ball of Fire should have a brilliance which should persist longer than at Trinity, since no dust should be mixed with it. In general, the visible light emitted by the units should be even more spectacular. Lethal radiation will, of course, reach the ground from the bomb itself. The minimum height of firing for which these conditions are likely to prevail is 1,000 feet above terrain.

C
O
P [redacted]

[redacted]

4. The possibilities of a less than optimal performance of the Little Boy are quite small and should be ignored. The possibility that the first combat plutonium Fat Man will give a less than optimal performance is about twelve percent. There is about a six percent chance that the energy release will be under five thousand tons, and about a two percent chance that it will be under one thousand tons. It should not be much less than one thousand tons unless there is an actual malfunctioning of some of the components.

5. It is probably not desirable to attempt at Defo mation to establish, on a statistical basis, the reliability of Fat Man Components. On the other hand, it is desirable to subject the components scheduled for hot use to inspection and testing with the greatest care. It is suggested, and requested, that if the tests of Fat Man components appear to involve a delay beyond the scheduled date in readiness to deliver this unit full information be transmitted to Site Y in order that we may assist in every way possible in clearing the matters up.

6. Good luck.

/s/
J. R. Oppenheimer

atw

Serial number: 1.054

Distribution:
1 A - General Farrell
2 A— Captain Parsons
3 A - General Groves
4 A - Oppenheimer's files
5 A - Oppenheimer's files

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C O P Y

(LANL)

20 — CG Pac — Hickam
Info — ~~Wendcorst~~ Hamilton — (Houghton)
— Kirtland C.O.
— West Coast Wing, S.F.

Call de Silva — NQATC # 1537 7/25
TS wire — sent to Albu sepa
Cum - nt 1538 -
Inst. on C-54
Ref C.O. @ Kirtland & Brief

TOP SECRET

2, C-54's — ETD 0900 7/26/45, Albuquerque
OIC — Lt. Col. Peer de Silva
2nd Lieut. Robert A. Taylor, Jr. } couriers
Mr. Raemer E. Schrieber
Require 3 Cargo parachutes, Type G-1, per plane
(X) 1, C-54 will carry the cargo of —
1 suitcase, wt. approx 100#
1 small box wt. approx 30#
(X) 1, C-54 will accompany and probably be empty.
Col. de Silva + Mr. Schrieber will ride with the Cargo, Lt. Taylor will ride in the other plane.
Each person will have 65# personal baggage.

3, C-54's — ETD 0900 7/27/45, Albuquerque
OIC — Maj. Claude C. Pierce, Jr.
2nd Lieut. William A. King } couriers
1st Lieut. Nicholas del Genio
Commander A. F. Birch, USNR
Require 3 Cargo parachutes, Type G-1, per plane
All, C-54's will carry cargo.
(X) 1, C-54 will carry — 1 box, wt. 60#
1 box, wt. 120#
Maj. Pierce + Cmdr Birch will ride in this plane.
(X) 1, C-54 will carry 1 box, wt. 60#
Lt. King will ride on plane
(X) 1, C-54 will carry 1 box wt. 60#
Lt. del Genio will ride in plane
Each person will have 65# personal baggage

Brass, Rogers 71460, 71329
Col. ... 73904

TOP SECRET

~~Monday~~ Col. Johnson TOP SECRET

(8/9 copies letter)

~~Col Ray W. Ireland, Gravelly Pt Rm. 1942~~
X 73904

(300)

The 270 lbs. package will leave Site Y @
0800 on 14 July, accompanied by
Major Furman + Capt. Nolan. ATC will
pick up package at Kirtland Field
for delivery to Capt. King @ San Francisco.
(ETA of package at Albu. is 1200-1300).
Should be loaded on ship 15 or 16 July.
No specialized technical personnel needed.
Also scheduled for ship is an inert
package weighing 10,000 lbs., size
138" x 44" x 47"; King will deliver this
package to ship.

(26)

On 25 July (24 July - 28 July) next
material shipment ready from Y.
Need 2 C-54's @ Kirtland. First
will carry main package, second
will carry accessories plus ~~probably~~
~~at least one + probably two civilians~~
~~plus 2 tech. [illegible]~~ not more than 4 persons.
Cannot send both lots in one C-54.
This shipment goes to destination.
~~[illegible] ATC ships~~
~~[illegible] (24 July - 28 July) will~~
(28)
~~[illegible]~~

TOP SECRET

(27)

3. On 28 July (24 July - 28 July) next
shipment goes from Y + Kirtland. Either
2 or 3 C-54's will be required. Cmdr. Birch
and one other will go along. (ATC ships)?

These two pages detail shipments of the combat *Little Boy* and *Fat Man* critical components to Tinian by both C-54 airplanes and the *Indianapolis*. This includes both the *Little Boy* uranium and *Fat Man* plutonium components along with the names of the scientists and security couriers. (National Archives/Courtesy of Steve Bice)

.AVE

ER TO FILE No

TOP SECRET

WAR DEPARTMENT

P. O. Box 2610

WASHINGTON, D. C. THIS DOCUMENT CONSISTS OF 1

NO. 2 17 August 1945. OF 3 SERIES A

MEMORANDUM FOR: Admiral W. S. De Lany

Subject: Transportation of Critical Shipments.

The U.S.S. Indianapolis departed from San Francisco on 16 July 1945 after picking up the following project cargo at Hunters Point:

a. 1 box, wt. about 300 lbs, containing projectile assembly of active material for the gun type bomb.

b. 1 box, wt. about 300 lbs, containing special tools and scientific instruments.

c. 1 box, wt. about 10,000 lbs, containing the inert parts for a complete gun type bomb.

The Indianapolis arrived at Tinian Harbor, Marianas on 28 July and discharged the project cargo wit out mishap.

3 ATC C-54 airplanes departed from Kirtland Field, Albuquerque, New Mexico, at 1510Z 26 July, with each airplane carrying equal segments of the target assembly of active material for the gun type bomb. The airplanes arrived at Tinian on 28 July (about 48 hours lapsed time) and discharged project cargo without mishap.

2 ATC C-54 airplanes also departed from Kirtland Field at 1510Z 26 July and carried the sphere of active material and initiator for the implosion type bomb. The airplanes arrived at Tinian on 28 July and discharged project cargo safely.

3 B-29 specially modified bombers departed from Kirtland Field at 1250Z 28 July and carried 3 HE preassemblies of the implosion type bomb encased in the outer shell. All 3 B-29's arrived at Tinian at 0230Z 2 August and discharged project cargo safely.

J. A. DERRY,
Major, C.E.

(LANL)

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21 August 1945

Lt. Col. Lockridge

F. Birch

Disposition of Material, etc.

CLASSIFICATION CANCELLED
PER DOC REVIEW JA...

LB

1. As nearly as I can make out, it is desired to store all LB units temporarily at W-47, or later at Sandia, when facilities become available there. This includes units L12 and L13, (Batch 5) which were held at 627A, and also units L3, L4, L7, L8, L9 and L10 which have been delivered to Destination. I do not know that there is any requirement for speed in returning these units.

F. Birch

A-84-019
17-5

cc: Oppenheimer
Larkin
Zacharias
File

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
NOV 3, 1980

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PER DOC REVIEW JAN. 1973

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(LANL)

Table 3.4. Beta Calutron Operations June 24, 1944— May 4, 1947.

Beta Cycle Production Period	Alpha Cycle Product		UF_6 from K-25		UCL_4 Vaporized	Salvage to K-25		R Pocket Enriched Product		Q Pocket Depleted Tails	
	kg U	% U_{235}	kg U	% U_{235}	kgU	kg U	% U_{235}	kg U	% U_{235}	kg U	% U_{235}
06/24/44—08/04/44	27.69				75.08			1.12		4.96	
08/04/44—08/14/44	4.33				26.55			0.34		1.52	
08/14/44—08/28/44	7.70				24.24			0.28		1.26	
08/28/44—09/11/44	10.32				41.87			0.14		2.59	
09/11/44—09/25/44	8.64				57.65			0.46		3.26	
09/25/44—10/23/44	21.35				144.09			1.19		6.33	
10/23/44—11/06/44	14.94				104.12			1.00		7.39	
11/06/44—11/20/44	17.38				135.72			1.27		10.00	
11/20/44—12/04/44	30.18				159.38			1.60		12.36	
12/04/44—12/16/44	23.70				164.66			1.75		13.76	
12/16/44—12/31/44	34.11	10.98			220.81			3.26	73.04†	16.16	0.58†
12/31/44—01/14/45	32.70	10.75			212.30			3.26	79.37	22.84	0.37
01/14/45—01/27/45	35.31	10.17			229.44			3.29	80.63	23.53	0.30
01/27/45—02/11/45	34.86	10.30			217.82			3.41	81.14	24.67	0.30
02/11/45—02/25/45	34.69	9.94			210.30			3.22	82.59	24.81	0.30
02/25/45—03/11/45	33.99	10.02			223.51			3.67	82.10	28.19	0.30
03/11/45—03/25/45	33.38	9.82			225.32			3.58	82.75	26.89	0.30
03/25/45—03/07/45	33.22	9.72			219.55			3.26	82.51	24.41	0.30
03/07/45—04/21/45	33.35	10.06			208.46			3.12	83.53	23.98	0.29
04/21/45—05/19/45	70.80	10.47			410.32			6.02	86.53	47.73	0.22
05/19/45—06/02/45	39.17	11.78			202.10			3.11	88.38	24.07	0.17
06/02/45—06/16/45	32.60	12.09			265.23			4.05	87.32	31.72	0.16
06/16/45—07/28/45	114.41	11.92	259.95	18.05	1,727.65	117.39	7.75	22.26	65.01	183.63	0.17
07/28/45—08/11/45	32.76	13.04	66.80	22.73	506.52	17.69	9.11	7.74	65.69	56.40	0.19
08/11/45—09/08/45	62.89	13.62	304.31	23.57	583.14	138.70	12.02	22.11	91.56	92.74	0.32
09/08/45—09/22/45	24.14	12.19	180.46	23.90	523.78	71.45	13.46	14.81	93.00	50.28	0.37
09/22/45—10/06/45	6.81	16.15	189.71	23.76	514.92	21.97	17.64	16.07	92.39	55.33	0.37
10/06/45—10/21/45			144.47	23.69	529.45	38.66	22.69	14.49	93.55	48.07	0.38
10/21/45—11/04/45			98.28	25.65	584.32	2.68	15.51	16.52	93.26	54.35	0.38
11/04/45—11/18/45	0.11		98.99	29.34	556.80	0.89	13.71	18.26	94.06	57.47	0.38
11/18/45—12/02/45			103.44	29.81	644.40			21.23	94.42	63.05	0.38
12/02/45—12/16/45			114.40	28.15	699.43			24.20	94.44	71.34	0.38
12/16/45—12/30/45			115.89	27.59	754.08			28.25	94.67	70.54	0.45
12/30/45—01/13/46			111.92	28.65	753.92			29.52	95.03	70.50	0.45
01/13/46—01/27/46			110.57	27.95	743.63			31.00	95.20	78.58	0.45
01/27/46—02/10/46			78.84	28.17	751.23	0.04	35.71	32.06	95.13	80.56	0.45
02/10/46—02/24/46			128.81	27.25	790.61			32.29	95.19	84.03	0.55
02/24/46—03/10/46			173.63	27.58	783.04			32.71	95.21	84.63	0.55
03/10/46—03/24/46			162.73	27.31	774.90	61.09	29.84	32.98	95.19	86.00	0.55
03/24/46—04/07/46			196.21	26.97	771.84	41.59	22.49	32.92	95.21	86.12	0.55
04/07/46—04/21/46			148.43	29.44	777.14	13.00	13.16	33.33	95.41	87.97	0.54
04/21/46—05/05/46			164.57	29.77	767.83	29.01	27.34	33.01	95.00	87.44	0.54
05/05/46—05/19/46			167.84	29.87	747.35	58.36	28.66	33.49	95.20	85.15	0.50
05/19/46—06/02/46			147.78	30.07	760.65	9.57	22.66	34.40	95.40	84.76	0.50
06/02/46—06/16/46			122.62	29.93	758.59	3.65	12.69	34.67	95.21	82.90	0.50
06/16/46—06/30/46			105.43	30.02	765.30			34.53	94.97	79.59	0.60
06/30/46—07/14/46			62.65	29.88	750.79			34.27	94.91	77.92	0.60
07/14/46—07/28/46			76.12	29.81	753.50			34.59	94.90	78.49	0.65
07/28/46—08/11/46			128.76	29.82	758.01			34.75	94.74	78.64	0.69
08/11/46—08/25/46			129.78	29.71	773.58			36.63	94.71	82.97	0.70
08/25/46—09/08/46			131.39	29.89	768.33			37.46	95.03	82.87	0.70
09/08/46—09/22/46			130.73	29.90	760.32			37.34	94.82	82.75	0.64
09/22/46—10/06/46			128.66	29.76	761.04			37.54	94.72	83.03	0.69
10/06/46—10/20/46			120.01	29.64	764.23			38.29	94.88	84.81	0.67
10/20/46—11/03/46			64.19	29.97	601.79			30.30	94.87	67.39	0.67
11/03/46—11/17/46			0.15	29.80	459.44			22.98	94.58	51.06	0.59
11/17/46—12/01/46					511.53			24.91	95.13	54.41	0.62
12/01/46—12/15/46			89.73	29.97	519.00			26.19	94.82	57.31	0.61

This table shows the U-235 output from the Oak Ridge Calutrons that produced the uranium for *Little Boy*. The column on the right headed "R Pocket Enriched Production" shows the actual quantity and final enrichment rate of each batch of weapon-grade uranium produced at Oak Ridge that was then sent on to Los Alamos to be fabricated into the *Little Boy* projectile and target pieces. The total amount produced by 7/28/45 was 74.68 kg with an average enrichment rate of 82.68% U-235. *Little Boy* used 64.15 kg of U-235. (ORNL/Courtesy of Robert Norris)

PART 1 [redacted] KIT Long Bomb Assembly, Light & Heavy, Special

KITS DESTINATION 5
KITS SPARES 3

Birch EQUIPMENT

ITEM NO.	CODE NO.	DESCRIPTION	RQT. NO.	UNIT OF QUAN	QUAN PER KIT	QUAN FOR DEST	QUAN FOR SPARES	TOTAL QUAN	APPROX WT EACH	SHIPPING DATA			ORG. EQUIP. QUAN.
										DATE	QUAN	MARKING	
88.	20088	Wrench-Breech	special	No.	1	6	3	9					6
89.	20089	Wrench-Primer Holder	special	No.	2	12	6	18					18
90.	20090	Loading tray and platform	special	No.	1	6	3	9					8 Short 1 Tray
91.	20092	Primer Testing Sets	MR-90	No.	1	6	3	9					6
92.	20093	Lengths ~~wire-armored~~ -	19136	No.	9	54	27	81			54		[illegible]
93.	20094	Rammer-Projectile	special	No.	1	6	3	9					9
94.	20095	Flashlights - 2 cell	19137	No.	3	18	9	27			~~18~~		27
95.	20096	Batteries for above.	19137	No.	18	108	54	162			~~108~~		162
96.	20097	50' lengths, ½" rope, Sisal	19137	No.	1	6	3	9			6		
97.	20098	Front Nut Handling Plate	special	No.	1	6	4	10					10

PART 1 [redacted] KIT Long Bomb Assembly, Light & Heavy, Special

KITS DESTINATION 6
KITS SPARES 3

Birch EQUIPMENT

ITEM NO.	CODE NO.	DESCRIPTION	RQT NO.	UNIT OF QUAN	UNIT PER KIT	QUAN FOR DEST	QUAN FOR SPARES	TOTAL QUAN	APPROX WT EACH	SHIPPING DATA			ORG. EQUIP. QUAN.
										DATE	QUAN	MARKING	
98	20099	15" Adjustable Wrenches	19139	No.	1	6	3	9					9
99	20100	10" Adjustable Wrenches	19139	No.	1	6	3	9					9
100	20101	Wrench-contact pin	special	No.	1	6	3	9					9
101	20102	2 x 8½ threaded bolts handling nose nut	special	No.	2	12	8	20					18
102	20103	1½" x 6 nuts for 2" x 8½" bolts	special	No.	2	12	8	20					18
103	20104	Wooden Loading Tray Adapters	special	No.	1	6	3	9					9

These are two pages from the January 30, 1947, 265 page LAMS-506 Catalog: Kit Equipment, which was a partial list of the thousands of pieces of equipment used at Tinian in July and August, 1945. It lists the "special" items for *Little Boy* such as the Breech Wrenches, Primer Holder Wrenches, Projectile Rammer, Front Nut Handling Plate, (Primer?) Contact Pin Wrench, and the threaded bolts and nuts used to remove the large nose nut. (LANL)

GENERAL SUBJECT	PERIOD COVERED	
Bomb Design and Testing	FROM (Date)	TO (Date)

SOURCE OCG Files, Gen Corres (MP) Files, Folder 16, Tab XXVIII, 213, 2 A, (S) Report of Gun Assembled Nuclear Bomb, dated 6 Oct 1945, written by A.F. Birch, 82 pp.

Part I , a summary statement of progress to 7 May 1945 Component tests
p. 4. A total of 32 Type B 6.5" guns are on order of which 18 have been delivered, and 10 have been proof fired. 43 rounds have been fired with these guns. No failure of any sort has occurred in the guns.
Targets
p. 5 Fourteen target shots have been made at full scale.... The 24" target broke up, and of the 28" targets only two did not fail in some respect. One was still intact afte 4 shots. In no case , however, was the assembly of the tuballoy parts affected by the rupture of any part of the target.
Projectile and Inserts
p. 6 The projectile consists of rings of tuballoy, a disc of carbide and a steel back, assembled in a steel can of 1/16" wall thickness. The original design contemplated a nearly equal division of the activ material between projectile and target insert. Later 60%vo f active material on the projectile, 40% in the targte
Drop tests
p. 9 Up to the end of April there had been dropped 12 1418 units, 6 1491 units, and 6 1792 units. The 1418 units were constructed of pipe, lead weight and sheet metal and their behavior was somewhat erratic. Some models were tail heavy others nose heavy.

OCS FORM 669 1 MAY 54 — EDITION OF 1 JUL 53 WILL BE USED UNTIL EXHAUSTED. — RESEARCHERS BRIEF — E61020

DECLASSIFIED
Authority NND 903075
By ______ NARA, Date ______

This series of five Researchers Brief cards give brief descriptions of *Little Boy* reports. (National Archives/Courtesy of Chuck Hansen)

Rep on Gun assembly 2

Table I, p. 11 ✗ 6.5" Guns. Firing started on 1 Dec 44, 4 shots in Dec, 8 shots in Jan, 12 shots in Feb, 6 shots in Mar., 12 shots in Apr, 1 shot to 2 May.

Part II, form May to end of project.
p. 20 During May , Jun, Jul., there were 40 proof shots of all types at Anchor, 28 drop tests at Kingman and other points in this country, and 4 drop tests at Destination. For the greater part these were etests of a unit which by that time was well standardized. A few new details of minor impert were introduced. The final Hiroshima unit was essentially identical with the units tested during this period.

Guns

p. 20 Since May 14 more guns have been proof-fired and stocked. No failures occurred. Difficulties with breech block threads continued. [in earlier tests the breech blocks had a tendency to stick, because the threads were too finely machined] Partly to eliminate this and partly to provide a means of eliminating the danger of take off accidents with a loaded gadget, a new breech plug was designed and tested, and used on the Hireshima unit.

Drop Tests

p. 22 During May Jun and Jul 11 normal drops were accomplished, with full charge and firing by normal 0-3 equipment. All 11 had tuballo projectiles and inserts, and 10 of the inner assmeblies were recovered for examination. The other fell on wet ground and could not be recovered.
23 a total of 34 fuse tests were made with falling units.
in additien 4 practice dreps were carried out at Destination with the units L1, L2, L5 and L 16.

Rep on Gun assembly 3

all except L 5 were fired in the air, L 5 was fitted with 4 Archies and allowed to fall without firing for the purpose of obtaining all four informer records. These were all satisfactory

Details concerning the Hiroshima Unit

24 the unit used for combat delivery was known as "L 11". It included Gun #27 (fired on Rd. 303A) , Rear Assembly # 41, and the 2-piece target C-O known as "Old Faithful". This target had been proof-tested in Rounds 42B, 45B, 271 A and 285 A (16 Dec 44, 18 Jan 45, 6 Feb, 15 Mar), with no sign of damage to the case. Overall length of the assmebled projectile was 161/4 inches. L 11 was shipped in the heavy cruiser Indianapolis along with the active projectile, and arrived at Destination in perfect condition. No difficulty was experienced in any of the operations of loading and final assembly.

24 The projectile contained 9 rings of active material, total weight 38,531.12 grmas.

p. 25 The insert contained 6 rings of active material and a total weight of 25, 616.44 grams

p. 26 The projectile was loaded on 30 Jul in the usual manner and rammed home. The same day the insert was loaded, initiators installed, and the anvil and nose nut assmbled. The active insert assembly was secured with a lock nut. No further handling of these parts was nec.

On 31 Jul the Archies, clock box, baros and firing lines were installed and checked by 0-3 personnel. atteries were not installed until 4 Aug , when it seemed that loading would take place. This was postponed, however, until 5 Aug. Covers and antenna plates were then screwed on, and the unit was leaded on the transport at about 1400. The inner breech plug was in the unit, with the primers installed and checked, but with no charge. Rear plates were installed, but with only half of the screws.

Rep on gun assembly 4

The unit arrived at the pit at 1430 and was lowered on the hydraulic jack. The plane was in position at 1500, and at 1545, the unit was secured in the plane. A gxxx great deal of photography went on during the loading operation. Check of fuzing was completed at 1745. At 1845, a final check of powder, breech wrench and tool kit for loading in plane was made. The powder charge was in a Navy powder can, lashed in the bomb bay. The catwalk was secured in loading position. The breech wrench was lashed to the main wing spar.

A watch was kept to prevent tampering up to the time of takeoff, at 0245, 6 Aug.

EZ

GENERAL SUBJECT	PERIOD COVERED	
	FROM (Date)	TO (Date)
Postwar tech dev's--production "little boy components" Dec 46	(Rear Admiral)	

SOURCE OCG Files, Gen Corres (MP) Files, Folder 27 (TS), Memo, LRG to W.S.Parsons, Director of Atomic Defense, ND, 5 Dec 46, sub: Production of Little Boy Components (TS). Draft (Final ltr dated 9 Dec 46).

1. We desire a certain no. of Little Boy cmpnts in excess of the quant now on hand.
2. It is requested that the MD mfd and deliever to the MP the fol items:

Item	Units	Nomenclature	Drawing No.
1.	19	Exp. Gun, 6½", Type B, Mod 0	BuOrd 423957
2.	39	Exp. Gun, 6½", Type A, Mod 0	BuOrd 437897
3.	41	Special Breech Plug	Los Alamos 01-359
4.	42	Tails	Los Alamos 1791
5.	29	Case Assembly	Los Alamos 1852
6.	35	Dummy Case Assembly	Los Alamos ----
7.	35	Dummy Breech Plug	Los Alamos ----

Pertinent drawings are attached hereto.

3. Dummy ~~///~~ cmpts and Type A gun tubes may be of mild steel.
4. Funds for this prgm are avail. MD will be reimbur upon submiss of Form 1080.
5. It is reqsted that your off desig a lia officer for this prgm. Policy matters shld be handled directly with this office, but routine admin of this prgm may be handled diredtly with offices conerned at Proj "Y".

Incl (Drawings) (These are listed but not attached to this copy of memo)

OCS FORM 660 1 MAY 54 EDITION OF 1 JUL 53 WILL BE USED UNTIL EXHAUSTED. RESEARCHERS BRIEF E61020 VCJ

DRAFT
5 Dec mg

~~TOP SECRET~~

This document consists of 1 pages
Copy No. 1 of 6 Series.

SUBJECT: Production of Little Boy Components.

TO: Rear Admiral W. S. Parsons, Director of Atomic Defense, Navy Department

1. ~~Revised weapon requirements indicate the need for~~ We desire a certain number of Little Boy components in excess of the quanti[redacted] hand.

2. It is requested that the Navy Department manufacture and deliver to the Manhattan Project the following items:

~~RESTRICTED DATA~~

~~This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.~~

Item	Units	Nomenclature	Drawing Number
1.	19	Exp. Gun, 6 1/2", Type B, Mod 0	BuOrd 423957
2.	33	Exp. Gun, 6 1/2", Type A, Mod.0	BuOrd 437897
3.	41	Special Breech Plug	Los Alamos 01-359
4.	42	Tails	Los Alamos 1791
5.	29	Case Assembly	Los Alamos 1852
6.	35	Dummy Case	Los Alamos ----
7.	35	Dummy Breech Plug	Los Alamos ----
8.	2	K-46 liner Assembly	Los Alamos 1850-5

DECLASSIFIED
E.O. 11652, Sec. 3(E) and 5(D) or (E)
Authority NND 730039
By EAG NARS, Date 6-4-74

3. Dummy components and Type A gun tubes may be of mild steel.

4. ~~3.~~ Pertinent drawings are attached hereto.

5. ~~4.~~ Funds for this program are available. The Navy Department will be reimbursed upon submission of Form 1030.

CLASSIFICATION CANCELLED
~~OR CHANGED TO~~
BY AUTHORITY OF
BY ______ DATE 1/24/72

6. ~~5.~~ It is requested that your office designate a liaison officer for this program. Policy matters ~~will~~ should be handled directly with this office, ~~However,~~ but routine administration of this program may be handled directly with offices concerned at Project "Y".

OK G

Incl (Drawings)

~~TOP SECRET~~
L. R. GROVES
Major General, USA

This is the original memo covered by the previous Researchers Brief card. Note Item 8 regarding the K-46 Liner Assembly, which is missing from the card. This item was crossed out in this memo and was carefully restored for legibility purposes by the author in the reproduction presented here. (National Archives)

~~SECRET~~ UNCLASSIFIED

~~THIS~~ DOCUMENT CONSISTS OF ~~......~~ FAC..(S)
NO.______ OF ______ COPIES, SERIES ....

INTER-OFFICE MEMORANDUM

~~This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, U.S.C. 50; 31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.~~

TO: E. R. Jette

FROM: J. M. Taub

DATE: January 24, 1947

SUBJECT: Special Materials Report of Group CMR-6 for the Period Dec.20,1946 - January 20, 1947.

Job and Personnel	Progress
7. Initiators Wellborn	Ten gun type initiators were finished and delivered to Group CMR-3. Twenty five urchin type initiators were completed and are being inspected for flaws. These will be ready for delivery to CMR-3 within a few days.
8. Miscellaneous Hot Pressing Wellborn Smith Johnson	✓ Ten tungsten carbide rings, thirteen inches in diameter, were produced this month. At this time the total number of rings produced is 26.

J. M. Taub

JMT/sk

cc/file

~~SECRET~~ UNCLASSIFIED

This postwar Los Alamos document confirms the *Little Boy* target case tungsten-carbide (WC) rings were "thirteen inches in diameter" as first measured by the author in 1995 on a target case WC fragment. (Courtesy of Shawn Hughes)

THIS DOCUMENT CONSISTS OF 1 PAGE(S)
NO. 8 OF 13 COPIES, SERIES A

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PER DOC REVIEW JAN. 1973

~~SECRET~~

A-84-019
41-12

471, 86

July 3, 1945

7/4 Ppn

TO: Mr. Oppenheimer 321050

FROM: C. S. Smith and I. C. Schoonover

SUBJECT: Gun Fabrication Plan - Second Supplement to Memorandum of June 13, 1945.

R

In the supplement dated June 28th, the decisions of a meeting held that day regarding cadmium plating was reported. It was decided to plate the inner cylindrical surface of the projectile and the outer cylindrical surface of the target range only if this were found to be technologicaly feasible.

Experiments carried out by J. Pannell in Group CM-11, using newly designed equipment, have shown this to be perfectly feasible and we are therefore proceeding with the plating as outlined below.

Each projectile ring will be plated on its inner cylindrical surface to an average thickness of approximately 0.005 in., (0.110 g/cm^2). This thickness will be controlled by current density and time measurements. No cadmium will be deposited on any other surface.

BEST COPY AVAILABLE

Cyril Stanley Smith

I. C. Schoonover

42235-1287

CSS/bc
Distribution:
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FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
FEB 4, 1981

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act ... the revelation of its contents in any manner to an unauthorized person is prohibited by law.

VERIFIED UNCLASSIFIED
LMR FEB 4 1981

CLASSIFICATION CANCELLED
DOE NSI DECLASSIFICATION REVIEW EO 12958
BY: [signature], 9/25/97 LANL/FSS-16
(NAME) (DATE)

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PUBLICLY RELEASABLE
LANL Classification Group
[signature] 9/25/97

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

This ultimate "Smoking Gun" Los Alamos document, mistakenly declassified in 1981 during the Reagan Administration, mentions "the inner cylindrical surface of the projectile and the outer cylindrical surface of the target" thus confirming for the very first time the still-secret so-called "hollow-projectile" LB design first described to the author in 1994 by Harlow Russ. (Courtesy of Alex Wellerstein)

A-84-019
46-6

July 1 1945

470.1
Boron

ADHESIVE FOR BORON-PLASTIC SHELLS

This adhesive consists of a solution of 10,000 cps Parlon (chlorinated rubber) in benzene. Adhesive action is obtained in two ways - action of the benzene on the polystyrene binder used in the shells and adhesive action of the chlorinated rubber. Since the benzene attacks the molded shell, care should be exercised to prevent the adhesive solution from coming in contact with surfaces of the plastic other than those which are to be glued. If this should occur, the adhesive should be wiped off immediately.

The adhesive should be applied in solution as supplied and allowed to become "tacky" after application and before the surfaces to be glued come into contact. Very little solution is necessary to obtain a good joint and it need be applied only to one of the surfaces of the joint.

This adhesive "sets" solely by evaporation of the solvent. At ordinary room temperature, the glued pieces should be subject to no strain for approximately 8 hours to allow evaporation to take place. This time may be shortened appreciably by using an ordinary 60 - 100 watt light bulb as a heat source to speed the evaporation. Application of more intense heat might cause "crazing" of the molded pieces.

The adhesive solution should be kept in a tightly closed container when not in use to prevent evaporation of the solvent. It should also not be used near an open flame due to the inflammability of the solvent.

J.S. Church
Plastics Section
CM-7

kh

These two reports specify the composition and dimensions for the boron-plastic shell that surrounded the uranium tamper sphere in the 1561 implosion device. It also explains the specific process by which this shell was adhesively bonded to the tamper sphere. (National Security Archives/Chuck Hansen Collection)

A-84-019
46-6

file

TENTATIVE SPECIFICATIONS FOR Al-B ALLOY

470.1
boron

The present plastic shell (9 x 8.75") contains about 114 gm. of enriched boron or 93.5 gm of Vit. B. The area of the shell is 1700 cm^2; so the density of boron is 66 mg/cm^2. A neutron entering radially must traverse this much boron.

If an Al-B shell 18.5" x 12" is used, a neutron will travel through a wall a minimum of 3.25" or 8.25 cm. To encounter .066 gm. of B, the B concentration must be:

$$\frac{.066}{8.25} = 8 \text{ mg/cm}^3$$

or the percentage by weight must be $\frac{.008 \times 100}{2.7} = .3\%$.

This is for 80% Vit. B.

For normal B (18% Vit. B) the % by weight must be ~~4.5~~

4.5 $\left(= \frac{80}{18}\right) \times .3 = 1.35\%$.

In the case of the plastic shell, neutrons entering at very oblique angles will still penetrate the Tu and produce secondary fast neutrons. This is true in the case of the Al-B alloy to a lesser degree because the geometry is less favorable. An evaluation of the difference between the two cases involves solid angle consideration both for the incident and the secondary neutrons. Such a calculation should be made, but until it has been completed one can only say that the direction of the effect is to require a larger concentration of B than calculated above for the alloy.

If one arbitrarily takes a factor of two for this effect, one requires 2.7% B by weight.

If experiments prove that a 1 or 2 percent alloy has much better physical properties than a 3 percent alloy, this fact would be an incentive to make a thorough investigation of the whole problem from a nuclear standpoint.

Until such an investigation has been made, we must assume that the present specifications represent a lower limit for B content.

RES
11/30/45

[redacted]

8 February 1946

C
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P
Y

To: M. F. Roy

From: D. Gurinsky

Lenses which are being made at Inyokern may show a more marked tendency to lag in the center than those produced at Y during our successful period of operation. I have a hunch that this lag may be directly attributable to the technique employed in making up the Baratol melt. The present technique in use at I involves the making of what the laboratory now calls a "high quality Baratol slurry". By this is meant one which is as nearly as possible devoid of air, and this is accomplished by cooking the slurry for whatever length of time is necessary to rid it of air. Judgment is passed as to whether or not the air is completely removed, by turning off the stirrer and waiting for bubbles to rise to the surface. If none do, then the operators are advised to continue cooking, usually at 205° F, until 1/2 hour before the intended pouring time. At the 1/2 hour mark, the Stearoxyacetic Acid is added and the melt is cooled to the pouring temperature. A variation of this is to cool to within 10° or 15° F of the pouring temperature and then add the Stearoxyacetic Acid. Such slurries show a very low viscosity and perhaps this is the reason for the lagging center, since the low viscosity probably allows for more rapid settling of the Barium Nitrate.

The above procedure for making Baratol differs from that which was employed at Y while we were making good firing lenses. The difference was that in this former period, the Stearoxyacetic Acid was added at some definite time interval after all of the Barium Nitrate had been added to the melt. This definite time interval between the addition of Barium Nitrate to the Nitrocellulosed TNT was definitely not long enough to have rid the melt of all of the air. The function of the acid, therefore, was to uniformize and stabilize some of the air which was still encompassed in the melt. These slurries had a higher viscosity and probably a higher yield value than the ones now being prepared at I. Therefore, I would like to recommend that in the event the lenses prepared at I are too slow in the center, the following procedure for preparing Baratol be used:

(1) Melt up the TNT Nitrocellulose.
(2) Add preheated Barium Nitrate.
(3) 1/2 hour after the last portion of Barium Nitrate is added, introduce the required quantity of Stearoxyacetic Acid.
(4) Continue to stir, but at a lower RPM -- somewhere in the vicinity of 30 RPM -- until melt is uniform.
(5) Pour these and test by firing.

[redacted]

UNCLASSIFIED

C
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Y

-2-

You will note that 30 minutes is recommended. There is no scientific or experimental basis for this time, but it should be in the right range of times. It may be necessary to add it 15 minutes or 45 minutes after the last addition of Barium Nitrate, depending on the temperature of Barium Nitrate and the temperature of melt at the last addition of the melt. However, once the proper time has been determined by firing results, the procedure then can be fixed and I am quite certain melts of continuing uniform quantities of air can be prepared day in and day out, as was the case at Y.

Dave Gurinsky

om

cc to Shapiro
Levy
Arthur Ellings at I.

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PER DOC REVIEW JAN. 1973

(LANL)

A-84-019
40-15

[redacted]

THIS DOCUMENT CONSISTS OF ...... PAGES
NO. 4 OF 8 COPIES, SERIES A
Capt. Parsons

INTER-OFFICE MEMORANDUM

UNCLASSIFIED

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

VERIFIED UNCLASSIFIED
PUBLICLY RELEASABLE
LANL Classification Group

Date: March 17, 1945
18 Mar

To: Mr. C. C. Lauritsen

From: R. W. Henderson

Subject: Loading of F. M. Booster-Detonator Units

Confirming our discussion Friday afternoon 16 March, there are certain phases of the F.M. Booster-Detonator Unit program on which we would appreciate assistance if we are to meet the tight schedule now confronting us.

At present we have an order in the Detroit office for 1?,000 assemblies of the mechanical components of the unit with deliveries (at the manufacturer's plant) scheduled to begin 17 April at the rate of 500 per week. An identical order is now in the hands of your organization with the same requested delivery schedule.

The bottlenecks, if any, appear, first, to be in our ability to get the bridge wires soldered in place under adequate skilled supervision; second, to get the PETN charge pressed into the detonators; and third, to get the PETN pressed into the initiator tube which is located between the detonator and the tetryl booster pellet.

We would appreciate it if you would give the following proposal studied consideration, and let us know as soon as possible whether or not such a program could be undertaken by C.I.T.

1. Coax Core Assemblies per drawing Y177387 will be delivered to C.I.T. at the rate of 2000 per week, complete except for the bridge wire. C.I.T. will furnish and solder these wires in place.

   (A decision will be reached at this project by 1 April as to whether Pt or Ag will be used.)

2. C.I.T. will assemble the Coax Core Unit in the main Detonator Housing Assembly as shown on drawing Y177386 at the rate of 1000 housings per week.

3. C.I.T. will load the PETN into the Detonator cavities per drawing Y177384 at rate of 2000 detonators per week (1000 Booster-Detonator Assemblies per week).

   Note: The above three items cannot be done at an established loading plant such as Picatinny as the unusually rigid specifications and requirements are not compatible with the quality of workmanship and inspection one would get in such a plant. For this reason we are of the opinion the job must be done either at Site Y or at C.I.T. Of the two locations your organization is at present in a better condition than ours to undertake the job; however if the production requirements are inconsistent with your facilities, Site Y must start at once to construct a loading plant to take over as soon as possible.

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4. C.I.T. will load Initiator Tubes per drawing Y177385 at the rate of 1000 per week until such time as Picatinny can get into production, which will probably be around 8 May.

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(over)

5. C.I.T. will install the Initiator in the Detonator-Booster Housing, insert the Tetryl Booster Pellet, and crimp the gilding metal Booster Cap in place per drawing Y177302 at the rate of 1000 assemblies per week. Tetryl Pellets will be supplied by Site Y from Eastern production facilities.

Note: Site Y is now designing, and hopes to have in production use by 29 March, a complete set of special loading tools and equipment for all work covered by Items 1 through 5. We can furnish your organization with these unproven designs by 23 March if they will be of help to you.

It is fully realized that the program outlined above is a large one and for that reason it will require the closest cooperation for successful completion. To this end we are anxious to do all we can to share responsibilities with you and your men.

It is well to point out here that although a production rate of 1000 loaded assemblies per week seems large at first glance, it is really not as bad as it seems. We estimate that one man can load a complete unit in 20 minutes, i.e., 24 units per day or 144 units per week. A rate of 1000 per week would keep 7 men busy plus, say, 2 helpers weighing out charges.

To ease this program Site Y will start loading a pre-production run of some 64 units per week, made in our own shops starting, hopefully, around 26 March. This rate can be increased in all probability to take over approximately 1/4 of your requested output during the initial operating period of your production line, which time is always the most critical.

RWH/bss

R. W. HENDERSON

cc - J.R.Oppenheimer
Capt.W.S.Parsons
G.B.Kistiakowsky
Comdr.N.E.Bradbury
L.Alvarez
K.Griesen
file

(LANL)

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URGENT

THIS DOCUMENT CONSISTS OF 1 PAGE(S)
NO. 2 OF 18 COPIES, SERIES A

A-84-019
29-5

February 19, 1945

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
JUL 17, 1979
OK

Mr. B. Waldman

Lt. W. F. Schaffer

H.E. Assembly of 1560 F.M. Design with H.B.X.

1. The memo isintended to point out the difficulties encountered with the assembly of this unit with H.B.X. blocks cast by a Navy facility and to make known the fact that the unit may be dangerous to handle for reasons covered below.

2. The manufacture of the F.M. unit appeared to be satisfactory and excellent as far as mating of the component parts and installation of the cork lining. The only feature in doubt was the location of the booster holes. This is now being checked by Mr. Henderson.

3. There are several points about the H.B.X. blocks which may cause the unit to become dangerous during the handling and shaking tests which are scheduled for tonight.

(a) A large percentage of the blocks used in the assembly had fine hairlike cracks across the upper face (not more than 0.01" in width). These cracks may develop to such an extent that the blocks may break during the shaking operation.

(b) The length of the blocks conforms to the minimum tolerance permitted. This means that the compression of the cork is less than experienced with inert assemblies, and allows the blocks to be more subject to movement, when the unit is shaken. When the top polar cap was set in place it indicated for all practical purposes that there was no compression of the cork at this point.

(c) The spacers used on the blocks are either too thin or the actual cross section of the blocks is too small (due to shrinkage of the casting or mold construction). This fact was evidenced when the tightening of the case did not close the gap between the blocks in the upper portion of the assembly as experienced in previous inert assemblies. Gaps varying from 0.27" to 0.86" remained after the belly band segments were tightened.

(d) Since no lubricant for ease of assembly and desensitization of powdered explosive was used on this assembly except around the tamper sphere and a band 6" inwidth around and immediately above the lower polar cap, powdering of the explosive caused by shifting of the blocks during the handling or shaking may be dangerous.

W. F. SCHAFFER

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 197[illegible]

WFS/bea

cc - Oppenheimer ✓ Neddermeyer
Parsons Dow
Kistiakowsky Tenney
Bainbridge deSilva
Warner Ramsey
Henderson Popham
Bradbury Crocker
Ackerman Davalos

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(LAN)

A-84-019
82-16

4 April 1945

Files

G. B. Kistiakowsky

Booster Detonator Units for FM--Henderson Assembly Drawing Y-1773C2

The following sets down agreements on procedure in the pre-production manufacture of above units at Y reached at a conference between Bradbury, Bradner, Kistiakowsky and Lofgren. It supersedes and amends some of the statements made by Henderson on page 2 of his memorandum of March 30, 1945.

1. Group X-2 is responsible for the design and installation of all tools needed for the assembly of these units, and for the supervision of the manufacture of the metal parts in local shops.

2. The soldering of the detonator wires will be done by Group G-7 at South Mesa until external procurement makes the manufacture of these units at Y unnecessary.

3. The first pressing of low density PETN into detonators will be done by G-7 at South Mesa until such time when external procurement makes this activity unnecessary.

4. Group X-2 therefore will install the tool for this part of the manufacture at South Mesa on instructions from Group G-7.

5. PETN tubes will be filled and sealed at Two-Mile Mesa to specifications furnished by G-7 by personnel of Group X-6.

6. The pressing tools for this operation will be installed therefore by Group X-2 at Two-Mile Mesa.

7. The transportation trays and the transportation itself of detonators from South Mesa to Two-Mile Mesa will be furnished by Group G-7.

8. The assembly of PETN tubes and of tetryl pellets, including crimping, into the booster units will be done at Two-Mile Mesa by Group X-6.

9. Group X-2 will therefore install the tools needed for these operations at Two-Mile Mesa.

10. The control testing of the booster assemblies will be done by section X-1A. It is expected that in the beginning all production will be used in testing but that later these units, if proven satisfactory, will be available for field use by other groups.

cc to: Bacher, Lofgren, Bradbury, Henderson, Bradner, and Roy

G. B. Kistiakowsky

(LANL)

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A-84-019
82-16

CLASSIFICATION CANCELLED PER DOC REVIEW JAN 1973

April 6, 1945

Lt. W. F. Schaffer

R. S. Warner, Jr.

Detonator-Booster Assembly Operation

Under the most recent clarification of responsibility for this operation, it is my understanding that Group X-6 will provide at Two-Mile Mesa both buildings and personnel to handle the following operations:

1. Initiator

    1.1 Classify and weigh out PETN
    1.2 Press PETN to high density
    1.3 Seal PETN into the tubes

2. Booster

    2.1 Assembly of tetryl pellets and crimp gilding metal seal

3. Assembly

    3.1 Assemble [redacted] and booster into the detonator

I further understand that this operation should be expected to get under way on about 14 April to reach a rate of 300 assemblies per week on about 21 April.

While X-6 can expect temporary help from G-7 at the beginning to learn the technique, etc., at first blush it would appear that the job would require four men by about the 18th and two additional men by the 21st. If you believe this to be approximately correct, we should request the loan of three people to remain with this operation until completed.

Mr. Greisen should be notified that the first assemblies will probably not have any gilding metal crimped over the end due to procurement difficulties.

RSW/bsa
cc - Comdr. N. E. Bradbury
R. W. Henderson
file

R. S. WARNER, Jr.

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(LANL)

[redacted]

Copied From Los Alamos National Laboratory Archives

INTER-OFFICE MEMORANDUM NO. 1 OF 6 COPIES, SERIES A

A-84-019
13-3

TO: Comdr. N. E. Bradbury

DATE 14 April 1945

FROM: G. B. Kistiakowsky

CLASSIFICATION CANCELLED

SUBJECT: Allocation of Large Lenses

During the meeting of the Cowpuncher Committee today, it was emphasized that two problems are of great importance in connection with work on lenses. One is to get accurate data on the total time of passage of detonation waves thru larger lenses. I have taken the liberty to request Martin and Hoffman to give highest priority to this job; if necessary borrowing the electronic timing equipment from Linschitz and enlisting the technical help of Linschitz and his staff.

The second is the high urgency of obtaining information on the behavior of first quality 9" lenses by both Koski and Froman. In your allocation of lense please bear this in mind and try to allocate them first quality lenses as soon as possible. My understanding is that the two RaLa shots requiring 9" lenses will be made on April 19, and about April 26. This should be borne in mind in allocating the lenses as above.

For your information I should like to add that it appears possible, provided lens molds arrive here on Monday as now promised, to meet a schedule of five or six full scale charges before July 1. The allocation of these charges should be roughly as follows:

2 charges to Hoffman, Koski and Froman with the understanding that Hoffman gets altogether not less than one-half charge, i.e., 16 lenses of first quality.

2 next charges will go to Creutz, while the 5th charge will be scheduled for Trinity or, if Trinity is delayed, then for assembly work. Otherwise the 6th charge will be so scheduled.

Capt. Parsons believes that he may be able to divert some low quality charges from McAlester for preliminary work by Koski. In the meantime S Site will attempt in spare time (!!!) to produce at least one low quality charge without Baronal inserts also for Koski. It is hoped that at least one of these two sources will crash thru and thus Koski will be able to fire for instrumentation purposes two shots early in May. It is, of course, not expected that the results of these shots will be of any technical interest except insofar as they will show the operation of his equipment.

VERIFIED UNCLASSIFIED
LMR OCT 28 1980

GBK

GBK:he

G. B. Kistiakowsky

Copies to: Marley
Rossi
Lt. Hopper
Allison

[redacted]

This memo specifies the exact size of the lenses used in the implosion device exploded at Trinity. (LANL)

MJ 3/6/84

X-6

11 May 1945

Messrs. Henderson, Stout, Warner, and Lt. Schaffer

Comdr. N. E. Bradbury

HE Assembly Problem

1. Kistiakowsky and others have pointed out the difficulty of guaranteeing that the HE in the 1560 assembly cannot shift with respect to the case in the event of pronounced temperature changes, vibration, oscillation, etc. It is apparently essential that some positive method of anchoring the charge to the case be adopted before any active gadget is dropped. Kistiakowsky has suggested a rubber torus method, as well as the use of dowels. The most feasible method at the moment seems to be to use dowels, and the most attractive from the point of simplicity is to use in some fasion the booster holes for this purpose.

2. By copy of this memo, Group X-6 is requested to assemble a Mk IIIm charge and to pay special attention to the manner in which the booster holes (or points on the plaster blocks) can be lined up with the 1560 sphere holes, since this variable indicates the extent of departure from center which must be allowed for in the dowels.

3. It is hoped that Mr. Henderson will give immediate attention to the design of a combination 1773 booster detonator holder and dowel, and that Mr. Stout will consider the design of an appropriate drilling tool.

4. Alternate methods of doweling should not be excluded, but they should be considered in the light of the possibility of including them in the first active gadget.

N. E. Bradbury

NEB:hs

X-6

11 May 1945
-019

Lt. Schaffer, and R. Warner

Comdr. N. E. Bradbury

Trap Door Assembly

1. Kistiakowsky has suggested, and Oppenheimer concurred, that it would be very desirable if the FM gadget could be completely assembled at Site Y, and only the active material inserted at the destination. GBK has suggested that this might be accomplished by the use of a "trap door" in the polar cap through which a dummy charge would be removed at destination, a plug in the tamper sphere unscrewed, the active material inserted, the tamper plug returned to position, and an HE charge inserted in place of the dummy. The trap door would then be replaced and provided with positive pressure. It might be even more simple to remove the whole polar cap; a process which would then require no modification of the cap.

2. By copy of this memo, X-6 is requested to determine whether and under what circumstances blocks can be removed from an assembled Mk IIIm charge in such a manner as to permit the operations suggested above.

3. What is the largest opening which would then be available at the surface of the tamper?

N. E. Bradbury

NEB:he

(LANL)

A-84-019
17-8

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CLASSIFICATION CANCELLED PER DOC REVIEW JAN. 1973

MR106

TY 18356

FROM PARSONS CLEAR CREEK JUNE 4 (27) 1841Z

TO WASHINGTON LIAISON OFC WASHINGTON DC [redacted]

~~RESTRICTED~~

PREVIOUS INSTRUCTIONS TO MCALESTER ON PREPARATION OF CASTINGS FOR SHIPMENT ARE HEREBY MODIFIED. THESE INSTRUCTIONS WILL NOT APPLY TO ANY OF THE FIRST THREE SETS TO BE PROVIDED HERE IF TI WILL CAUSE ANY DELAY IN SHIPMENT OF THE SETS. CASTINGS ARE TO BE COATED WITH THE NEW FAST DRYING VARNISH AND PLASTIC COATING SHIPPED TO MCALESTER VIA REA ON 16 JUNE. ONE COAT EACH OF THE VARNISH AND PLASTIC COATING ARE TO BE APPLIED IN THAT ORDER. THESE MAY BE APPLIED EITHER BY SPRAYING OR PAINTING, MAINTAINING A TOTAL THICKNESS OF APPROXIMATELY 4 TO 8 THOUSANDTHS INCHES. BLOTTING PAPER AND FELT WILL THEN BE APPLIED AS PREVIOUSLY INSTRUCTED. NO TAPE IS TO BE APPLIED UNTIL FURTHER NOTICE. CASTINGS SHOULD BE IDENTIFIED BY MARKING WITH RED CRAYON MOLD NUMBER ON CASTINGS. THIS INFORMATION HAS BEEN FORWARDED TO MCALESTER.

2271 0745

cc: Bradbury
Stout
Greening
Schaffer
file

CLASSIFICATION CANCELLED PER ~~DOC REVIEW JAN. 1973~~

~~Classification changed to ... by authority of the U.S. Atomic Energy Commission,~~ 8/54

~~(Person authorizing change in classification) (Date)~~ 5/11/54

(Signature of person making the change, and date)

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
NOV 3, 1980

VERIFIED UNCLASSIFIED
2/13/87

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(LANL)

Mr. G. W. Galloway

J. C. Batteiger

SEALING OF THE 1560 UNITS AT W-47

Some difficulty was experienced this past week in sealing 1560 units at W-47 which caused a slight delay in meeting schedules on the unit that was sealed. This delay was due to the following reasons.

1. A suitable air compressor for doing the job was not available where the work was to be done. This condition still exists.

2. The rear ellipsoid on T-123 was an obsolete part and slight alterations had to be made before sealing operations could be started.

To correct these situations, I should like to suggest that a compressor which is capable of producing 100 p.s.i. and 60 cu. ft. per minute of volume be installed at the location where sealing is to be done in the future. On units to be sealed, I think it advisable to use only parts that are up to date, having all the latest changes incorporated on them, whenever possible.

In sealing T-123 the following procedure was used:

1. Two lug gaskets, Y-2048, were assembled between the lug and the top center sphere segment. (This operation is done before the sphere is assembled).

2. Nine holes were drilled and tapped in the "D" plate to take 9 silica gel units (Zenith 1814).

3. A 5/16 hole in the center of the "D" plate was tapped to take a breather valve.

4. Two 1/4 rubber gaskets, Y-1771-5 were glued to the forward face of the "D" plate.

5. Bolt holes to take pull-out wire gasket assemblies were drilled in the aft ellipsoid.

6. Eight plug gaskets, Y-1771-2, were installed along with the 8 Amphenol and safing plugs.

7. Five gasket assemblies, Y-1748, were installed for pull-out wires.

8. After assembling the front and rear ellipsoids and the tail, a fairlead block, Y-1868, and gasket, Y-1771-4, were installed on the rear face of the "D" plate, carrying five cables through the "D" plate.

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PER DOC REVIEW JAN. 1973

[redacted]

G. W. Galloway

J. C. Batteiger

29 June, 1945

Page two

9. The rear ellipsoid being an obsolete part, wood plugs were made to fill holes that do not exist on up-to-date parts.

10. Holes were drilled and tapped to take lug fairings and 8 fairings, Y-2006, were installed over the lugs.

11. Strips of tape were used to bridge over all cracks and openings. This was done around the lift lug, at the joint of front and rear ellipsoids and at the joint of the front ellipsoid and nose plate. Tape was also used to mask off openings for impact fuses and antennae plates.

12. M-190 Pliobond was next applied over all areas to be sprayed with strippable plastic film. The bonding material was allowed to dry for at least 20 minutes.

13. O.S. 3602 strippable plastic film was sprayed over the joints. It covered an area of approximately one foot on either side of the joint.

14. The silica gel units and a breather valve were installed on the "D" plate.

15. Four gaskets, Y-1771-3 were installed along with the antennae plates after the unit was loaded in the plane.

After sealing operations were completed, the film was allowed to dry for approximately twenty hours before take-off. During this time, however, the unit was moved from the assembly building to the pit and loaded into the plane. The unit arrived at the pit with the sealing film in good condition, but it was slightly damaged while loading from the pit into the plane. This was due to the fact that the fairings being covered with the film rested on the cradle in the pit and as a result cut small holes in the film.

In connection with the drop test made on T-123 at S.B. the following observations of sealing were made.

1. During the entire trip from W-47 to S.B. to an altitude of 32,000 ft. the sealing film remained intact and went through no change in form whatsoever. That is, there was no puffing out of the film, which might be caused from a higher pressure within the unit.

2. During the time of drop my observation was that the sealing film did not tear loose from the surface of the unit as far down as I could see it.

cc Warner
Parsons

[redacted]

John C Batteiger
J. C. BATTEIGER

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973
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(LANL)

UNCLASSIFIED

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NO. ... OF ... COPIES, SERIES ...~~

[redacted]

MEMORANDUM

9 July 1945

VERIFIED UNCLASSIFIED
LMR 7-17-79

JUL 9 1981

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
[redacted]
July-17-1979

TO: Personnel Concerned

FROM: Comdr. N. E. Bradbury

SUBJECT: TR Hot Run

1. The firm dates for the TR Hot Run are as follows:

Saturday, 7 July, 1700	Schaffer Shake Test ready to deliver
Sunday, 8 July, 0830	Assemble Schaffer Shake Test, load on truck
Monday, 9 July, 0830	Schaffer Shake Test charge given eight-hour road test. Remove polar cap and dummy plug and inspect top of charge only after three hours riding.
Tuesday, 10 July, 0830	Completely disassemble charge and inspect each casting for condition. Verbal report of charge condition by 1630 Tuesday PM. Reassemble and remove.
Tuesday, 10 July, 1730	TR and Creutz charges ready for delivery. Start papering. Arrange for night shift if necessary to paper charges. Additional personnel will be furnished as required.
Wednesday, 11 July, 0830	Information will be furnished as to which charges will be used in TR shot and which in Creutz shot. Separate charges. Complete papering of TR charges. Complete papering of Creutz charges (use separate groups--request additional personnel as needed).
Wednesday, 11 July, 1730	Both charges completely papered. Work another night shift if necessary to complete this job. Request personnel as necessary. This job must be done so that assembly of both charges can start on Thursday, 12 July, at 0830.
Thursday, 12 July, 0830	Use two groups--one at V Site to assemble TR charge (Lt. Schaffer supervise), and one at Pajarito for Creutz charge (Mr. North supervise). Tamper needed by 1000 at V Site.
Thursday, 12 July, 1500	Assembly of TR charge complete. Notify interested personnel that it is ready for inspection if desired.
1600	Seal up all holes in case; wrap with scotch tape (time not available for [illegible]) [illegible] start loading on truck. Tie [illegible]

SPECIAL RE-REVIEW
FINAL DETERMINATION
UNCLASSIFIED, DATE: JUL 9 1981

225203

This document [redacted] the n[redacted] tion [redacted] ing of the [redacted] mission [redacted] manner to a[redacted] law.

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973
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Thursday, 12 July, 1600	Box charges, inner and outer, with 2 spares for each. Stow on truck so they cannot shift, and are padded from truck bottom.
Friday, 13 July, 0001	TR charge starts on its way to TR. G-2 escort cars fore and aft. G. B. Kistiakowsky to ride in fore car.
Friday, 13 July, 1200	TR charge arrives at base of tower. Following personnel to be at base of tower by 1300: N. E. Bradbury G. B. Kistiakowsky R. S. Warner H. Linschitz Lt. W. F. Schaffer T/5 Jercinovic T/3 Van Vessem A. B. Machen
Friday, 13 July, 1300	Assembly starts at this time.

A. Unloading at TR

1. Truck backs up into base of tower.
2. Tarpaulin is removed, cradle and assembly unlashed.
3. Main hoist lifts sphere off cradle with spreader bar or tongs.
5. Drive truck out from under sphere.
6. Place new cradle under hoist and lower sphere suspended by tongs into it with main hoist.

B. Assembly at TR

1. Sphere is now resting on cradle with polar cap up.
2. Detach main hoist; pick up gently with hook, lower, pull out over gadget, and secure.
3. With jib hoist, remove polar cap and dummy plug. Special polar cap and funnel put in place. Gadget now belongs to tamper people (at about 1400 on Friday). Prior to their taking over, a fifteen minute period will be available for generally interested personnel to inspect the situation. After this time, only G engineers and two representatives from the assembly team will be present in the tent.
4. G Engineers work till 1600 with active material insertion.
5. Lights must be available to work in tent at night.
6. At 1600, dummy plug hole is covered with a clean cloth, and all

people take over. Attach tongs to tent peak by chain. Place tongs on trunnion. Lift sphere and turn over with jib hoist for HE insertion. Return sphere to cradle.

7. Place in hypodermic needle <u>in right place.</u> (Note: check this carefully.)

8. At this point another 15-minute period will be availabe for inspection by generally interested personnel.

9. Insert HE - this to be done as slowly as the G Engineers wish. Have on hand extra paper if charges are slightly small. Also grease and hypodermic needle grease gun. Be sure glass tape and/or shim stock shoe horn is on hand.

10. When HE has been inserted and He-Me people and G Engineers are satisfied that all is OK, another inspection period of 15 minutes will be available.

11. Lift sphere with tongs by chain to tent peak. Return to polar cap up position. Remove special polar cap with jib hoist; replace with regular polar cap.

12. Turn sphere over with tongs, chain and tent peak so that lug is up.

13. Place sphere in special cradle for tower top, and attach cradle firmly to sphere. Remove all tongs, chains, etc. and generally clear deck.

14. Leave tent in place till morning.

NOTE: The HE vacuum cup has arrived and appears to be extremely useful in handling HE charges. It is possible that the entire assembly may be done in the vertical position using the jib hoist and vacuum cup to lower the HE as slowly as the G Engineers wish. This would then require no handling between tent peak and tongs, and the sphere will be left overnight with the <u>cap up</u> and in small dishpan.

15. It is anticipated that we will leave the tent (guarded) at about 2200.

Saturday, 14 July, 0800 <u>Lift to tower top</u>

1. Remove tent with main hoist.

2. Turn over with main hoist and place on special cradle. (This operation necessary only if not previously done as it would not be in a vertical assembly.)

3. Rig guide lines.

4. Lift to tower top. Ready for X unit at 0900.

5. Bring up G Engineer footstool.

Saturday, 14 July, 0900 <u>Operations aloft</u>

1. Wiring of X unit proceeds direction of and by He-Ms people. Note that X unit should have cables attached to cone prior to this time.
2. Detonators are staked to coax by Caleca of detonator group.
3. Detonators are placed by Caleca to conform with requirements of informer switches. HE people stand by to criticise potential rough handling.
4. Detonators and informers in place, verified by Greisen.
5. X unit and informer unit safed--verified by Bradbury or Kistiakowsky.
6. X-7 will provide all detonators, informer switches, informer cables (adequate length), informer apparatus (where they get it is their business). X-5 will supply prepared detonator cables. X-6 will obtain detonator springs and other necessary gear from appropriate sources. X-6 will supply all fittings for wiring. Schaffer to check that all mechanical parts (nuts, bolts), etc. are supplied.
7. Note that once detonators are on sphere, no live electrical connection can be brought to X unit, informer unit, or anywhere else on sphere. Hence all testing must be done before sphere is lifted to tower. After that it is too late.

Saturday, 14 July, 1700 <u>Gadget complete</u>

Sunday, 15 July, all day Look for rabbit's feet and four leafed clovers. Should we have the Chaplain down there? Period for inspection available from 0900-1000

Monday, 16 July, 0400 BANG!

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[redacted]

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PER DOC REVIEW JAN. 1973

General Notes

The same responsibility for procurement of items exists as in the dry run. Machen to check his list for parts left down there. Could they have been stolen? Schaffer to get vacuum cup and two pumps ready to go down. Have glass tape handy to tie charge to hook of jib hoist to guard against vacuum failure.

It is assumed that the following things will have been done at TR:

Guide wire hold down improved
Method of holding down tent improved
Ionization chambers either not connected to pipe coax or off to one side. Wilson's chamber to be connected later; Rossi's chamber to be pulled off to wall side.
Rig a roped off area about base of tower allowing 20 ft. clear space. Provide "Keep Out" signs (Oppenheimer). All spectator personnel stay outside this area except at inspection times.

The following points were noted in the dry run assembly. Personnel listed should take appropriate steps:

Shim stock shoe horn was missing. (Machen)
Longer screws needed for X-Unit cable clamps. (Schaffer)
Sphere not grounded. (Schaffer)
All detonators off floor; all detonator cables off floor. (Greisen)
Shorter screws could be used for detonator leaf springs. (Schaffer)
Washers needed for informers. (Greisen)
Cable lengths too short? (Hornig)
Headless screws to protect screw holes (not necessary with scotch wrap).
Need good cover for HE hole while turning over. (Schaffer)
Need proper clevis for attaching tongs to main hoist. (Henderson)

Need better method of getting up tent and securing. (Henderson)
Upper platform should be tested with concrete weight. (Oppenheimer)

It will not be possible to permit any personnel on the assembly platforms other than those actually engaged in assembly operations. However, personnel may observe the operations from beyond the roped off area, and may inspect the assembly at times as noted in the above operations list.

N. E. Bradbury

NEB:hs

Distribution:
J. R. Oppenheimer
F. Oppenheimer
G. B. Kistiakowsky
Major Ackerman
R. W. Henderson
R. S. Warner
Lt. Schaffer (2)
A. B. Machen
Morrison
Holloway
R. F. Bacher
N. Baney
K. T. Bainbridge
Lt. Comdr. Keiller
K. Greisen
D. Hornig
H. Linschitz
R. W. Carlson
John Williams
B. Rossi
R. Wilson

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

UNCLASSIFIED

[redacted]

(LANL)

July 25 1945

We met at 11 A.M. today. That is Stalin, Churchill and the U.S. President. But I had a most important session with Lord Mountbatten & General Marshall before that. We have discovered the most terrible bomb in the history of the world. It may be the fire destruction prophesied in the Euphrates Valley Era, after Noah and his fabulous Ark.

Anyway we think we have found the way to cause a disintegration of the atom. An experiment in the New Mexican desert was startling – to put it mildly. Thirteen pounds of the explosive caused the complete disintegration of a steel tower 60 feet high, created a crater 6 feet deep and 1200 feet in diameter, knocked over a steel tower 1/2 mile away and knocked men down 10,000 yards away. The explosion was visible for more than 200 miles and audible for 40 miles and more.

This weapon is to be used against Japan between now and August 10th. I have told the Sec. of War, Mr. Stimson to use it so that military objectives and soldiers and sailors are the target and not women and children. Even if the Japs are savages, ruthless, merciless and fanatic, we as the leader of the world for the common welfare cannot drop this terrible bomb on the old Capitol or the new.

He & I are in accord. The target will be a purely military one and we will issue a warning ~~state~~ statement asking ~~the~~ the Japs to surrender and save lives. I'm sure they will not do that, but we will have given them the chance. It is certainly a good thing for the world that Hitler's crowd or Stalin's did not discover this atomic bomb. It seems to be the most terrible thing ever discovered, but it can be made the most useful

This 7/25/45 diary page by President Truman in pencil was copied directly from the original by the author. Truman mentions on line 9 the exact quantity of plutonium used during the Trinity test. (Truman Library)

19 July 45

471.6
Little boy
A-471.6
Hiroshima

Dear Dr. Oppenheimer: I have received your teletpye dtd July 19, 1945, and have discussed its contents with some of our Washington associates. Factors beyond our control prevent us from considering ~~and~~ any decision other than to proceed according to existing schedules for the time being.

X-471.6 Nagasaki
X-201 Oppenheimer
X-353.4 Japan

It is necessary to drop the first Little Boy and the first Fat Man and probably a second one in accordance with our original plan. It may be that as many as three of the latter in their ~~present~~ best present condition may have to be dropped to conform with planned strategic operations.

5/16/85

This is Grove's reply to Oppie's twx.
~~Oppie's twx was not located.~~

attached Walt

B.L.
8/9/67

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

A-84-019
17-5

2271 0628

VERIFIED UNCLASSIFIED
NOV - 3 19[illegible]

ok Ew3

This is Groves' rejection to Oppenheimer's suggestion that the uranium from *Little Boy* be used in a plutonium/uranium composite core design for the implosion device thereby increasing the quantity of *Fat Man* bombs that would be available. (LANL)

75 Q

~~TOP SECRET~~

WAR DEPARTMENT
WASHINGTON

10 August 1945.

MEMORANDUM TO: Chief of Staff.

The next bomb of the implosion type had been scheduled to be ready for delivery on the target on the first good weather after 24 August 1945. We have gained 4 days in manufacture and expect to ship from New Mexico on 12 or 13 August the final components. Providing there are no unforeseen difficulties in manufacture, in transportation to the theatre or after arrival in the theatre, the bomb should be ready for delivery on the first suitable weather after 17 or 18 August.

L R Groves

L. R. GROVES,
Major General, USA.

8/10/45

It is not to be released on Japan without express authority from the President.

G C Marshall

~~TOP SECRET~~

(LANL)

[redacted] UNCLASSIFIED

4 August 1945
A-84-019
67-3

Lt. Col. R. W. Lockridge

Captain Larkin

Trap Door FM Assemblies

1. Recent experience in methods of HE assembly in FM gadgets has led to the adoption of the so-called Trap Door method of assembly for all future Fat Man assemblies destined for use at destination. In this method, the HE is completely precision assembled at Site Y with the exception of two charges whose ultimate place is filled by an inert plug. In the field, this plug is removed after taking off the polar cap, the appropriate parts of the pit inserted, two live charges placed in the space formerly occupied by the inert plug, and the polar cap replaced.

2. This procedure makes it unnecessary for crews to be trained in the technique of charge assembly since it will be possible for Site Y or another casting activity to prepare all necessary charges at the currently anticipated rate. HE charges for experimental use at W-47 will be prepared at Y from McAlester HE blocks at the rate of at least one per week as long as needed. No further plaster block assemblies will be sent to destination, and all inert charges to be used at W-47 and at destination will henceforth be cast at W-47 from an appropriate plaster or concrete mixture directly in the 1561 sphere.

3. It is requested that you inform Captain Roerkohl of this change in procedure in order that he may take the necessary steps to adjust his training program to this technological improvement. If he desires that his officers become familiar with trap door methods, we should be glad to inform them of the dates on which we expect to be carrying out such assemblies in order that they may be present.

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
APR 23-1979
P. M. Lang, 2-1-88

R. A. Larkin

RAL:NEB:he

Copies to: Comdr. N. E. Bradbury
Glen Fowler

This [redacted]g the national [redacted] the meaning of the [redacted]2, its transmission [redacted] in any manner to an unauthorized person is [redacted]y law.

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PER DOC REVIEW JAN. 1973

UNCLASSIFIED

[redacted]

(LANL)

UNCLASSIFIED

~~SECRET~~

Bradbury

Dept

FIRST TECHNICAL SERVICE DETACHMENT
A.P.O. 336, C/O POSTMASTER
SAN FRANCISCO, CALIF.

11 August 1945

Document 5

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
OCT 27, 1980

TO: W. S. Parsons

FROM: N. F. Ramsey

SUBJECT: Test Schedule

1. At a special meeting of the Project Technical Committee on 11 August the following test schedule was agreed upon.

Serial Number	Description	Schedule
F101	Inert FM with no detonator equipment. Test of fusing equipment only.	Assemble on 11 and 12 August and drop on 13 August or as convenient.
F103	Same as F101.	Assemble on 13 and 14 August and drop on 15 August or as convenient.
F102	Final rehearsal model of FM. Plaster blocks. Electrical detonator, complete fusing, 3 Wright switches, informers and smoke puffs on Wright switches.	Assemble on 11, 12, 13, and 14 August. Load on trailer at 1400 on 14 August, and load into plane at 1500 on 14 Aug.

N. F. RAMSEY

VERIFIED UNCLASSIFIED

cc: General Farrell
Kirkpatrick
Tibbets
Begg (2)
Bradbury (2) ✓
Serry
Oppenheimer
Ashworth (2)
Warner
Alvarez
Stevenson
Doll
Morrison
Serber
Ramsey (2)
Nolan

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2264008

(LANL)

[redacted] No. 2 of 4 Copies, Series A

UNCLASSIFIED

J. R. Oppenheimer

W. S. Parsons

17 August 1945

Document 8

Paraphrased Teletype Reference NR-371 dated 16 August

To Larkin and Oppenheimer from Parsons and Ramsey, Via Derry

The following is given as project status:

Although they are completely ready, F-101, 103 and 102 will not be dropped due to surrender agreement. An active sphere for F-32, it is also assumed, will not be sent.

Now underway is the first phase of our post surrender plan which includes efforts of personnel of Project A being directed as follows:

To be left in our buildings will be materials, suitably sorted, for return to the states, for dumping in deep water, or to be disposed of through normal salvage channels. Materials, however, will be left in such a state of readiness, in case of an emergency that, within a few days, our organization, on a few days notice, can be reactivated and operational.

On or about August 20th, a special green hornet will be used to return technical personnel into the empire, not scheduled on the special missions.

For disposition and shipment of property and supervision of the wind-up, Ashworth and Kirkpatrick, and perhaps DiSabatino will remain here after August 20th.

VERIFIED UNCLASSIFIED
LMR OCT 27 1980

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
OCT 27, 1980

22641080

ja
cc: Bradbury
Fowler
File

UNCLASSIFIED

[redacted]

(LANL)

[redacted]

UNCLASSIFIED

INTER-OFFICE MEMORANDUM

X-6 PL 3-6-86

TO: Comdr. N. E. Bradbury

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

DATE August 30, 1945

Copied From Los Alamos National Laboratory Archives

A-84-019 3-4

FROM: R. A. Bice

SUBJECT: H.E. Assembly with Condenser Spacers for Stress Measurements

We would like to start the subject assembly Wednesday Sept. 5 if this suits your schedule. The requirements on the charge are as follows:

1. The blocks must be dimensionally accurate in all respects.

2. The usual chimney pads shall be installed on the lens blocks.

3. All lens castings should be furnished without blotter paper.

4. All inner charge castings should be furnished with felt on the inner spherical surface but none on the outer spherical surface.

5. Three of the 12 inner charge pents should be furnished without blotter paper.

6. Fifteen of the 20 inner charge hexes should be furnished without blotter paper on <u>one</u> of the large faces.

If this schedule meets your approval or if you have any suggestions, we would appreciate hearing from you as soon as possible.

RAB/bsa
cc - R.W.Henderson
G.B.Kistiakowsky
Capt.W.F.Schaffer
J.W.Stout
J.R.Zacharias
file

R. A. BICE

R A Bice

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
SEP 13, 1979
P. M. Lang 3-6-86

UNCLASSIFIED

[redacted]

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

This document contains information affecting the national defense of the United States within the meaning of the Espionage Act U.S.C. 50 31 and 32, its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Form 25

TOP SECRET TOP SECRET TOP SECRET

Headquarters
FIRST TECHNICAL SERVICE DETACHMENT
A.P.O. 336, c/o Postmaster
San Francisco, California

13 September 1945

MEMORANDUM TO: Officer-in-Charge.

SUBJECT : Security of Disposal of Pumpkins, and Project Material.

1. Disposal of the pumpkins, FM models, LB models, X-5, O-3 Laboratory equipment, and component parts of these models brought about the following security measures:

A. Pumpkins:

This was considered the problem of the 509th Composite Group, inasmuch as the Project previously informed the Group that the Project was not concerned with the Pumpkin program. However, upon receipt of a telecon from the War Department that the size, shape and design of the atomic bomb was top secret, the pumpkin came under the category of shape security. There were 66 pumpkins to be disposed of at the time of V-J Day. Forty-four were still in crates, and twenty-two uncrated but covered with canvas. All were stored in the Island Ammunition Depot. The crated pumpkins were hoisted onto the truck float, transported to the LCT dock and loaded on barges while still crated. They were then taken ten miles out to sea, the tops of the crates removed, and the pumpkins with the aid of a crane outfitted with a pelican hook were lifted from the barge and dropped into the sea. Those pumpkins which were not crated were handled in the following manner:

Pumpkins were covered with canvas while at the Ammo Depot and the canvas cover was slit at the place where the lug was fitted on the pumpkin. The cranes were thus able to hoist the pumpkins on the float trucks without removing the canvas covers, then transported to the LCT docks and placed on the barges with the canvas covers still on the pumpkins. The pumpkins were taken out ten miles by LCT and disposed of in the same manner as the crated pumpkins. Thus the canvas covers were retained over the pumpkins until they were ready to be lowered into the sea.

B. Security of FM Models:

FM models (the spheres, tails and noses) were first cut up by blow torches into several sectors and sections, in order that they could not be identified. Then these pieces were placed in a truck, a canvas cover placed over the part of the truck containing the pieces of the FM models and transported to the LCT docks. There the trucks were driven onto the LCT and taken out three miles to sea, where the truck dumped its cargo into the ocean.

C. SECURITY OF LB Models:

The LB models and component parts were handled in the same manner as the FM models.

TOP SECRET

Page Two Memo to Officer-inCharge.
Security of Disposal.

D. Security of the Component Parts:

Component parts of the LB and FM models were placed in various trucks, covered with canvas and thus transported to the LCT docks. There the trucks were driven onto the LCT and disposal was accomplished in the same manner as FM models. However, the TNT blocks for the FM model were taken out ten miles to sea and dropped into the ocean. Lugs, targets, projectiles, etc., were dropped three miles out to sea.

E. Security of the O-3 Laboratory Equipment:

The O-3 Laboratory equipment was taken from the B and D quonset huts, packed, weighed down and then disposed of in the same manner as the component parts.

F. Security of the X-5 Laboratory Equipment:

Disposal was made in the same manner as the O-3 Laboratory equipment.

G. Security of the Pit Teams Equipment:

Disposal was made in the same manner as the O-3 Laboratory equipment.

H. Navy Personnel Security:

Navy personnel manning the LCT which transported the Project materiel out to sea were given a security talk covering Project materiel. The same crew was used on all disposal trips. The LCT captain was given several security talks about the disposal of Project materiel and he was informed that he would be responsible for his crews not discussing the matter (Project) with unauthorized personnel. There have been no reports of security violation from this crew.

2. Agent's Notes:

All material disposed of had been previously decided upon by the Project. Equipment being transported back to the United States will be guarded by a courier.

All project equipment marked for disposal, had been dumped at sea by the 13th September 1945.

WILLIAM H. MCKELDIN
Special Agent, MIS.

WHM/lhb

TOP SECRET

DECLASSIFIED

These two pages describe the final disposition of critical components remaining at Tinian after the war ended. (National Archives)

COPY **UNCLASSIFIED** INTER-OFFICE MEMORANDUM

PER DOC REVIEW JAN. 1973

1/2/87
A-84-019
17-2

DATE October 24, 1945

TO: Capt. E. F. Schaffer

FROM R. W. Henderson

SUBJECT: Disassembly Inspection of Overseas F. M.

VERIFIED UNCLASSIFIED
1/2/87

Group Z-4 is interested in making the following observations and tests of the subject F. M.

1. Examine condition of detonator chimney pads.
2. (a) With the sphere oriented with the dummy plug down, install special calibrated tension bolts in the 10 through holes of the top polar cap flange which are not now occupied by bolts.

   (b) Take up these 10 bolts only to the point where they begin to take load, then remove all other bolts.

   (c) Measure length of tension bolts to determine load applied by polar cap to charge.

   (d) Remove polar cap noting if there is a tendency for the plastic covering on the blocks to stick to the cork and/or rubber.
3. (a) Using vacuum cup technique, remove or attempt to remove the top pentagonal lens and its inner charge block.

   (b) Replace these charge blocks and bolt the polar cap back in place.
4. Invert sphere and remove other polar cap noting if there is a tendency for sticking.
5. Remove dummy plug.
6. Examine condition of blotter paper adjacent to dummy plug.
7. Is there surface moisture present.
8. Is there any evidence of elevated temperatures inside the charge.
9. Install or attempt to install a pentagonal inner charge block and lens in the hole.
10. Remove the pentagonal lens and its inner charge using vacuum technique.
11. (a) Remove or attempt to remove dummy brass plug from tamper.

    (b) Examine metal surfaces for evidence of corrosion.
12. Disassemble entire charge and turn tamper over to G engineers who will proceed with detailed inspection of this unit.
13. Examine condition of all blotter paper and felt.
14. Measure thickness of cork liner and rubber pressure pads.

R. W. HENDERSON

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
NOV 3, 1980

UNCLASSIFIED

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

Form 25

17-2
A-84-019

November 1, 1945

Capt. W. F. Schaffer

R. A. Rice

Disassembly of 1560 Sphere After Overseas Shipment

I. Observations

The following observations were made by Henderson, Germer and Rice at the time of disassembly:

1. The temperature of the H.E. as measured by a thermometer stuck in a booster hole was 54°F.

2. The polar cap opposite the dummy plug was removed. It stuck to the H.E. at joints of the vinylite black coverings. Extensometer bolts were placed in vacant holes of the cap before loosening the standard bolts, but their elongation readings were meaningless due to the low loads encountered and the sticking of the cap.

3. The center lens block of the exposed end was removed without difficulty. However, the corresponding inner charge block would not loosen with approximately 1000 lbs. force being applied to it by a vacuum cup.

4. The rubber pads in the case had relaxed and were apparently taking very little load. They were almost flush with the cork at the edges, but the parts next to the chimney pad were permanently indented. After a few hours, however, the pads had recovered almost their normal position at the outer edges.

5. The cork was in good shape, but showed indentations at the joints where H.E. blocks were riding high or low. Ten readings were taken with a scale on the thickness of the cork liner at the joints of the belly-band segments:

5 readings	-	1/2"
5 readings	-	31/64"

6. The lens charge was replaced, the polar cap bolted on and the sphere inverted. The other polar cap was removed, exposing the dummy-plug end. This plug was broken at the top--apparently during previous removal overseas. The metal and plywood supports for the locating lug were exposed. They were wet and rusted. The plaster had broken because the supporting arms of the locating lug were improperly fastened to the plywood core.

7. The dummy plug was removed. Adjacent blotters were damp and discolored in spots. The exposed part of the pit was somewhat corroded, but the screwed-in plug was removable after tapping the wrench with a rubber mallet.

8. The tamper could be rotated in the charge by a 30-40 lb. force at the end of an 18" arm.

9. An inner charge and a lens charge were placed in the dummy-plug cavity. There was a small amount of slop without using shims.

10. Some blotters away from the dummy plug showed brown stains.

II. Conclusions

1. The H.E. charge was tight in the case so that there was no possibility of shifting or rattling.

2. The moisture around the dummy plug could probably have been kept out by properly sealing the booster hole at that point.

3. In storage it would be desirable to replace the dummy plug with H.E. blocks so assembled (metal-foil lining of the cavity if necessary) that they could be readily removed for insertion of the core.

R. A. BICE

RAB/bsa
cc - N.E. Bradbury
R. W. Henderson
M. F. Roy
R. S. Warner, Jr.
file

A-84-019
17-2

8 November 1945

G. B. Kistiakowsky

UNCLASSIFIED

Capt. Schaffer

Unit F-32 Disassembly, 25 October 1945

Unit F-32 was originally assembled on 25 July 1945 and along with F-31 was flown to destination from Albuquerque, New Mexico by B-29. The unit was returned several weeks ago to this Site for inspection. The unit had thus undergone, in effect, a short term surveillance test under conditions encountered only in the field, such as, temperature cycling, vibration, and humidity changes.

When the unit was returned the tail was missing and the rear ellipsoid was open to the atmosphere. The cork used to seal the booster holes, with the exception of those in the forward polar cap, were in place, although not sealed by the strippable plastic. The only evidence of deterioration from outside appearances was the fact that all unpainted metal parts were either totally or partially rusted. The lug was entirely covered by rust with the exception of the bronze insert which was in good condition. The spring detonator retainer slips, although partially rusted, were in good condition and serviceable. Thus the rusting of the metal would have in no way affected the use of the weapon. However, such conditions are correctable.

In order to cover all points in which other groups were interested, the disassembly was carried out following the steps as listed in the memoranda from these groups covering these points, copies of which are attached. The following comments are given in accordance with the numbers listed on the attached memorandum from X-4.

1. The detonator chimney pads were all in perfect condition, centered in each booster hole, and securily held in place by the cement.

2. In accordance with step 2, the tension bolts were put in place. Then after the standard bolts were removed the tension bolts were measured. These measurements indicated no pressure on the polar cap. However, when the next step in the disassembly was attempted, the reason for this was apparent.

In the next step the polar cap sling was attached, the bolts removed, and an attempt was made to lift the cap off with the floor crane. It was found that the cap had become cemented to the charge. For this reason and because the castings were compressed very tightly together, the readings taken above were not valid. Load was applied to the polar cap by the crane. Then by pounding on the cap with a rubber mallet, the cap was broken loose from the charge. The assembly itself was perfect. There was no space between adjacent castings other than that filled by the paper spacers. At a few points on the surface of the charge small flakes of H.E. had become disengaged from the casting and had stuck to the polar cap. This was due to extruded adhesive from the vinylite tape used to cover the edges of the blocks. A slight creeping of the tape was also noticed. However, it is believed that this was the same as would normally occur in the process of assembly. All chimney retainers were securely cemented in place on the casting.

UNCLASSIFIED

3. Using the vacuum cup together with the floor crane, the top pentagonal lens was easily removed from the charge. There was no evidence of any damp spacing paper or any other detrimental effects. The felt was removed from the inner casting with kerosene and the vacuum cup was used in an attempt to remove it. However, it was found impossible to remove this casting without applying an unreasonably high force, and it was decided to allow it to remain in place. The tightness of the assembly together with the small amount of adhesive extruded from the vinylite tape was undoubtedly cause for the above condition. The use of a feeler gauge showed that there was no space between the inner casting and its adjacent casting. The lens was replaced and the polar cap was set back into position. There was approximately 1/16" gap between the polar cap and the belly segments compared to a gap of approximately 3/16" as normally experienced. However, the charges were still positioned in their compressed state and this fact would account for the apparent lack of compression.

4. The sphere was then inverted so as to have the dummy plug in an upright positio

5. The polar cap was removed after similar treatment with a rubber mallet. Upon removal, it was found that the entire top portion of the dummy lens was missing. Apparently this cap had been removed at destination and the dummy plug had either been broken in removal or was found broken upon removal of the polar cap and the pieces were disposed of. The iron inserts in the dummy plug were exposed and were badly rusted. Several drops of free moisture were present on these parts. The drops of moisture were tested by means of indicator and found to be neutral. Since moisture coming from cement would normally be alkaline, it is believed that the moisture present in this unit came from the outside. The booster hole which keyed the dummy plug in place was the only point that moisture could enter the sphere, since all other booster holes were tightly sealed by means of (1) the rubber pad against the chimney plate, (2) the plastic lacquer covering the casting, (3) the vinylite tape sealing the booster cavity, and (4) the cork in the booster hole. The dummy plug was removed with very little effort. The aluminum cover plates were badly pitted with a "wormy type corrosion".

6. The blotting papers immediately adjacent to the dummy plug were very slightly damp.

7. Previously answered.

8. There is no evidence of elevated temperature inside the charge.

9. There was slight corrosion on the brass shipping plug in the pit and on the aluminum immediately surrounding the brass plug, i.e., the area covered by the dummy plug. The key of the pit was removed and the dummy plug was replaced by a quality inner casting and a lens. The castings fitted perfectly.

10. The castings were again removed without difficulty using the vacuum cup technique.

[redacted] CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

UNCLASSIFIED

11. The G-Engineers using their special tools attempted to remove the dummy brass plug from the tamper. Although it was tight at first try, by slight tapping with a rubber mallet upon their special tool, it turned freely. It was possible to move the pit within the charge by the application of approximately 50 to 70 ft. lbs.

12. The remainder of the charge was disassembled with very little difficulty. The side plates were cemented to the castings in the same manner as the polar caps. However, they were removed with very little difficulty. The pit was turned over to the G-Engineers who made a detailed inspection of this unit. A summary of their findings is covered in the attached report.

13. The felt and blotting paper were all in very good condition.

14. There was evidence of permanent set in the cork. Measurements taken several days after disassembly revealed a set of approximately 1/16" under normal thickness. The rubber also showed a permanent set although it was not possible to measure it, due to the variation in the original thickness of the rubber. The impression of the chimney disks was clearly visible in the rubber.

Felt, blotting paper, and tape were removed from the castings by means of kerosene. All castings were carefully inspected and measured by the S-Site inspection personnel. The comments on their inspection is covered by a memorandum, a copy of which is attached. X-ray inspection of two of these castings gave negative results.

SUMMARY

Unit F-32 was designed and assembled for immediate use and not for prolonged storage. If the condition of the unit is judged on this basis, it can be said that all was satisfactory. Even for long term storage, there would be only two changes to make. The detonator spring clips and other metal parts would have to be protected from corrosion and the dummy plug redesigned or eliminated. The problem of the dummy plug could be solved by using it for aligning the charge in the assembly process and then replacing it with the H.E. castings for storage.

The two points mentioned above were minor and it is believed that all present for the disassembly will agree that the unit would have functioned properly at the time of disassembly.

Improvement is desirable to the material used (now cork) for lining the sphere. However, such changes are underway in the new design of the bomb.

UNCLASSIFIED

W. F. Schaffer, Jr.
Captain, C.E.

cc: ✓Bradbury
Roy
Warner
Henderson
Major Ackerman
Holloway
[illegible]

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973
[redacted]

(LANL)

A-84-019

November 5, 1945

FM Pats

TO: Capt. W. F. Schaffer

FROM: R. E. Schreiber

SUBJECT: Pit from FM 32

1. This is a report on the examination of the pit removed from FM 32 on 25 October 1945.

2. Aluminum sphere (#175): Brass alignment plug was removed without difficulty. There was evidence of some corrosion near the hole, but not at boundary of brass and aluminum. This corrosion had penetrated only about .0005" and was removed by mild scraping. It is presumably associated with the moisture found around the plaster dummy plug. The corrosion is not regarded as being serious enough to interfere with the proper functioning of the pit. No dimensional inspection was made.

3. Tuballoy ring and plug (#5): A dummy loading operation was performed, and no difficulties were encountered. There was considerable surface oxidation of the tuballoy as evidenced by comparing the appearance of the surfaces with those of freshly-cut tuballoy. This was expected and is not thought to be serious. An inspection was made of the dimensions of the ring and plug. All dimensions checked with the original inspection to within .003" except the O.D. of the ring which had increased by .005". No evidence of serious dimension change or warpage was found. The I.D. of the ring and the O.D. of the plug remained quite constant, these being the critical dimensions for the assembly operation.

4. Boron plastic shell (#3): No flaws or important dimensional changes were observed.

5. Summary: Except for the slight corrosion discussed in (2), no damage was observed. The pit appears to be as good functionally as when first loaded.

cc: Holloway

(LANL)

[redacted]

22 October 1945

MEMORANDUM TO Major General L. R. Groves

SUBJECT: Status of Project Officer in Combat Airplane - Atomic Bomb Operations

1. Two officers from the atomic bomb project were in the attack airplane on both the Hiroshima and the Nagasaki mission. Commodore W. S. Parsons, USN, was the senior project officer on the Hiroshima mission; Commander F. L. Ashworth, USN, was the senior project officer on the Nagasaki mission.

2. The duties and responsibilities of the senior project officer were covered generally in the following paragraph quoted from a letter sent in June, 1945, by Major General Lauris Norstad, Chief of Staff, 20th Air Force to Major General Curtis LeMay, Commanding General, 21st Bomber Command.

> "In actual delivery it is desired that the B-29 airplane which carries the bomb also carry two military officer specialists. The senior officer specialist will be qualified by familiarity with the design, development and tactical features of the bomb, to render <u>final judgment</u> in the event that an emergency requires deviation from the tactical plan. Captain W. S. Parsons, U. S. Navy, will undoubtedly be the senior officer specialist for initial battle deliveries, with Commander F. L. Ashworth, as his alternate. Other alternates will be designated when they are fully qualified. The junior officer specialist will have the duty of performing tests and planned adjustments on the circuits of the bomb during flight."

3. The subject was discussed in conferences between General Groves, General Norstad and General Farrell and between General Groves, General LeMay and General Farrell. There were also discussions in the field. Some of the officers participating in the field discussions were General Farrell, Col. Blanchard (of Gen. LeMay's staff), Col. Paul Tibbetts, Commodore Parsons, Commander Ashworth and Major Charles Sweeney.

4. There was agreement between Commodore Parsons and Colonel Tibbetts, and similarly between Commander Ashworth and Major Sweeney as to methods of operation. In amplification of General Norstad's instructions it was agreed that the project officer would be consulted if there was any difficulty on identification of target. It was also understood that there would be a joint agreement between plane commander and project officer on questions of ditching the bomb; delivery on a less favorable than the primary target; delivery at lower elevation than ordered or by other than visual observation. In case of disagreement the project

[redacted]

K0311

[redacted]

officer would have final decision. It was recognised that the plane commander did not have sufficient detailed knowledge of the bomb and its operation to render final judgment in those matters. While the Air Forces hoped at a later date to have senior air officers as plane commanders who would be fully qualified to make final decisions concerning the bomb, it was understood that their officers were not so qualified at the time of delivery of the first bombs.

5. The command on the mission could be properly called a joint command, with the plane commander primarily responsible for all things connected with the operation of the airplane, including command of the crew, navigation and defense against enemy attacks; while the project officer was primarily responsible for the care and operation of the bomb until its release on the target and for decisions concerning its tactical use.

T. F. FARRELL
Brigadier General, USA

K0312

[redacted]

(National Archives)

TOP SECRET

TOP SECRET
Auth: CG, Twentieth Air Force
Initials: [illegible]
Date: 2 August 1945

FIELD ORDERS)
:
NUMBER 13)

TWENTIETH AIR FORCE
GUAM
2 August 1945 - 1500K

Map: JAPAN Aviation Chart 1:218,880.

Copy 20 of 32

20

1. a. Omitted.

b. (1) Omitted.

(2) (a) No friendly aircraft, other than those listed herein, will be within a 50 mile area of any of the targets for this strike during a period of four hours prior to and six hours subsequent to strike time.

(b) Air-Sea Rescue facilities will be provided for this mission through standard channels by Headquarters, Twentieth Air Force.

2. Twentieth Air Force attacks targets in JAPAN on 6 August.

3. a. Omitted.

b. Omitted.

c. 313th Wing, 509th Group:

(1) Primary target: 90.30 - HIROSHIMA URBAN INDUSTRIAL AREA.

(a) Aiming Point: 063096. Reference: XXI BomCom Litho-Mosaic HIROSHIMA AREA, No. 90.30 - Urban.

(b) IP: 3424N - 1330530E.

(c) Breakaway (if target is bombed):

Right turn of at least 150 degrees 3400N - 13334E.

(2) Secondary target: 90.34 - 168, KOKURA ARSENAL.

(a) Aiming Point: 104082. Reference: XXI BomCom Litho-Mosaic KOKURA ARSENAL, No. 90.34 - 168.

(b) IP: 3343N - 1313830E.

(c) Breakaway (if target is bombed)

Left turn of at least 150 degrees 3343N - 1313830E.

(3) Tertiary target: 90.36 - NAGASAKI URBAN AREA.

(a) Aiming Point: 114061. Reference: XXI BomCom Litho-Mosaic NAGASAKI AREA, 'MITSUBISHI STEEL and ARMS WORKS, No. 90.36 - 546.

(b) IP: 3228N - 13039E.

- 1 -

TOP SECRET

INITIAL

CLASSIFICATION CANCELLED (OR CHANGED TO Confid.) BY AUTHORITY OF THE COMMANDING GENERAL, 20TH. AIR FORCE BY [signature] JAN 23 1951
(NAME & GRADE) (DATE)
[illegible]
Captain USAF
Asst Adjutant General

Classification canceled to Unclassified, by Authority of The Chief of Staff, U. S. Air Force by [illegible]

F.O. #13

(c) Breakaway (if target is bombed):

Left turn of at least 150 degrees
3137N - 13128E.

(4) Force required:

(a) Strike force: 3 A/C.

(b) Spare: 1 A/C, which will proceed to IWO JIMA to stand by in case of abort. This A/C will be loaded with full gas load but no bombs.

(c) Weather: 3 A/C, which will be dispatched one to each target at such a time as to be able to relay, from their assigned target, the target weather forecast for strike time, broadcasting this message between 060845K and 060915K. This will enable strike force to select either the secondary or tertiary target in the event the primary is found to be cloud-covered. Each weather A/C will have aboard a weather observer furnished by the 313th Wing.

(5) C.O., 509th Group, will insure that necessary personnel and special equipment are dispatched to IWO JIMA to handle transfer of bomb load to spare A/C in case of abort.

(6) Route:

Base
IWO JIMA
3337N - 134303 (Departure Point)
341530N - 1333330E
IP
Target
Breakaway
IWO JIMA
Base.

(7) Altitudes:

(a) Enroute to target: Below 10,000 ft. until necessary to climb to bombing altitude. Below 5,000 ft. prior to passing IWO JIMA.

(b) Of attack: 28,000 to 30,000 ft.

(c) On route back: At or below 18,000 ft. when passing IWO JIMA.

(8) Time Control: Pass Departure Point at 060915K.

(9) Bombing Airspeed: 200 mph CIAS.

(10) Bomb load and special equipment: As specified by C.O., 509th Group.

(11) Only visual bombing will be accomplished. Strike force will pass sufficiently close to primary target to assure, before going on to secondary target, that visual bombing is not possible on the primary.

(12) Post-strike photography: C.O., 509th Group, will be responsible for briefing and dispatching two F-13 A/C, which will be detached to the 509th Group by the 3rd Photo Recon Sq., for this strike. These A/C will not enter target area until 4 hours after bombs away. To insure this schedule is maintained regardless of whether the strike force has to make use of the spare A/C at IWO JIMA or not, the photo A/C will be required to check in with the ground stations at both TINIAN and IWO JIMA to obtain clearance to proceed past IWO JIMA. If these photo A/C do not receive notification of which target has been bombed, they will photograph all three targets.

d. Omitted.

e. Omitted.

f. 3rd Photo Recon Sq.:

(1) Dispatch 2 F-13 A/C to NORTH FIELD, TINIAN, to land by C-516OOK, reporting to C.O., 509th Group, for post-strike photo briefing as specified above in par. 3. c. (12).

g. CSC, IWO JIMA:

(1) Participate in event of abort landing at IWO JIMA, making all necessary facilities available upon request of the 509th Group Project Officer.

(2) Provide clearance to photo A/C, as provided for above in par. 3. c. (12), after assurance from 509th Group Project Officer that no abort has occurred.

4. No Tactical Mission Number is assigned to this mission. For record purposes, Special Bombing Mission Number 13 is assigned.

5. a. (1) Strike reports will be transmitted in accordance with Headquarters, Twentieth Air Force Regulation 100-20, dated 15 May 1945. 313th Wing Air-Ground Station will rebroadcast strike reports via the F method on all 313th Wing strike frequencies.

(2) Contact reports will be transmitted in accordance with Headquarters, Twentieth Air Force Regulation 100-19, dated 2 July 1945.

(3) IFF doctrine will be as follows: Turn IFF to position #1 immediately before take-off. Turn IFF off when 50 miles from coast of Japanese mainland. Turn IFF on at land's end (enemy coast) when returning from target. Turn IFF off when landing.

(4) Channel G (143.01 mcs) of the AN/ARC-3 will be used as inter-plane command channel.

(5) Retune Channel 7 of AN/ART-13 transmitter of strike aircraft to 7455 kcs. Any strike plane aborting will immediately call the Twentieth Air Force Weather Station, IWO JIMA, call sign OOV131, on 7455 kcs and transmit message saying "aborting". The 313th Wing Ground Station will monitor 7455 kcs and pass any aborting message to C.O. of 509th Group.

(6) Radio operators of strike aircraft will monitor 7310 kcs and intercept in-flight weather reports from weather planes over target. These weather reports will be addressed to 313th Wing Air-Ground Station, OOV670. The strike aircraft will intercept these in-flight weather reports.

F.O. #13

(7) Photographic aircraft will return AN/ART-13 Channels 1, 3 and 7 as follows: Channel 1 - 3410 kcs; Channel 3 - 10125 kcs; and Channel 7 - 7310 kcs. Photographic aircraft will be controlled by 313th Wing Air-Ground Station, OOV670. Photographic aircraft will monitor appropriate 313th Wing strike frequencies during their entire mission and intercept strike reports as rebroadcast by 313th Wing Air-Ground Station. Strike reports will determine which target will be photographed.

(8) Photographic aircraft of the 3rd Photo Recon Sq., attached to the 509th Group, will contact the 313th Wing Air-Ground Station, OOV670, on 7310 kcs, and the Twentieth Air Force Weather Station, IWO JIMA, on frequency 7455 kcs, call OOV181, and question both stations as to whether any striking aircraft of the 509th Group have aborted. This will determine whether the photographic aircraft will proceed to target or land at IWO JIMA.

(9) Annex A, attached hereto, will be the weather code used by the weather aircraft to transmit in-flight weather observations from over the target. The letter scramble indicated on the form will be used. Transmission of weather information will take the following form: letter indicated in column under letter scramble will indicate the weather element being reported. Each letter (weather element) will be followed by a number which indicates the actual condition. These numbers, one through zero, appear at the top of the weather code form. An example of an in-flight weather transmission might be as follows: ØØV67Ø V 21V675 - 16Ø7Ø33 BT Y2Q1KØB13ØXØC2R1 BT IMI ØØV67Ø V 21V675 - 16Ø7Ø33 BT Y2Q1KØB13ØXØC2R1 BT AR. The above message, when decoded, would indicate the following: low clouds, 1 - 3/10 small; middle cloud amount, none; height of tops, unknown; high cloud, none; height of base, unknown; height of tops, unknown, advise, bomb secondary; visibility in clear air, clear. This message will be handled by the broadcast method and repeated as shown in the example above.

(a) Each weather aircraft will be designated a specific target to observe. Each weather aircraft's radio call sign, together with the name of the target assigned to that aircraft, must be carried in both the Pilot's and the Radio Operator's Folders. A simple way of designating this would be as follows:

Aircraft Call Sign	Target Observed
21V675	Primary - HIROSHIMA
7V675	Secondary - KOKURA
12V675	Tertiary - NAGASAKI

b. Command Post: Hq., Twentieth Air Force, GUAM.

BY COMMAND OF LIEUTENANT GENERAL TWINING:

R K TAYLOR
Colonel, Air Corps
Chief of Staff

OFFICIAL:

[signature]
J B MONTGOMERY
Colonel, G.S.C.
D C/S, Operations

(USAF)

WAR DEPARTMENT
A. A. F. FORM NO. 1 A · FILE
REV. (1 JAN. 44)

AIRPLANE FLIGHT REPORT - ENGINEERING

INSPECTION STATUS

	DATE OR HOURS DUE	INSPECTED TODAY BY	STATION
PREFLIGHT	8-8-45	Mc	
DAILY	8-9-45	McCabe	
25 HOURS	176:55		APO # 336
50 HOURS	171:55		
100 HOURS	171:55		

SERVICING AT STATION OF TAKE-OFF (CHECK IMMEDIATELY BEFORE TAKE-OFF)

SERVICE	FUEL (GALLONS) SERVICED	FUEL IN TANKS	OIL NO. 1 SERVICED	NO. 1 IN TANKS	NO. 2 SERVICED	NO. 2 IN TANKS	NO. 3 SERVICED	NO. 3 IN TANKS	NO. 4 SERVICED	NO. 4 IN TANKS	RADIATOR
1ST	9455	7100		520		520		520		520	
2ND											
3RD											
4TH											
5TH											

INSPECTION OF AUXILIARY EQUIPMENT

EQUIPMENT	SYMBOL	INSPECTED BY	STATION
BOMBARDMENT	L	Litzak	
GUNNERY	L	Litzak	
CHEMICAL	L	Litzak	
COMMUNICATIONS	N	Nelson	
PHOTOGRAPHIC	D	Dabe	APO # 336
NAVIGATION	Mc	McCabe	
A.P.R.	Mc	McCabe	
RADAR	B	Beer	

STATUS TODAY: 1. / 2. 3. 4.

EXPLANATION: T.O. 01-1-23 [illegible]

EXCEPTIONAL RELEASE

WHEN THE "STATUS TODAY" IS INDICATED BY A RED SYMBOL, AND AN "EXCEPTIONAL RELEASE" HAS NOT BEEN GRANTED BY AN AUTHORIZED MAINTENANCE OFFICER, THE PILOT OF THE AIRCRAFT WILL SIGN THIS RELEASE BEFORE FLIGHT.

RELEASED FOR FLIGHT: 1. Geo. Marquardt * 2.

REMARKS: PILOTS AND MECHANICS - SEE INSTRUCTIONS INSIDE FRONT COVER.

[illegible] installed
#2 VACUUM PUMP INOPERATIVE - HEATER ON #3 ENG. INOPERATIVE

AIRCRAFT AND ENGINE TIME RECORD (ENTER IN HOURS AND MINUTES)

ENGINE	NO. 1	NO. 2	NO. 3	NO. 4
HOURS TO DATE	[illegible]	[illegible]	142:15	[illegible]
HOURS TODAY	12:40	12:40	12:40	12:40
TOTAL	154:55	154:55	154:55	154:55
OIL CHANGE DUE	Engine Change			
CUNO. CLEANING DUE	[illegible]	[illegible]	[illegible]	

AIRCRAFT	
HOURS TO DATE	142:15
HOURS TODAY	12:40
TOTAL	154:55

[illegible] - McCabe
#1 - 9:45
#2 - 2:55

25 HR INSP. COMPLETED - McCABE
#3 ENG. HEATER DUCT FUSE REPLACED - McCABE
#2 VACUUM PUMP REPLACED - McCABE
#1 CREEPING COWL FLAP MOTOR REPLACED - H/a/c.
Camera Removed - Dub
RADIO EQUIP. PREFLIGHTED - 8/8/45 MECHANICS
AUX RADAR PREFLITED - MITRO
APR-13 PreflTed 8-7-45 Beer
CAMERAS K-22, K-20 - RADAR SCOPE INSTALL

DATE	AIRCRAFT ORG. DATA	AIRCRAFT DATA	ENGINE DATA	
8-9-45	AIR FORCE: 20	COMPONENT:	ENGINE MODEL: R-3350-57	
STATION: APO #336	COMD., SERV. COMD. OR DEP'T: 21	VHR	SERIAL NO.: [illegible]	SERIAL NO.: [illegible]
CREW CHIEF OR ENGINEER: S/Sgt. McCabe	GROUP NO. & TYPE: 509	AIRCRAFT MODEL: B-29	SERIAL NO.: [illegible]	SERIAL NO.: [illegible]
	SQUADRON NO. & TYPE: 393	AIRCRAFT SERIAL NO.: 44-86292	TOTAL FLIGHT TIME → 12:40	

* R Gackenbach - Navigator

This report signed by Commander George Marquardt shows the *Enola Gay* (44-88292) being released for flight on 8/9/45 as the weather plane to Kokura during the Nagasaki mission. (Courtesy of Russell Gackenback)

[illegible]
[illegible] c/o Postmaster
San Francisco, California

8 August 1945

OPERATIONS ORDER)
:
NUMBER 39)

Date of Mission: 9 August 1945

Briefings: See Below

Take-off: Weather ships: 0230
Strike Ships: 0330

ETA: 1630

Out of Sacks: Weather 2300
Strike 2400

Mess: 2345 to 0145

Lunches: 24 at 2400
48 at 0100

Trucks: 2 at 0045
4 at 0145

A/C NO.	VICTOR NO.	APCO	CREW SUBS	PASSENGERS
Weather Mission:				
292	82	Marquardt		
347	95	McKnight		
Combat Strike:				
297	77	Sweeney		Beser
353	89	Bock		
354	90	Hopkins (Crew C-14)		
To Iwo				
298	83	Taylor		Col Smith T/Sgt Kupfenberg
Alternates for above aircraft:				
291	91	1st Alternate		
301	85	2nd Alternate		

GAS: A/C #77 7250
All others 7400

AMMUNITION: 1000 rds per gun.

BOMBS: Special

CAMERAS: K-20 in all strike A/C & Alternates

RELIGIOUS SERVICES: Catholic: 1830
Protestant: 2300

BRIEFINGS:

__Weather Ships__
General briefing in War Room at 2330
Special briefings immediately following General as follows:
A/C and P - Operations
Nav. and Rad Oprs. - War Room.
Bombardiers - War Room.
Flt Engs - Library.

__Strike Ships__
General briefing in War Room at 0030.
Special briefings immediately following General as follows:
A/C and P - Operations.
Nav and Rad Opr. - War Room.
Bombardiers - War Room.
Flt Engs. - Library.

__All Radio Operators brief in Communications at 2230.__

James I Hopkins Jr.
JAMES I HOPKINS JR,
Major, Air Corps,
Operations Officer.

This is the Nagasaki mission order showing the *Enola Gay* (A/C No. 292) being assigned as one of the weather planes. (Courtesy of Russell Gackenback)

DECLASSIFIED
Authority NND 730039
By PT NARA Date 7-18-05

THE MAKING OF AN EXACT COPY OF THIS MESSAGE, AND ITS TRANSMISSION IN LITERAL PLAIN TEXT ARE AUTHORIZED SUBJECT TO NORMAL PROCEDURE FOR THE SAFEGUARDING OF MILITARY INFORMATION.

TWENTIETH AIR FORCE.

TOP SECRET

INCOMING MESSAGE

CLASSIFICATION: TOP SECRET

SECTION	INITIALS	COPY NO.
CHIEF OF STAFF		5
DC/S OPRS		DIST. BY FJB 6819
DC/S P&A		
DC/S THE		TYPED BY
A.G.		emd

TELECON MSG NO.	SUBJECT	DATE
CMDW. 576	RETURN REPORT FOR CENTERBOARD OPERATION	9 August 1945

TO:	INFO:	FROM:
COMGENUSASTAF For Kilpatrick		COMGENAAF 8 Who passes for Commander Ashworth

090600Z .. 2345 EWT

This message for Farrell (Top Secret) Sweeney, Hopkins and Bock landing Okinawa 090345Z. Arrived rendezvous point at scheduled time waiting about forty-minutes being joined by aircraft piloted by Bock only. Received weather reports and made decision to attack primary target. Arrived in target area 090055Z. Target about 3/10 cloud with some haze and heavy smoke. Made 3 runs on primary but each time target was obscured by haze and smoke. After fifty minutes decided to attack secondary. Attacked in accordance strike report already submitted. Approach made by radar with about last thirty seconds visual. Preliminary conference with observers with Hopkins and Bock places impact approximately on Mitsubishi Steel and Arms Works, target number 546. Consensus of opinion visual effect equal to or probably greater than at Hiroshima. Column of smoke and mushroom reached about 30,000 feet in 3 minutes and soon reached at least 40,000 . Dust covered area at least two miles in diameter. Probably fair amount of blast on unprofitable areas. Gasoline consumption at high altitude, cruising, failure to rendezvous, and time over primary target forced decision to drop rather than attempt questionable chance of reaching Okinawa with unit.

END

TOD 0800Z

DECLASSIFIED
DOD Dir. 5200.9, Sept. 27, 1958
NWD by [illegible] date 27 May 59

DIST	ACTION	INFO
		TOP SECRET

CLASSIFICATION TOP SECRET CLASSIFICATION

5-33, AF (REV 1 APR 45)

This is the Nagasaki post-mission report sent immediately after landing at Okinawa. (National Archives)

TOP SECRET

10 AUGUST 1945

REPORTS 091848Z

X

X

COMGENUSASTAF GUAM

INFO: COMGENUSASTAF (REAR) WASH (URGENT) ATTN: GENERAL NORSTAD

AIMCR 5482 SUBJECT: FINAL REPORT, 509TH SBM 16, STRIKE CENTERBOARD, FLOWN 9 AUGUST 1945.

1. TARGET ATTACKED: NAGASAKI

2. TIME TAKE OFF: FIRST: 081749Z LAST: 081751Z

3. NUMBER A/C AIRBORNE: 3

4. BOMB [redacted] DATA: A. LOAD AND TYPE: SPECIAL

   B. FUSING: SPECIAL

   C. DISPOSITION: 3 SECONDARY NAGASAKI URBAN AREA

   A/C VICTOR 77, VICTOR 89, VICTOR 90

5. METHOD OF BOMBING: VISUAL

6. TIME BOMBS AWAY: FIRST: 090158Z LAST: 090201Z

7. WEATHER: 7-10/10 ALTO CUMULUS. BOMBED THROUGH HOLE.

8. PRESSURE ALTITUDE: 28,000 FEET

9. ENEMY AIR OPPOSITION: NONE

TOP SECRET

11. OBSERVATIONS: 1 LARGE SHIP IN HARBOR AREA AT NAGASAKI, NUMEROUS SMALLER VESSELS IN SAME AREA. 4 UNIDENTIFIED SINGLE ENGINE AT 33/15 N 132/00 E, LOW, CIRCLING. 13 UNIDENTIFIED S/E AT 30/25 N 130/38 E, 12 SILVER IN COLOR, 1 OFF COLOR, 2 MILES EAST AT 12-15,000 FEET. NEAR SENDAI, SE COAST OF KYUSHU SMOKE WAS SEEN, VERY MUCH LIKE THAT OBSERVED WHEN SPECIAL BOMB EXPLODES, INTENSITY MAINTAINED TILL OUT OF SIGHT.

12. BOMBING RESULTS: FAIR TO GOOD.

13. TIME OF LANDING: FIRST: 091306Z LAST: 091339Z.

14. OTHER SIGNIFICANT INFORMATION: 90 PERCENT OF RUN WAS RADAR, BOMBARDIER TOOK OVER AND MADE VISUAL CORRECTIONS IN LAST 10 PERCENT. BOMB HIT APPROXIMATELY 500 FEET SOUTH OF MITSUBISHI PLANT. COMPANION SHIP OBSERVED. AFTER EXPLOSION LARGE WHITE SMOKE RING FORMED, RED BALL OF FIRE COVERING 1/2 OF AREA. THEN COLUMN OF SMOKE FORMED 1/2 MILE WIDE, FUNNELING UPWARD, BOTTOM DARK BROWN IN COLOR, CENTER AMBER COLOR, TOP WHITE. COLUMN ROSE TO 50,000 FEET, RISING TO 30,000 FEET IN ONE AND ONE HALF TO TWO MINUTES. MANY SMALL BRIGHT FIRES OBSERVED. CONSIDERABLE SMOKE OBSERVED 175 MILES FROM AREA. FIVE SHOCK WAVES FELT.

15. MISSION EFFECTIVE.

16. REMARKS: A/C VICTOR 83 STOOD BY AT IWO JIMA FOR EMERGENCY BUT WAS NOT CALLED UPON, RETURNING THIS BASE 090910Z. A/C VICTOR 77, 89, AND 90 LANDED OKINAWA 090400Z - 090404Z, SHORT OF GAS, TOOK OFF 090703Z - 090705Z.

END...

This is the final Nagasaki Strike Report. Note the two different bomb drop times even though only one bomb was dropped. (USAF)

THE YIELDS OF THE HIROSHIMA AND NAGASAKI EXPLOSIONS

by

John Malik

ABSTRACT

A deterministic estimate of the nuclear radiation fields from the Hiroshima and Nagasaki nuclear weapon explosions requires the yields of these explosions. The yield of the Nagasaki explosion is rather well established by both fireball and radiochemical data from other tests as 21 kt. There are no equivalent data for the Hiroshima explosion. Equating thermal radiation and blast effects observed at the two cities subsequent to the explosions gives a yield of about 15 kt. The pressure-vs-time data, obtained by dropped, parachute-retarded canisters and reevaluated using 2-D hydrodynamic calculations, give a yield between 16 and 17 kt. Scaling the gamma-ray dose data and calculations gives a yield of about 15 kt. Sulfur neutron activation data give a yield of about 15 kt. The current best estimates for the yield of these explosions are the following:

Hiroshima	15 kt
Nagasaki	21 kt

The outside limits of uncertainties in these values are believed to be 20 percent for Hiroshima and 10 percent for Nagasaki.

I. INTRODUCTION

The Manhattan Project culminated in the design and fabrication of two types of nuclear weapons--Little Boy and Fat Man. The first type was exploded over Hiroshima, the second over Nagasaki. Estimates of radiation exposures depend in part on explosive yields, and much of the evaluation of radiation effects upon man depends on data from the Hiroshima and Nagasaki explosions. The yield of the Fat Man has been determined rather well, being given variously from 19-24 kt. (Present official yield is 23 kt.[1]) Estimates[2-7] for the Little Boy have ranged from 6-23 kt. (The current official yield is 13 kt.[1]) The data from which estimates may be made are fragmentary, and the

These excerpts from Los Alamos report LA-8819 describe the Report Abstract, Mission Summaries, Mission Parameters, and Weapon Yields. (LANL)

TABLE I

MISSION SUMMARIES FOR STRIKE AIRCRAFT

	Hiroshima	Nagasaki
Bomb designation	L-11, Little Boy	F-31, Fat Man
Mission number	13	16
Strike aircraft	V-82, Enola Gay	V-77, Bock's Car
Aircraft commander	Col. P. W. Tibbets	Maj. C. W. Sweeney
Pilot	Capt. R. A. Lewis	1st Lt. C. D. Albury
Navigator	Capt. T. T. Van Kirk	Capt. J. F. Van Plet
Bombardier	Maj. T. W. Ferebee	Capt. K. K. Beahan
Weaponeer	Capt. W. S. Parsons (USN)	Cdr. F. L. Ashworth (USN)
Time of detonation	0815, August 6, 1945	1102, August 9, 1945
Indicated air speed	200 mph	200 mph
True air speed	328 mph	315 mph
Wind	8 knots at 170^{o}	1-knot head wind
True heading	262^{o}	
True course	265^{o}	
Indicated altitude	30 200 ft	28 000 ft
True altitude	31 600 ft (34 640 ft)[a]	28 900 ft
Temperature	Ind. $-22^{o}C$, True $-33^{o}C$	
Height of burst[28]	580 $\pm$ 15 m	503 $\pm$ 3 m
Time of fall	44.4 s (46.9 s)	47.0

[a] Quantities in parenthesis have been derived from canister pressure-time records and test drop data.

(LANL)

TABLE III

MISSION PARAMETERS

	Hiroshima	Nagasaki
Height-of-burst (ft)	1 903 (Ref. 28)	1 650 (Ref. 28)
Aircraft altitude (ft)	31 600 (Ref. 26) 32 700 (Ref. 10) 35 000 (Ref. 25)	28 900 (Ref. 26)
Ground speed (mph)	328 (Ref. 26,16)	315 (Ref. 26)
Head wind speed (mph)	0 (Ref. 10)	1 (Ref. 26)
Aircraft separation (ft)	300 (Ref. 27)	300[a]
Time delay from bomb to canister release[a] and start of record[25] (s)	1	1
Parachute opening time (s)[a]	1	1
Canister drop speed (ft/s)(?)	16	16

[a] Estimates.

(LANL)

TABLE X

YIELD EVALUATIONS FOR LITTLE BOY (HIROSHIMA)

Method	Yield (kt)
Canister P(T) Data	16
Equivalent Thermal	14
Cypress Charring	15
Equivalent Blast	15
Lord Penney, et al.	12
Thermoluminescence of Roof Tile	17
Sulfur Activation	15
Design Predictions (Schiff)	15

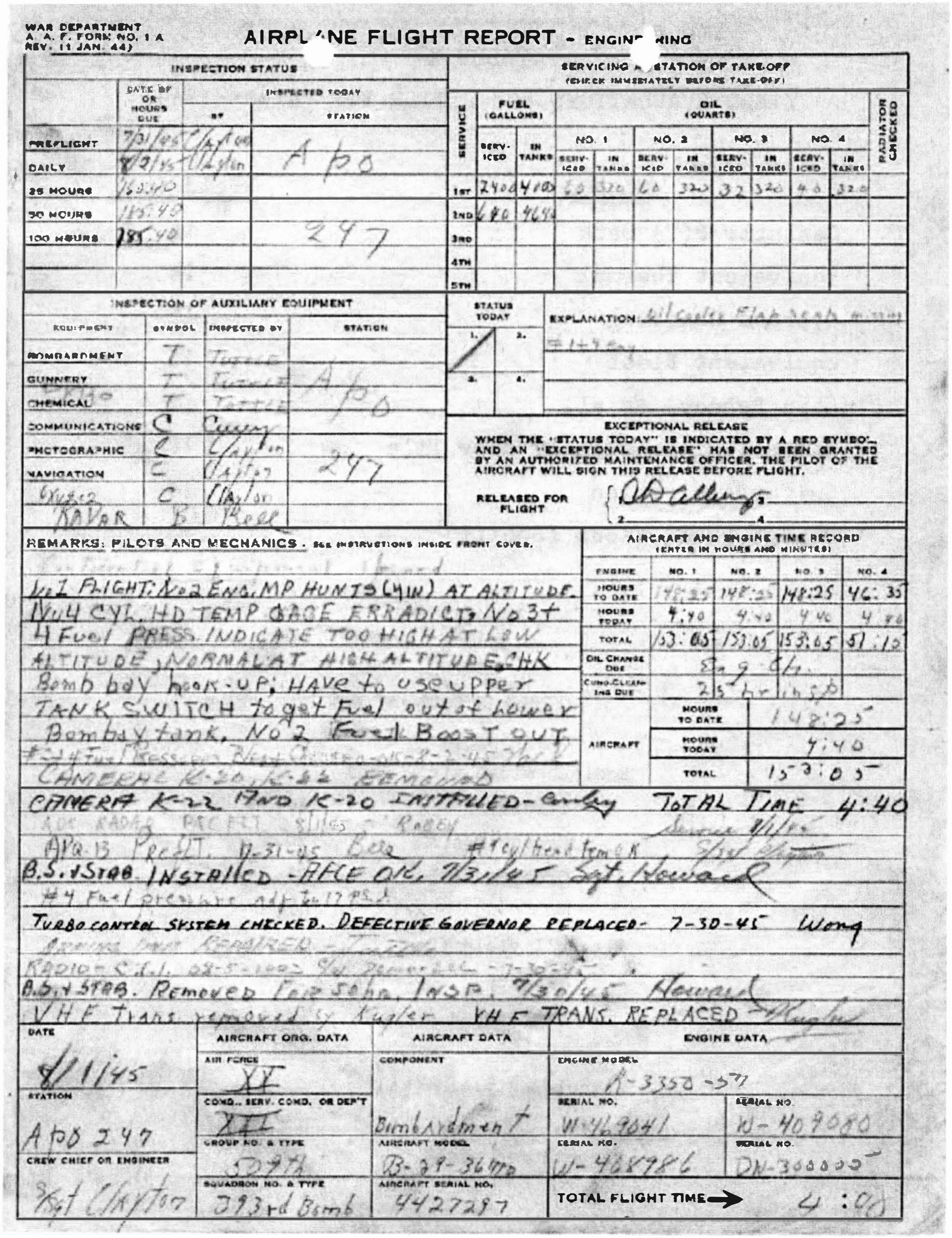
(LANL)

YIELD OF THE FAT MAN

Radiochemical yield (kt)	
Trinity	20.3
Crossroads A	20.4
Crossroads B	21.7
Fireball yield (kt)	
Trinity	20.8
Crossroads A	21.4
Calculated yield (kt)[a]	22
Recommended yield	21

[a] By R. Osborne, Los Alamos National Laboratory Group X-4.

(LANL)



WAR DEPARTMENT
A. A. F. FORM NO. 1 A
REV. (1 JAN. 44)

AIRPLANE FLIGHT REPORT - ENGINEERING

INSPECTION STATUS

	DATE OF OR HOURS DUE	INSPECTED TODAY BY	STATION
PREFLIGHT	7/31/45	Clayton	A P O
DAILY	8/2/45	Clayton	
25 HOURS	165.40		
50 HOURS	185.40		247
100 HOURS	185.40		

SERVICING AT STATION OF TAKE-OFF (CHECK IMMEDIATELY BEFORE TAKE-OFF)

SERVICE	FUEL (GALLONS) SERVICED	FUEL IN TANKS	OIL NO. 1 SERVICED	NO. 1 IN TANKS	NO. 2 SERVICED	NO. 2 IN TANKS	NO. 3 SERVICED	NO. 3 IN TANKS	NO. 4 SERVICED	NO. 4 IN TANKS	RADIATOR CHECKED
1ST	2400	4100	60	320	60	320	32	320	40	320	
2ND	640	4640									
3RD											
4TH											
5TH											

INSPECTION OF AUXILIARY EQUIPMENT

EQUIPMENT	SYMBOL	INSPECTED BY	STATION
BOMBARDMENT	T	Tuttle	A P O 247
GUNNERY	T	Tuttle	
CHEMICAL	T	Tuttle	
COMMUNICATIONS	C	Curry	
PHOTOGRAPHIC	C	Clayton	
NAVIGATION	C	Clayton	
Gyro 2	C	Clayton	
RADAR	B	Bell	

STATUS TODAY

EXPLANATION: Oil Cooler Flap Seal missing #1+4 Eng.

EXCEPTIONAL RELEASE

WHEN THE "STATUS TODAY" IS INDICATED BY A RED SYMBOL AND AN "EXCEPTIONAL RELEASE" HAS NOT BEEN GRANTED BY AN AUTHORIZED MAINTENANCE OFFICER, THE PILOT OF THE AIRCRAFT WILL SIGN THIS RELEASE BEFORE FLIGHT.

RELEASED FOR FLIGHT: 1. D.D. Albury

REMARKS: PILOTS AND MECHANICS. SEE INSTRUCTIONS INSIDE FRONT COVER.

1. FLIGHT: No 2 ENG. MP HUNTS (4 IN) AT ALTITUDE. No 4 CYL. HD TEMP GAGE ERRADIC. No 3 + 4 Fuel PRESS INDICATE TOO HIGH AT LOW ALTITUDE, NORMAL AT HIGH ALTITUDE. CHK Bomb bay hook-up; HAVE to use upper TANK SWITCH to get Fuel out of lower Bomb bay tank, No 2 Fuel Boost OUT.
CAMERAS K-20, K-22 REMOVED
CAMERA K-22 AND K-20 INSTALLED - Cowley TOTAL TIME 4:40
APQ-13 Rec'd. 7-31-45 Bell #1 cyl head temp OK
B.S. + STAB. INSTALLED - AFCE OK. 7/31/45 Sgt. Howard
#4 Fuel pressure adj to 17 PSI
TURBO CONTROL SYSTEM CHECKED. DEFECTIVE GOVERNOR REPLACED - 7-30-45 Wong
Radio ... 7-30-45
B.S. + STAB. Removed For Schn. INSP. 7/30/45 Howard
VHF Trans removed by Kugler VHF TRANS. REPLACED

AIRCRAFT AND ENGINE TIME RECORD (ENTER IN HOURS AND MINUTES)

ENGINE	NO. 1	NO. 2	NO. 3	NO. 4
HOURS TO DATE	148:25	148:25	148:25	46:35
HOURS TODAY	4:40	4:40	4:40	4:40
TOTAL	153:05	153:05	153:05	51:15
OIL CHANGE DUE				
CUNO-CLEANING DUE				

AIRCRAFT	
HOURS TO DATE	148:25
HOURS TODAY	4:40
TOTAL	153:05

DATE: 8/1/45
STATION: APO 247
CREW CHIEF OR ENGINEER: Sgt Clayton

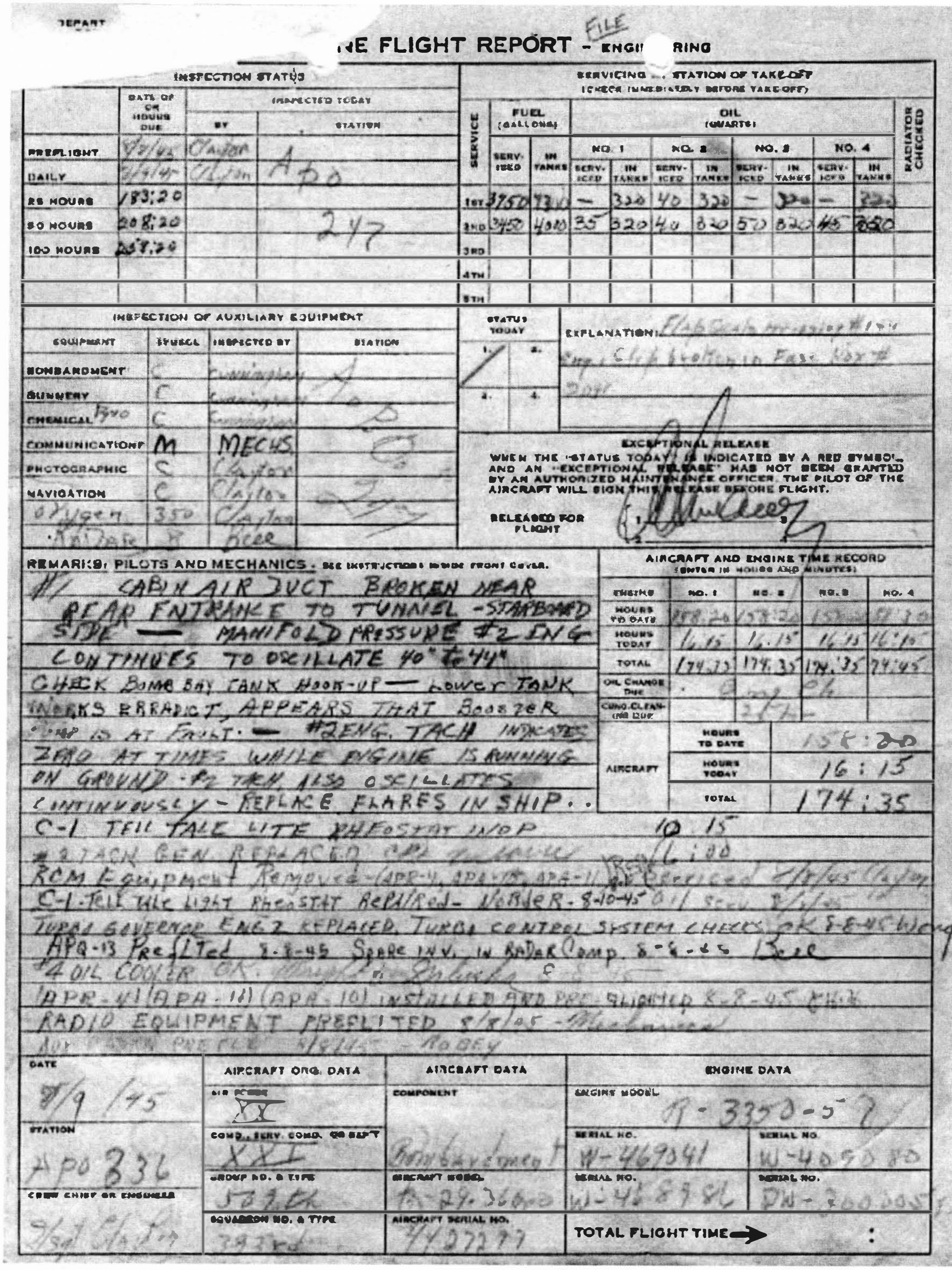
AIRCRAFT ORG. DATA — AIR FORCE: XX; COMD., SERV. COMD. OR DEP'T: XXI; GROUP NO. & TYPE: 509th; SQUADRON NO. & TYPE: 393rd Bomb

AIRCRAFT DATA — COMPONENT: Bombardment; AIRCRAFT MODEL: B-29-36 MO; AIRCRAFT SERIAL NO.: 4427297

ENGINE DATA — ENGINE MODEL: R-3350-57; SERIAL NO.: W-469041; SERIAL NO.: W-409080; SERIAL NO.: W-488986; SERIAL NO.: DN-300000

TOTAL FLIGHT TIME → 4:40

These are copies of the *Bockscar* maintenance records dated 8/1/45 and 8/9/45. These show that even as early as a week before the mission, there were problems with the bomb bay tank fuel transfer system. (Courtesy of USAF Museum Historian Jeff Underwood)



REPORT

…NE FLIGHT REPORT - ENGI…RING

FILE

INSPECTION STATUS

	DATE OR HOURS DUE	INSPECTED TODAY BY	STATION
PREFLIGHT	8/9/45	Clayton	A
DAILY	8/9/45	Clayton	APO
25 HOURS	183:20		
50 HOURS	208:20		247
100 HOURS	257:20		

SERVICING — STATION OF TAKE-OFF (CHECK IMMEDIATELY BEFORE TAKE-OFF)

SERVICE	FUEL (GALLONS) SERVICED	FUEL IN TANKS	OIL NO. 1 SERVICED	NO. 1 IN TANKS	NO. 2 SERVICED	NO. 2 IN TANKS	NO. 3 SERVICED	NO. 3 IN TANKS	NO. 4 SERVICED	NO. 4 IN TANKS	RADIATOR CHECKED
1ST	3750	7310	—	320	40	320	—	320	—	320	
2ND	3450	4010	35	320	40	320	570	820	45	820	
3RD											
4TH											
5TH											

INSPECTION OF AUXILIARY EQUIPMENT

EQUIPMENT	SYMBOL	INSPECTED BY	STATION
BOMBARDMENT	C	Cunningham	A
GUNNERY	C	Cunningham	APO
CHEMICAL Pyro	C	Cunningham	
COMMUNICATIONS	M	MECHS	
PHOTOGRAPHIC	C	Clayton	
NAVIGATION	C	Clayton	
Oxygen	350	Clayton	
Radar		Beee	

STATUS TODAY — EXPLANATION: Flap Seals … Eng. … in … #3 …

EXCEPTIONAL RELEASE

WHEN THE "STATUS TODAY" IS INDICATED BY A RED SYMBOL AND AN "EXCEPTIONAL RELEASE" HAS NOT BEEN GRANTED BY AN AUTHORIZED MAINTENANCE OFFICER, THE PILOT OF THE AIRCRAFT WILL SIGN THIS RELEASE BEFORE FLIGHT.

RELEASED FOR FLIGHT 1. [signature] 2.

REMARKS: PILOTS AND MECHANICS. SEE INSTRUCTIONS INSIDE FRONT COVER.

#1 CABIN AIR DUCT BROKEN NEAR REAR ENTRANCE TO TUNNEL - STARBOARD SIDE — MANIFOLD PRESSURE #2 ENG CONTINUES TO OSCILLATE 40" to 44"
CHECK BOMB BAY TANK HOOK-UP — LOWER TANK WORKS ERRATICT, APPEARS THAT BOOSTER PUMP IS AT FAULT — #2 ENG. TACH INDICATES ZERO AT TIMES WHILE ENGINE IS RUNNING ON GROUND - #2 TACH. ALSO OSCILLATES CONTINUOUSLY - REPLACE FLARES IN SHIP. .
C-1 TELL TALE LITE RHEOSTAT INOP 10 15
#2 TACH GEN REPLACED … 1:00
RCM Equipment Removed (APR-4, APQ-…, APA-11) … 8/8/45 Clayton
C-1 Tell Tale light Rheostat Repaired - … 8-10-45 Oil Serv. …
Turbo Governor Eng 2 Replaced. Turbo control system checks ok 8-8-45 …
APQ-13 Preflted 8-8-45 Spare INV. in Radar Comp. 8-8-45 Beee
#4 OIL COOLER OK. … 8-8-45
APR-4 (APA-11) (APA-10) installed and pre… 8-8-45 …
RADIO EQUIPMENT PREFLITED 8/8/45 - Mechanics
… PREFLT 8/8/45 - Rodey

AIRCRAFT AND ENGINE TIME RECORD (ENTER IN HOURS AND MINUTES)

ENGINE	NO. 1	NO. 2	NO. 3	NO. 4
HOURS TO DATE	158:20	158:20	158:20	158:30
HOURS TODAY	16:15	16:15	16:15	16:15
TOTAL	174:35	174:35	174:35	174:45
OIL CHANGE DUE				
CUNO-CLEANING DUE				

AIRCRAFT	
HOURS TO DATE	158:20
HOURS TODAY	16:15
TOTAL	174:35

DATE	AIRCRAFT ORG. DATA	AIRCRAFT DATA	ENGINE DATA	
8/9/45	AIR FORCE: XX	COMPONENT: Bombardment	ENGINE MODEL: R-3350-57	
STATION: APO 336	COMD., SERV. COMD. OR DEPT: XXI		SERIAL NO.: W-469341	SERIAL NO.: W-405080
CREW CHIEF OR ENGINEER: Sgt Clayton	GROUP NO. & TYPE: 509 Comp	AIRCRAFT MODEL: B-29-36-MO	SERIAL NO.: W-428981	SERIAL NO.: DW-200305
	SQUADRON NO. & TYPE: 393 Bomb	AIRCRAFT SERIAL NO.: 44-27297	TOTAL FLIGHT TIME → :	

This is the post-mission maintenance report. Note the references to the faulty bomb bay fuel tank booster pump and a note to replace the flares. (USAF)

A 84-019

35-2

~~SECRET~~ UNCLASSIFIED

FIRST TECHNICAL SERVICE DETACHMENT
A.P.O. 336, C/O POSTMASTER
SAN FRANCISCO, CALIF.

13 August 1945

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
OK JAN 29 1981
5/20/88

MEMORANDUM FOR: Capt. R. Larkin, Site Y

FROM: Officer in Charge, Project A

SUBJECT: Memorandum, Doll to Brode.

1. This letter is a message for Brode from Doll.

2. I am writing this during the lull in our operations which we all expected. As I write, peace rumors are prevalent, and it is extremely likely that drastic action will be taken regarding our plans prior to your receipt of this message. However, I shall try to present a progress report of the work here at destination.

3. We arrived in strength on July 4th. to find that the second batch was expected momentarily. The timing was perfect. There was little to do besides becoming acclimated and oriented until certain critical items from the second batch were unloaded. Because of various factors it was July 10 when the items needed were received, and we were ready to go to work.

4. A lay-out plan was made which, though generous, was not elaborate. This plan utilized all of the space in our two bomb-sight buildings. Work proceeded on this lay-out at a gratifying rate, and at no time were temporary measures taken. The local "Sea-Bees" gave much valuable assistance in the construction of benches, tables, cabinets, and stools. We installed a very considerable amount of additional wiring in each building, and in addition ran four signal circuits plus our D.C. system between the two buildings.

5. Various power difficulties were encountered at the start. However, most of these were solved by the distribution of our kit transformers throughout the Ordnance Area and by generator overhaul. Use of the air-conditioners began about July 20, but that in "D" building immediately broke down because of a bad condenser. Spare parts were ordered by Ordnance, but the unit is still inoperative at this time. I can say that I have noticed no detrimental effects of moisture in our apparatus. All test boxes, clock boxes, pressure switches, assembled "C" plates, etc., have been kept in

UNCLASSIFIED ~~SECRET~~

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

This is the post mission report by Commander Ashworth describing the success of the mission.

Building "D", with the only effect being the increase of leakage currents. Small spurious readings are sometimes noted in our high-impedance test circuits, but they cannot lead to erroneous results if the operators are properly instructed. I believe the air-conditioning to be very desirable, and perhaps quite necessary for long time operations, to say nothing of its very good morale effect.

6. Soon after our arrival arrangements were completed for the use of a B-24 as a test airplane. A 718 was borrowed locally and was later replaced by our own. This installation went along very well, and it appears to be superior to that previously made in the C-45 at Misplay. A standard CC1 coaxial cable is used for connecting Archie to the Yogi antenna mounted on the side of the fuselage. The antenna is easily removed for security. This installation is located just aft of the rear bomb bay. In general, no difficulties have been encountered in obtaining the use of this airplane as needed.

7. An intensive LB program was started on a schedule which coordinated with our facilities installation. In general no short-cuts were taken in conducting this program, and no haywire work was done on either the testing or fusing program. The set-up has continued until this date, and I can say that it is now complete, leaving the entire crew free for routine operations. Thus, the most critical period has passed, and we are now actually staffed to run a total of 10 - 15 units per month at a leisurely pace.

8. The informer station was completed without incident after the arrival of the limiters. An excellent antenna system was installed both for the informers and the 624-B communications station. The ground to plane communications has worked out excellently. The informer station was completed prior to the first drop, and it has remained unchanged. I can say that it is considerably superior to that at S.B., and it is a pleasure to operate since it is entirely an O-3 show.

9. Film development facilities were obtained on the island in time for the first test drop. At first the quality of workmanship was quite satisfactory, but some records were later lost because of poor processing. No vital results were lost, however, and it is expected that the processing will now be satisfactory.

10. The L.B. test program went off without incident on drops L1, L2, and L5. Twelve very satisfactory informer records were obtained, and everyone was quite pleased with the results obtained. On L6 weather prohibited the drop upon the return from IB, and an attempt was made to run it the following day in the normal target area without release. However, weather interfered,

and the unit was finally released 200 miles at sea, where no informer records could be obtained. The approach of the "hot" unit required the completion of this test, and it is not safe to bomb through bad weather in the normal target area because of danger to shipping. The clouds here almost always start at 2000 - 10,000', and it is nearly always necessary to find holes in the clouds for practice bombing.

11. In general, everyone was quite pleased with the LB test program, since it proved conclusively that the Papacy facilities were ready for bigger things.

12. It sounds like an understatement, but I can honestly say that the "hot" LB unit (L-11) was routine. The schedule was stepped up, and we were ready for delivery on 2 August. However, shortly before this bad weather was predicted over the Empire, and the batteries were held back. We prepar d a new batch of batteries on alternate days, and finally completed the installation on August 5, loaded it that afternoon, tested it and were ready for take-off before dinner. As the whole world knows, it was delivered to target August 6, after a take-off at 0245.

13. We were all excited at what we were doing, but each step was carefully planned with double inspection and testing, and at no time was any misbehavior noted. In fact, due to the omission of informers this unit was more pleasant to prepare than any past unit, either here or at Misplay.

14. The confidence and certainty with which L-11 was prepared and delivered are perhaps the best justification for the exhaustive test program conducted during the past ten months.

15. The F.M. test program went off without incident, except for the fact that all informer records were not received. All components checked perfectly from the time of assembly until release. The informer trouble simply duplicated that previously encountered at Misplay. On F13 only one good record was obtained, but we were fortunate in that this one record gave all the really pertinent data required. F18 gave the only full set of F.M. records I have seen since the addition of X-5 apparatus. All records looked sharp and clear on the monitoring scopes. However, one film was destroyed in development with enough of the other films surviving to give readable results. We were all broken-hearted to lose what looked like a perfect set of informer data. However, we obtained more than the pertinent data, and the informer data proved X-5 operation, after the puffs failed. The importance of this cannot be overemphasized, since it prepared the way for the use of the hot F.M. unit.

16. Certain inconsistencies were noted in the AR data from F13 and F18. These were reconciled with Penney, Serber and Ramsey,

35-2

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and they will be discussed separately.

17. The rehearsal F.M. unit (F-33) was prepared exactly like the forthcoming "hot" unit, and went off without incident. The detonation occurred about 200 miles away f om our base.

18. The "hot" F.M. unit (F-31) was advanced drastically, and we had little trouble in meeting it. It sounds trite to say the job was routine, but I know no other way to describe it. Again the experience of a test program stood us in good stead, and we went ahead with the job in a confident manner. Because of a last minute change there was some struggle in prepari g batte ies, but no corners were cut, and the complete assembly tests were completed the afternoon of August 8. The bomb was then loaded, the plane tests completed, with take-off at 0345 on August 9. You know of the result.

19. We all feel gloriously relaxed and confident. We know we can keep this up at the same caliber as fast as the material can be delivered. Furthermore, we cannot help but feel that we have made a positive contribution to the war, and we are all dazed at the results and consequent publicity.

20. As I look at our installation today I do feel pleased. It has surpassed the fondest dreams you and I had for it. It is neat, workmanlike, and well organized, all of which inspire the men to better work. For the most part we have been self-sufficient, and in some cases have helped others. These fa ilities are now complete, and I pray th t they will no longer be needed. I can leave this fine set-up without a qualm if it is no longer necessary to produce this h r ible device of ours. We can relax in the knowledge that we have delivered two tremendous blows against Japan; that we can continue it as necessary; and, that very possibly, having done what we have, we have convinced Japan and the world of our potentialities so that this device and its obvious deriv tives will never again have to be used in anger.

21. In closing, let me say that our men here cannot receive sufficient praise. I include those from Y and those from Misplay. The end result here is a final tribute to their efforts. I have driven them hard, without a word of complaint. They are wonderfully trained for the job, and I would have complete confidence in turning the job over to those now here with no additional personnel from Y. I am proud of these men.

22. The success of any job is the result of careful planning and coordination. Your planning at home made this job here possible, while the excellent cooperation from Y since our departure has insured the success of the combat application of our weapon.

CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

cc: Parsons
Oppenheimer
Brode
Doll

F. L. Ashworth
F. L. ASHWORTH
Commander, USN
by direction

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4

This document consists of 1 Page(s)
No. 2 of 3 Copies, Series A

SECRET

370 History - Hiroshima etc.

MED
Oppie
Bx 16

P. O. Box 1663
Santa Fe New Mexico
27 September 1945

Brigadier General T. F. Farrell
Box 2610
Washington, 25, D. C.

Dear General Farrell:

I am enclosing a copy of the rough draft of a history of Project A which I prepared in the Marianas.

Although I have had time to make this report factually correct as to dates, etc., it is not completely revised for good readability. I was waiting to do this until Commodore Parsons had had a chance to read and criticize this history. I would appreciate your showing him these chapters in Washington and asking him to send his comments to me.

This report should be profusely illustrated with photographs of which all our best copies (all that show either bomb) are in Washington.

Sincerely yours,

Norman F. Ramsey

NFR:dc

VERIFIED UNCLASSIFIED
EMS 12-18-81
LMR 7-17-79

SPECIAL RE-REVIEW
FINAL DETERMINATION
UNCLASSIFIED, DATE: 12-18-81

SECRET
CLASSIFICATION CANCELLED
PER DOC REVIEW JAN. 1973

HISTORY OF PROJECT A

BY

N. F. RAMSEY

Chapter I

INTRODUCTION

The history of Project A is essentially the history of the combat use of the ATOMIC BOMB and of the preparation and planning to make this use possible. Project A was responsible for the unification and direction of all activities concerned with the use of a nuclear explosion as a bomb to be delivered to the enemy as opposed to the experimental static firing of such a nuclear explosion on a test site. This responsibility included responsibility for design and procurement of components which were required to convert a nuclear explosion into a combat bomb, coordination with Air Forces activities including the modification of suitable aircraft, supervision of field tests on bombs without active material, planning and establishment of the necessary advance base where the final bombs would be assembled, assembly of active bombs and loading into aircraft, supervision of all tests and actions pertaining to the bomb while aboard the aircraft but prior to release, etc. Many of these responsibilities were shared with other groups and divisions at Project Y, but the basic responsibility for unifying all these activities was that of Project A.

Project A as such was not established until March of 1945. However, the activities later the responsibility of Project A were started long before this time in a different organizational form but with many of the same men in responsible positions. During this earlier period most of what were later defined as Project A problems were known as delivery problems, i.e. problems concerned with the successful delivery of an atomic bomb against the enemy. For this reason a history of Project A should begin with a history of the delivery program at Project Y prior to the establishment of Project A.

SECRET

Chapter II

HISTORY OF DELIVERY PROGRAM PRIOR TO THE ESTABLISHMENT OF PROJECT A

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Prior to the establishment of Project A the delivery program was primarily the responsibility of Captain W. S. Parsons, USN, who headed the Ordnance Division at Project Y and N. F. Ramsey in charge of the Delivery Group. These responsibilities were, however, completely shared with Commander Francis Birch who headed the Gun Group, K. T. Bainbridge who up until the establishment of Project A was responsible for the design of the implosion model, R. B. Brode in charge of the Fusing Group, and George Galloway who headed the Engineering Group.

The first major activities of any kind concerned with the delivery program began in June of 1943 when Ramsey at Parsons' request surveyed the Air Forces aircraft to determine approximate sizes, shapes and weights of bombs which could be carried in aircraft. At that time only the gun method of assembly was under consideration and it was thought that a 3000 ft/sec gun would be required to make possible the gun assembly of Pu^{239} so the gun would be 17 feet long. It was apparent as a result of this survey that the only United States aircraft in which such a bomb could be conveniently internally carried was the B-29 and even that plane would require considerable modification so that the bomb could extend into both the front and rear bomb bays by being close under the main wing spar. Except for the British Lancaster, all other aircraft would require such a bomb to be carried externally unless the aircraft were very drastically rebuilt.

On 13 August 1943 the first drop tests of a prototype of an atomic bomb were made at the Dahlgren Naval Proving Ground to determine stability in flight. These tests were on a 14/23 scale model of a bomb shape which was then thought might be suitable for a gun assembly. The model consisted essentially of a long length of 14" pipe welded into the middle of a split standard 500 pound bomb. It was officially known at Dahlgren as the "Sewer Pipe Bomb". For security reasons, Ramsey, who was in charge of these tests, presented himself as a representative of Section T, and much of the construction work on the models was conducted at the Applied Physics Laboratory, at Silver Sprir

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The first test on an atomic bomb model at Dahlgren was an ominous and spectacular failure. The bomb fell in a flat spin the like of which had rarely been seen before. However, in subsequent tests an increase in fin area and a forward movement of the c.g. provided stability.

In the months following August further tests of 14/23 scale models of current and ever-changing gun models were made at Dahlgren. Changes resulting from these tests were in turn incorporated into the design. Also during this time preliminary models of a proximity fuse which were constructed at the University of Michigan at Brode's request became available. These were extensively tested at Dahlgren beginning on 3 December 1943.

In September of 1943 the fast implosion model was proposed by von Neumann as an alternative to the slow implosion formerly advocated by Seth Neddermeyer. As it became clear that this model was a promising one, preliminary planning for converting it into a bomb were begun. A preliminary estimate of 59 inches diameter and of a nine thousand pound weight was made by von Neumann and Ramsey and on this basis the Bureau of Standards bomb group was asked to design suitable fairing and stabilizing fins for such a bomb.

In the fall of 1943 it became apparent that plans for full scale tests should be started. In view of the critical shortage of B-29's it was at first proposed that a British Lancaster be used for the test work even though a B-29 would almost certainly be used as the combat ship. The Air Forces, however, wisely recommended that a B-29 be u for the test work as well both to avoid non-standard maintenance and to accumulate experien in B-29 operations with such a bomb. In order that the aircraft modifications could beg two external shapes and weights were selected by Parsons and Ramsey as representative of the current plans at Site Y. One of these was 204 inches long with a maximum diamete of 23 inches and was a model for the current gun assembly. The other was 111 inches lon and 59 inches in diameter corresponding to a fast implosion assembly. For security reasons these were called by the Air Forces representatives the "Thin Man" and "Fat Man" respectively - the Air Forces officers tried to make their phone conversations sound as if they were modifying a plane to carry Roosevelt (the Thin Man) and Churchill (The F

Models to these dimensions were ordered from Detroit. Modification of the first B-29 officially began 29 November 1943. Colonel R. C. Wilson was Army Air Forces Project Officer for all aspects of the program, Colonel D. L. Putt at Wright Field was in charge of the division under whose supervision the modification was done, and Captain R. L. Roark was Project Officer in charge of the modification.

Tests with the modified aircraft and full scale dummy bombs were begun at Muroc on 3 March 1944. These tests were participated in by Brode's fusing group, Bainbridge's instrumentation group, and by the delivery group. Coordination of the activities of the different groups in these and subsequent field tests was a responsibility of Ramsey's delivery group. The purpose of the tests ~~were~~ was to check the suitability of the fusing equipment, the stability and ballistic characteristics of the bombs, the facilities we then had available for field work, and the suitability of the aircraft to carry and drop the bombs. After four weeks of delay due to torrential rain on the Mojave Desert and due to aircraft troubles, a series of tests were completed. The negative results of most of these tests thoroughly justified the holding of preliminary tests at such an early date. The fuses proved to be unreliable and on the basis of these results an investigation into the possibility of adapting an APS-13 fighter tail warning radar to this use was begun. Although the Thin Man proved to be very stable in its flight, the Fat Man with a tail which the Bureau of Standards bomb group thought would be extremely stable proved to wobble badly with its axis departing 20° from the line of flight. Although the B-29 release mechanism worked satisfactorily for the Fat Man it failed completely for the Thin Man. ~~Four~~ Three of the units were bad hang ups with the delay being up to 10 seconds and the final drop was 20 minutes premature while the plane was still climbing to altitude. The bomb in this case fell onto the bomb bay door which had to be opened to jettison the bomb and which ~~were~~ was badly damaged. With this accident the first Muroc tests were brought to an abrupt and spectacular end.

Between the end of the first tests and June 1944, all groups worked to correct the faults shown to exist in the first tests. Also durin this period it became apparent that Pu^{239} could not be used in a gun due to neutrons of Pu^{240} almost certainly causing a predetonation. Since the length of the gun model was due exclusively to the contemplated use with Pu^{239} it became clear that the gun velocity could for U^{235} be reduced to 1000 ft/sec and the length of the bomb correspondingly reduced so that it could be fitted into a single bomb bay of the B-29, thus simplifying the aircraft installation job. Detailed designing of this model was begun during this period under the supervision of McMillan and Birch. Due to the contrast in dimensions with the Thin Man this model finally acquired the appropriate name of Little Boy. Also during this period the detailed designing of the 1222 form of Fat Man assembly was begun. In this model the high explosive was held together with an inner dural shell consisting of 12 pentagon sections surrounded by an armor steel shell consisting of 20 triangles.

Tests at Muroc were resumed in June of 1944. These tests confirmed the previous results that the first form of fuse being developed at Michigan was not satisfactory. The first two APS-13's became available to the project during the test and two haywire drop tests (genuine bailing wire was actually used) were made with a field adaptation of this equipment to fusing. The first of these provided the first completely satisfactory fusing test accomplished and although the second failed it was probable that the failure was in some of the hastily prepared auxiliary equipment. The Fat Man with their tails modified from the original circular shroud to a square shroud 59 inches on a side still ~~proved to be unstable~~ had an undamped wobble. As a desperate last resort Ramsey suggested a drop be made with internal 45° baffle plates welded into the inside of the shroud as a field modification. To everyone's surprise this modification was successful with bomb being completely stable in its flight and with the ballistic coefficient being improved rather than decreased as anticipated. No release failures were experienced in the tests.

From the end of these tests until October 1944 when similar field tests were resumed, a strenuous program of design and procurement was under way at Site Y to obtain units which could be used as components of an actual atomic bomb as opposed to units which were merely ballistic models. Three basically different models were worked on at this time. One was the Little Boy model of the U^{235} gun assembly, one was the 1222 Fat Man model of implosion assembly, and the third was a model which grew into the finally adopted 1561 Fat Man implosion assembly. The latter arose from a redesign for the purposes of simplifying the assembly problem (the assembly of 1222 required the insertion of more than 1500 bolts) and of improving the flight characteristics by using an ellipsoidal shape for the outer armor. It consisted essentially of an inner spherical shell consisting of two polar caps and a segmented central zone which could be bolted together and surrounded by an armor ellipsoid to which a stabilizing tail including the necessary drag plates were attached. The auxiliary fusing and electrical detonating equipment was mounted in the space between the inner sphere and outer ellipsoid.

In August of 1943 Colonel R. C. Wilson and Colonel . . Dexler visited Site Y and recommended that the Air Forces begin immediately to train a combat unit for the delivery of the Atomic Bomb. Therefore, it was agreed that Site Y should definitely freeze the external shapes of the three models and the other requirements that affected t aircraft by 1 September 1944 so that modification of a production lot of fifteen B-29's could be started. These aircraft were modified at the Martin Nebraska Plant at Omaha and the first aircraft became available in October. Sheldon Dike and Milo Bolstad were the Project Y representatives during these and subsequent modifications. The special modifications for carrying and releasing the bomb were designed to incorporate the British F and G release mechanism as was currently used for the British 12,000 pound bomb. This mechanism required only a single lug on the bomb. At this time Wendover Army Air Base was designated as the center at which training of the new Atomic Bomb Group would be undertaken and at which future field tests would be held. The Second Air Force under General Ent and later under General Williams was designated as the parent

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organization to this group. Colonel Paul Tibbets was designated commanding officer of the combat group (509 Composite Group) and Captain Charles Begg was in command of the 1st Ordnance Squadron, Special. Colonel Clifford J. Heflin was commanding officer at Wendover, Major C. S. Shields was in charge of the Flight Test Section, and Captain Henry Roerkohl was in charge of the Ordnance Test Unit.

The first tests began at Wendover in October 1944. This began a period of tests whi which continued intermittently, then monthly, and finally almost continuously up to August of 1945. Initially the only groups concerned were the Fusing Group, under Brode and Doll and the Delivery Group lead by Ramsey. However as time went on the other groups which participated in the Wendover tests were the Gun Group headed by Birch, the High Explosives Assembly Group headed initially by Bainbridge and later by Bradbury and Warner, the Electrical Detonator Group headed by Fussell, and the Ballistic Group under Shapiro. At the end of November Commander F. L. Ashworth joined the Project and relieved Ramsey of the responsibility of directly supervising the field operations since by then important parts of the Delivery Program of necessity had to be under way concurrently at Wendover and Site Y. In these tests units approaching more and more closely to the final model were tested for ballistics information, for electrical fusing information, for flight tests of electrical detonators, for test of the aircraft release mechanism, for vibration information, for assembly experience, for temperature tests, etc. In addition a number of additional test drops were made at Naval Ordnance Test Station Inyokern under the supervision of Charles and Thomas Lauritsen, William Fowler, and Commander Heyward between 20 February of 1945 and August 1945.

From October until the formal establishment of Project A the main activities i n the Delivery Program were a continuation of development, design, production, and test of bombs approaching more and more closely to the final model. During this period the 1222 model was definitely dropped in favor of the 1561 model of Fat Man. Due to poor flying qualities of the first batch of B-29's and to certain weaknesses in the special project modifications a new batch of 15 aircraft were obtained in March and April of 1945. These aircraft had fuel injector engines, electric pitch controlled propellers, very rugged provisions for carrying the bomb and removal of all armament except the tail turret.

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By arrangement with Gen. Norstad, Messrs. F. R. Collbohm and Warren T. Dickinson participated in engineering tests of these modified aircraft. These aircraft proved to be extremely satisfactory. Colonel R. C. Doubleday was Army Air Forces Project Officer at the time of this last modification. In addition to the Wendover tests during this period numerous physics and engineering tests on complete units were made at V-Site initially under the direction of the Delivery Group and of Bernard Waldman and later after the formation of Project A under Bradbury and Warner. Considerable initial planning for the establishment of an overseas operating base was done during this period.

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CHAPTER III

HISTORY OF PROJECT A AT SITE Y

Project A was formally established in March of 1945. It incorporated many groups also assigned to other divisions and was for the purpose of unifying the activities of those groups as concerned the preparation anddelivery of a combat bomb. Captain W. S. Parsons was Officer in Charge of Project A, N. F. Ramsey was his deputy for scientific and technical matters, Commander F. L. Ashworth was operations officer and military alternate for Captain Parsons, Commander Norris Bradbury and Roger Warner were in charge of Fat Man Assembly, Commander Francis Birch was in charge of Little Boy Assembly, R. B. Brode was in charge of fusing, L. Fussell was in charge of the electrical detonator system, Phillip Morrison and Marshall Holloway were in charge of the pit (active material and tamper), Luis Alvarez and Bernard Waldman were in charge of Airborne observations of the combat explosions, George Galloway was in charge of ~~engine~~ engineering, Lt. Col. R. W. Lockridge was in charge of supply, Maurice Shapiro was in charge of ballistics and Sheldon Dike was in charge of aircraft problems. In addition the following persons were consultants to Project A: William Penney on damage problems, H. A. Bethe on general theory, and L. Hempelmann on radiological problems. In July as other personnel moved to Tinian, Sam Simmons and Lt. Comdr. T. J. Walker assumed the responsibility for the Wendover tests. The Technical policy committee responsible for initiating technical actions for Project A as recommendations to Capt. Parsons was the Weapons Committee consisting of N. F. Ramsey (Chairman), Comdr. Norris Bradbury (Chairman after Ramsey's departure), Roger Warner, Comdr. F. Birch, R. B. Brode, L. Fussell and Phillip Morrison.

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Project A at Site Y and Wendover was concerned chiefly with three matters: (1) the completion of design, procurement and preliminary assembly of units which would be complete in every way for use with active material, (2) continuation of the Wendover test program to confirm in so far as possible without using active material the adequacy in flight of the components and assembled units, and (3) preparation for overseas operations against the enemy.

In view of the shortness of the available time, the major designs were necessarily continued with as few alterations as possible. The chief design activities during this period were the numerous and urgent ones of supplying the many details necessary for successful operation and of rectifying faults which became apparent in tests. Such matters as the exact design of the tamper sphere, incorporation of features to make a trap door assembly possible, inclusion of a hypodermic tube between the HE blocks for monitoring purposes, strengthening the Little Boy tail, etc. characterize this period.

This was also the period of maximum activity in tests at Wendover. The unfortunate failure of the Raytheon Company to meet its delivery schedule on X-Units (electrical detonators) added markedly to the difficulty of the test program. This failure reduced the number of tests that were possible on the X-units, prevented efficient testing since many tests had to be repeated twice - once at an early date with all components except an X-unit and once at a critically late date with an X-unit, , and greatly complicated the scheduling of tests since there was no time in which to acquire a backlog of X-units. The tightness of schedule resulting from this is best illustrated by the fact that it was not until the end of July that sufficient X-units had been tested to confirm their safety with HE, the first HE filled fat man with an X-unit was tested at Wendover 4 August, the first HE filled Fat Man with an X-Unit was tested at Tinian 8 August, and the first complete Fat Man with active material was dropped on Nagasaki 9 August. Despite these difficulties, however, a total of 155 test units were dropped at Wendover or the Salton Sea between October and the middle of August 1945. Much information was learned in these tests and incorporated into the design of the units.

Planning for overseas operations was one of the chief activities of Project A during this period. Initial planning and procurement of some kits of tools, etc. began in December with these activities continuing at an accelerated rate up through July. In February of 1945 Comdr. Ashworth was sent to Tinian to make a preliminary survey of the location and to select a site for our activities. By March the construction needs for the Tinian Base were frozen as the following: Four (4) air conditioned 20' x 48' steel arch rib of the type normally used in the Navy for bomb sight repair (two for the fusing team, one for the electrical detonator team, and one for joint use by the pit team and observation team), three (3) airconditioned 20' x 70' assembly buildings for which the materials were accumulated at Inyokern, five (5) 40' x100' steel arch rib warehouse building, one (1) building of the same basic type as an ordnance administration building, one (1) building of the same type as a modification shop, three (3) 10' x 10' x 5' magazines, seven (7) 20' x 50' x 10' magazines and two (2) special loading pits equipped with hydraulic lifts forloading bombs into the air craft. A third such pit was constructed at Iwo Jima for possible emergency use. Materials for equipping the buildings and for handling heavy equipment in assembly, tool scientific instruments, and general supplies were all included in special kits prepared the different groups. A kit for a central stock room was also started but the materials for the ~~kit~~ latter were not shipped by August at which time further shipments to Tinian were stopped by the end of the war. Construction of the Tinian base began under the supervision of Colonel E. E. Kirkpatrick in April.

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Beginning in May so called batches of kit materials and of components for test an combat units were ~~shipped~~ sent by ~~boat to Tinian~~ water borne transportation to Tinian. A total of five batch shipments were made. (320th Troop Carrier Sqdn. Capt. [illegible] In addition a number of air shipments in five C-54 aircraft attached to the 509th Group were made for critically needed items. The availability of these C-54's for emergency shipments contributed greatly to the ability of Project A to beat its schedules in comba use of the Atomic Bomb.

CHAPTER IV

HISTORY OF PROJECT A AT TINIAN

The Project A organization at Tinian consisted of the following: Officer-in-Charge, Commodore W. S. Parsons; Scientific and Technical Deputy to Officer-in-Charge, N. F. Ramsey; Operations Officer and Military Alternate to Officer-in-Charge, Comdr. F. L. Ashworth; Fat Man Assembly Team headed by Roger Warner; Little Boy Assembly Team headed by Comdr. Francis Birch; Fusing Team headed by E. B. Doll; Electrical Detonator Team headed by Lt. Comdr. E. Stevenson; Pit Team headed by Phillip Morrison and C. P. Baker; Observation Team headed by Luis Alvarez and Bernard Waldman; Aircraft Ordnance Team headed by Sheldon Dike; and Special Consultants consisting of Robert Serber, W. G. Penney and Captain J. F. Nolan. The team leaders formed a Project Technical Committee under the chairmanship of Ramsey to coordinate technical matters and to recommend technical actions to Captain Parsons. The following persons were team members: Harold Agnew, Ensign D. L. Anderson, T/5 B. Bederson, Milo Bolstad, T/Sgt. Raymond Brin, T/Sgt V. Caleca, M. Camac, T/Sgt E. Carlso T/4 A. Collins, T/Sgt R. Dawson, T/Sgt F. Fortine, T/3 W. Goodman, T/3 D. Harms, Lt. J. D. Hopper, T/Sgt J. Kupferberg, L. Johnston, L. Langer, T/Sgt. W. Larkin, H. Linschitz, A. Machen, Ens. D. Mastick, T/3 R. Matthews, Lt. (jg) V. Miller, T/3 L. Motechko, T/Sgt. W. Murphy, T/Sgt E. Nooker, T. Olmstead, Ens. B. O'Keefe, T. Perlman, Ens. W. Prohs, Ens. G. Reynolds, H. Russ, R. Schreiber, T/Sgt. G. Thornton, Ens. Tucker, and T/4 F. Zimmerli. Although not strictly a part of Project A, the following were closely associated with the work of Project A; Rear Admiral W. R. Purnell representative of the Atomic Bomb Military Policy Committee; Brig. Gen. T. F. Farrell representative of Major Gen. L. R. Groves; Colonel E. E. Kirkpatrick, alternate to Gen. Farrell and officer in charge of construction; Colonel P. W. Tibbets, commanding officer of the 509th Composite Group; Lt. Col. Peer de Silva, commanding officer of the 1st Technical Service Detachment, which served as administrative, security and housing organization for Project A; and Major Charles Begg, commanding officer of the First Ordnance Squadron, Special.

Although preliminary construction at Tinian began in April of 1945, intense technical activities, however, did not begin until July. The first half of July was occupied in establishing and installing all of the technical facilities needed for assembly and test work at Tinian. After completion of these technical preparations, a little boy unit was assembled and on 23 July the Tinian base became fully operational for little boy tests with the dropping of unit L1. In this test the dummy little boy was fired in the air by the radar fuse. In this as in subsequent Tinian tests excellent results were obtained. The second little boy, Unit L2, was dropped 24 July, and a third, Unit L5, on 25 July. The only remaining little boy included as part of the test for a check of facilities at Iwo Jima for emergency reloading of the bomb into another aircraft. Since the Iwo facilities were not ready until 29 July this test was postponed until then. On 29 July a completely successful test of the Iwo facilities was completed. The plane landed with this unit, L6, at Tinian so that it could be used in the final rehearsal maneuvers. [illegible] On 31 July the plane with L6 took off accompanied by the two observation planes. The planes flew to Iwo where a rendezvous was made and then returned to Tinian where the bomb was dropped and observed to function properly. After the release of the bomb all three aircraft rehearsed the turning maneuvers which would be used in combat. With the completion of this test all tests preliminary to combat delivery a little boy with active material were completed.

The first fat man test, unit F13, was made on 1 August. This unit used cast plaster blocks, electronic fusing, eight electric detonators, Raytheon detonating unit and informers and smoke puffs on the operation of the detonators. The test showed that all essential components of the bomb functioned satisfactorily. A second inert fat man, F18, similar to F13 was prepared and loaded into a B-29 for drop on 3 August. However, due to the lack of information at Tinian of the results of the Kingman tests on the adequacy of the venting in the sealed fat man, this unit was unloaded and the barometric switches modified so that this information would be obtained on unit F18. In this modified form it was dropped on 5 August. All components functioned satisfactorily and the venting was adequate for the internal pressure to close a barometric switch set for 17,000 feet pressure altitude 17 seconds before impact. The only remaining preliminary fat man test was unit F33, a replica of the active unit except for the lack of active material and the use of lower quality high explosive lens castings. The components for this unit arrived at Tinian at 1230 on 2 August and preliminary assembly began the same day. Although this unit was fully prepared by 5 August, it was not dropped until 8 August due to absence of key crews and aircraft on the hot little boy mission. The mission was then conducted as a final rehearsal for the delivery of the first live fat man. Both the rehearsal operation and the detonation of the unit were completely satisfactory.

On 26 July the U^{235} projectile for the little boy was delivered by the cruiser Indianapolis. The U^{235} target insert arrived in three separate parts in three otherwise empty Air Transport Command C-54's during the evening of 28 to 29 July. All three had arrived by 0200 29 July. Since the earliest date previously discussed for combat delivery of the fat man was 5 August (at one time the official date was 15 August), Parsons and Ramsey cabled General Groves for permission to drop the first active unit perhaps as early as 1 August, with 2 August being more probable since the weather was forecast to be bad on 1 August.

Although the active unit, No. L11 was completely ready in plenty of time for a 2 August delivery, the weather was not. The first, second, third, and fourth of August were spent in impatient waiting for good weather. Finally on the morning of 5 August we received word that the weather should be good on 6 August. At 1400 on 5 August General Lemay officially confirmed that the mission would take place on 6 August.

The little boy was loaded onto its transporting trailer at 1400 5 August and with an accompanying battery of official photographers, under G-2 supervision, was taken to the loading pit. The B-29 was backed over the pit at 1500 and the unit was loaded shortly thereafter. The aircraft was then taxied to its hard stand where final testing of the unit was completed. By 1800 all was ready. Between then and take off the aircraft was under continuous watch both from a military guard and from representatives of the key technical groups.

Final briefing was at 0000 of 6 August. Following this and an early breakfast the crews assembled at their aircraft. There amid brilliant floodlights their pictures were taken and retaken by still and motion picture photographers as if for a Hollywood premier. For this mission Col. P. W. Tibbets was pilot of the B-29, named the Enola Gay which carried the bomb, Major Thomas Ferebee was bombardier, Captain W. S. Parsons was bomb commander, and Lt. Morris Jepson was electronics test officer for the bomb. L. Alvarez Bernard Waldman, Harold Agnew and Larry Johnston rode in the accompanying observation aircraft.

The progress of the mission is best described in the log which Capt. Parsons kept during the flight:

6 August 1945

0245 Take off

0300 Started final loading of gun

0315 Finished loading

0605 Headed for Empire from Iwo

0730 Red plugs in (these plugs armed the bomb so it would detonate if released)

0741 Started climb

Weather report received that weather over primary and tertiary targets was good but not over secondary target.

0838 Leveled off at 32,700 feet

0847 All Archies (electronic fuses) tested to be O.K.

0904 Course west

0909 Target (Hiroshima) in sight

0915½ Dropped bomb (Originally scheduled time was 0915)

Flash followed by two slaps on plane. Huge cloud

1000 Still in sight of cloud which must be over 40,000 feet high

1003 Fighter reported

1041 Lost sight of cloud 363 miles from Hiroshima with the aircraft being 26,000 feet high

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The crews of the strike and obsdrvation aircraft reported that 5 minutes after release a low 3 mile diameter dark grey cloud hung over the center of Hiroshima, out of the center of this a white column of smoke rose to a height of 35,000 feet with the top of the cloud being considerably enlarged.

Four hours after the strike photo-reconnaissance planes found that most of the city of Hiroshima was still obscured by the cloud created by the explosion although fires could be seen around the edges. However, the following day excellent pictures were obtained which showed the tremendous magnitude of the power of a single atomic bomb, which completely destroyed 60 percent of the city of Hiroshima.

The first fat man with active material, unit F31, was originally scheduled for dropping on 11 August local time (at one time the schedule called for 20 August). However, by 7 August it became apparent that the schedule could be advanced to 10 August. When Parsons and Ramsey proposed this change to Tibbets he expressed regret that the schedule could not be advanced two days instead of only one since good weather was forecast for 9 August and the five succeeding days were expected to be bad. It was finally agreed that Project A would try to be ready for 9 August provided it was understood by all concerned that the advancement of the date by two full days introduced a large measure of uncertainty into the probability of our meeting such a drastically revised schedule. However, all went well with the assembly and by 2200 of 8 August the unit was loaded and fully checked.

The strike plane and two observing planes took off at 0347 local time on 9 August. Major C. W. Sweeney was pilot of the strike ship, Capt. K. K. Beahan was bombardier, Comdr. F. L. Ashworth was bomb commander, and Lt. Philip Barnes was electronics test officer. This mission was as eventful as the Hiroshima mission was operationally routine.

Due to bad weather between Tinian and Iwo Jima a preliminary rendezvous was not pl[illegible] for the three aircraft at Iwo Jima and instead the briefed route to the empire was from Tinian direct to Yakoshima on Kyushu. The briefed ~~mmt~~ cruising altitude was 17,000 feet. Commander Ashworth's log for the trip is as follows:

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0347 Take off SECRET

0400 Changed green plugs to red prior to pressurizing

0500 Charged detonator condensers to test leakage. Satisfactory

0915 Arrived rendezvous point at Yakashima and circled awaiting accompanying aircraft

0920 One B-29 sighted and joined in formation

0950 Departed from Yakashima proceeding to primary target Kokura having failed to rendezvous with second B-29. The weather reports received by radio indicated good weather at Kokura (3/10 low clouds, no intermediate or high clouds, and forecast of improving conditions) The weather reports for Nagasaki were good but increasing cloudiness was forecast. For this reason the primary target was selected.

1044 Arrived initial point and started bombing run on target. Target was obscured by heavy ground haze and smoke. Two additional runs were made hoping that the target might be picked up after closer observation. However at no time was the aiming point seen. It was then decided to proceed to Nagasaki after approximately 45 minutes had been spent in the target area.

1150 Arrived in Nagasaki target area. Approach to target was entirely by radar. At 1158 the bomb was dropped after a twenty second visual bombing run. The bomb functioned normally in all respects.

1205 Departed for Okinawa after having circled smoke column. Lack of available gasoline caused by an in-operative bomb bay tank booster pump forced decision to land at Okinawa before returning to Tinian

1351 Landed at Yontan Field, Okinawa

1706 Departed Okinawa for Tinian

2245 Landed at Tinian

Due to bad weather, good photo reconnaissance pictures were not obtained until almost a week after the Nagasaki mission. These showed that the bomb detonated somewhat north of the Mitsubishi Steel and Arms Works. All other factories and buildings on the Urakami River from the Nakajima Gawa River through the Mitsubishi Urakami Ordnance Plant were destroyed. The distance from the northernmost factory that was destroyed to the southern boundary of complete destruction was about three miles and damage might have occurred north of the Urakami Ordnance Plant if any buildings had been there. Although only 44 percent of the city was destroyed by the official record, this was due to the unfavorable shape of the city and not to the location of the bomb detonation.

On the day following the Nagaskki mission, the Japanese initiated surrender negotiations. Consequently further activity in preparing active units was suspended. However, the entire project was maintained in a state of complete readiness for further assemblies in the event of a failure in the peace negotiations. For the first week following the Nagasaki mission the test program at Tinian was continued and three dummy fat man units, Nos. F101, F102, and F103 were prepared. They were not dropped, however, since the Japanese had stated their willingness to accept the American terms prior to the date scheduled for the drop. Originally it was planned to return all Project A technical personnel to the United States on 20 August except for those assigned to the Farrell Mission for investigating the results of the atomic bombing of Japan. However, on 18 August a message was received from General Groves stating that in view of the then current delays in the surrender procedures all key Project A personnel should remain at Tinian until the success of the occupation of Japan was assured. The scientific and technical personnel finally received authorization for return to the United States on 5 September and departed from Tinian on 7 September 1945. With this departure the activities of Project A were effectively terminated although Col. Kirkpatrick and Comdr. Ashworth remained behind at Tinian for final disposition of Project A property.

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CHAPTER V

CONCLUSION

Project A, after a long period of preparation in the United States, had a very short but highly intense and successful period of activity overseas. The shortness of the intense period of its overseas activities are best summarized by the attached figure one which shows the activity of Project A as measured by its number of transmitted dispatches plotted as a function of the date.

As in all urgently expedited development projects for which there are no precedents, many mistakes were made in Project A. With the benefit of the experience accumulated by Project A it would subsequently be possible to replan its activities to accomplish its objective both with greater economy and with improved designs. However, despite the novelty of the weapon and the lack of precedent for most of its problems, Project A did successfully accomplish all of its major objectives and did so on or ahead of time.

The object of Project A was to assure the successful combat use of an atomic bomb at the earliest possible date after a field test of an atomic explosion and after the availability of the necessary nuclear material. This object was very effectively accomplished. The first combat bomb was ready for use against the enemy within seventeen days after the first experimental nuclear explosion at Alamogordo and almost all of the intervening time was spent in accumulating additional active material for making an additional bomb. The first atomic bomb was prepared for combat use against the enemy on 2 August within four days of the time of the delivery of all of the active material needed for that bomb. Actual combat use was delayed until 6 August only by bad weather over Japan. The second atomic bomb was used in combat only three days after the first despite its being a completely different model and one much more difficult to assemble. The success of the combat use of the atomic bomb is best summarized by the fact that Japan began surrender negotiations four days after the use of the first atomic bomb.

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REPORT ON ACCIDENT OF AUGUST 21, 1945

AT OMEGA SITE

Section I - Description of Location and Circumstances of Accident

Section II - Description of Injury and Estimate of Radiation Received by Personnel Involved in Accident

(see Walt's memo attached)

FINAL DETERMINATION
UNCLASSIFIED
L. M. Redman
AUG 28, 1979
J. Lang 1-28-86

Classification changed to UNCLASSIFIED
by authority of the U.S.E.R.D.A.,
Per Joseph L. Watts, ISD-6 Mar. 3, 1975
(Person authorizing change in classification) (Date)
By Evelyn Stephenson January 30, 1976
(Signature of person making the change, and date)

Paul Aebersold

Dr. Louis Hempelmann

Louis Slotin

August 28, 1945

UNCLASSIFIED

~~OFFICIAL USE ONLY~~

This document contains [redacted] any manner to an [redacted] by law.

[redacted]

[redacted]

SECTION I UNCLASSIFIED

Part of the information contained in this report was obtained by questioning the participants in the accident and by measurements made at Omega subsequent to the accident.

Personnel Involved:

Harry K. Daghlian, civilian; Pvt. Robert Hemmerly, SED guard.

Time:

9:55 p. m., Tuesday, August 21, 1945

Place:

49 Room, Omega Site

Occasion:

Working with an assembly of tungsten carbide bricks and a 49 sphere, with the intention of determining the amount of WC required for criticality.

Description of Room:

The place in which the accident occurred is the linoleum covered room on the east side of the Omega building, commonly designated as the 49 room. This is a room set aside for the purpose of experiments with 49 material, including gadget testing and critical assemblies. The room is 25' x 25' and contained, at the time of the accident, a mock gadget set-up normally used in gadget tests, a rack of instruments used in these tests, and a steel dolly on which critical tests other than gadgets are performed. In addition, in the north end corner of the room there are two handling benches and, on the east side of the room, an office desk. The disposition of equipment in the room is shown in the attached diagram.

Previous History of WC Work:

The work in connection with which the accident occurred was part of a series of measurements to obtain data on the critical masses of 49 metal in various tamper arrangements. At the time of the accident the critical mass in a tungsten

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carbide (WC) tamper was being worked with.

Previous to the WC assembly with which the accident occurred, two other WC assemblies had been made on the morning and afternoon of that day. The first assembly, made on the morning of the 21st, consisted of a cube of WC bricks, seven units on a side (one unit equals 2-1/8"). This assembly was found to be critical with five unit layers complete and two blocks (one block is 2-1/8" x 2-1/8" x 4-1/4") in the center of the sixth layer. Subsequent experiments were to have been the determination of a completed cube which would have been critical with the amount of 49 used (6200 grams, as a sphere).

In the afternoon, another assembly was made consisting of a cube six units on a side, and this was found to be critical when five unit layers were complete. The next experimental step was an assembly five units on a side. This assembly was scheduled for the morning of August 22nd. For reasons unknown at present, Harry Daghlian decided to do it on the evening of the 21st.

An SED guard is on duty continually at Omega whenever 49 metal spheres are on the site. The duties of the guard are functional—guarding against contingencies such as fire and theft—and are not concerned with the technical use of the material. On the day of the accident Pvt. Hemmerly was on duty from 6:00 p. m. to 12:00 midnight. Daghlian left the Tuesday evening colloquium (at Theater #2) which ended about 9:10 p. m. and went to Omega, arriving there approximately at 9:30 p. m. On arrival, he immediately proceeded to build the assembly mentioned above. The operation was being monitored by three separate instruments. Two independent fission chambers operated numerical recorders, giving thereby audible indication. A BF_3 fission chamber operated a recording milliammeter and supplied a visual record. All those instruments were found to be in good operating condition after the accident. During the assembly the guard was seated at a desk facing away from the assembly (12 ft. away). Daghlian was in the position indicated on the diagram.

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According to the description given by Daghlian, the five unit cube containing the 6200 gram 49 sphere at its center had four layers complete and approximately half the fifth layer in place when the accident occurred. A reconstruction of the assembly is shown in Plate I. He was carrying one brick in his left hand over the assembly, to place it in the center of the fifth layer. While he had this brick suspended over the assembly, he noticed (from the instruments) that the addition of this brick would have made the assembly supercritical if placed onto the top of the assembly. Having realized this, he was withdrawing his left hand and the brick from over the assembly and while doing so the brick slipped out of his hand and fell immediately onto the center of the assembly. Knowing that this brick would make the assembly dangerous, he instinctively and immediately pushed this brick off the assembly with his right hand. While doing this, he stated that he felt a tingling sensation in his right hand and at the same time noticed a blue glow surrounding the assembly, the depth of the blue glow being estimated to be about two inches.

The guard, who was seated at the desk mentioned above, with his back to the assembly, also states that he noticed a flash of light in the room.

Immediately after the brick dropping, Daghlian disassembled the installation to the state shown in Plate 2. At that time Miss Joan Hinton arrived at Omega and immediately drove back with Daghlian to the hospital. The guard was left at Omega for the time being. After the accident, Sgt. Starner, who had been in the office section of the building (protected from the laboratory portion by a five-foot concrete wall) phoned M. G. Holloway at his home, notifying him of the occurrence. Mr. Holloway informed Mr. R. F. Bacher, and both went to the hospital to see Daghlian. During this time Dr. Hempelmann was also informed, and he and Mr. Aebersold came to the hospital to examine Daghlian. Arrangements had also been made (by Holloway) with the security office to relieve the guard at Omega, and he was brought to the hospital. Both participants in the event were confined to the hospital for

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observation.

Aebersold, Bacher, Hempelmann and Holloway then drove down to Omega. On arrival there Holloway phoned Mrs. Holloway to find Slotin and have him told about the event. Slotin arrived at Omega about 11:30 p. m. At Omega, measurements were made of the radiation coming from the 49 sphere in the assembly in the position indicated in Plate 2. These measurements were for purposes of evaluating the amount of radiation that was emitted in the accident. When the radiation measurements in the assembly had been taken, the spheres were removed from the assembly, placed in the vault and another set of radiation measurements on them, unperturbed by the shield ing effect of the tungsten carbide bricks, were taken. In addition to these measurements, that night and the following day measurements were made of the activity of various metal objects (coins, keys, badge, phosphorus from calamity badge) that Daghlian had in his pockets at the time of the irradiation.

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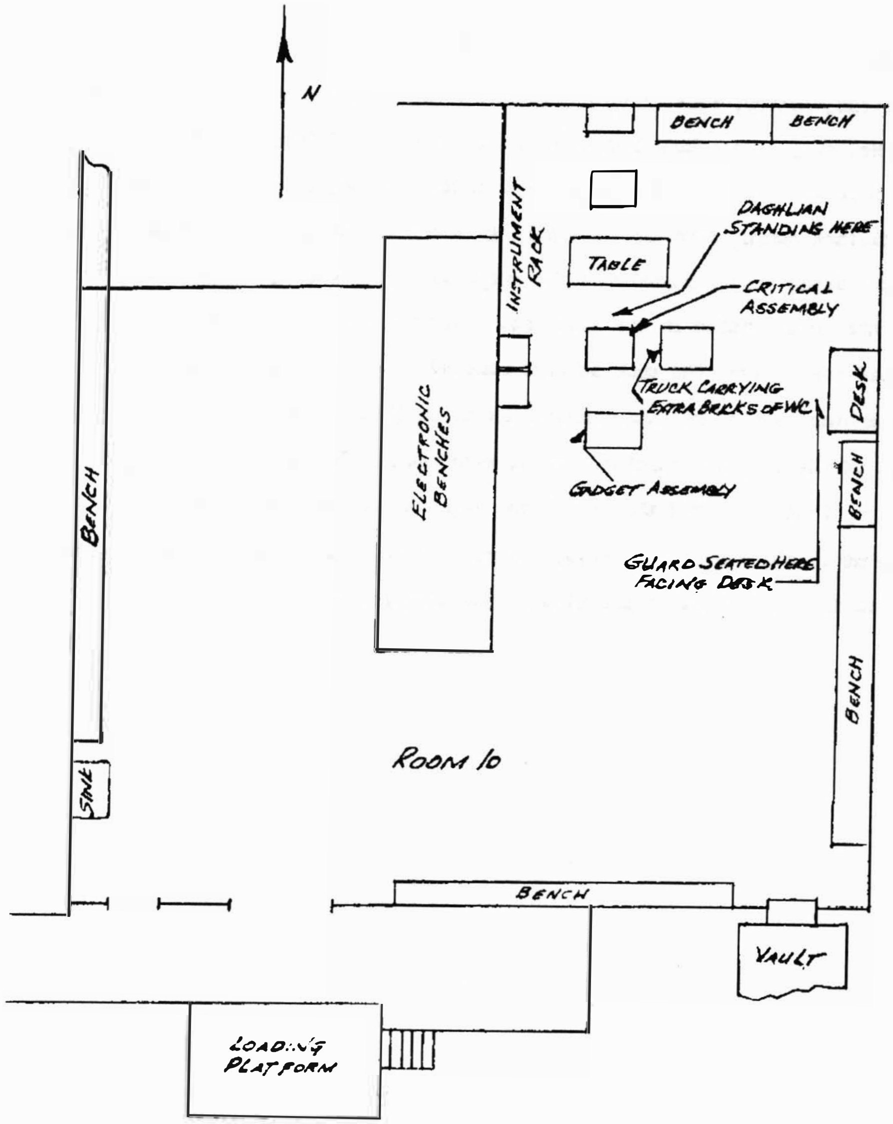


ARRANGEMENT OF "49" ROOM
DURING ACCIDENT
Scale - 1/8"=1'-0"

(LANL)

28 May 1946

D. K. Froman

R. E. Schrieber

Report on May 21 Accident at Pajarito Laboratory

The following presents the material you requested last Friday.

Perlman and I had gone to Pajarito Tuesday after lunch to carry out the field checking of the initiators and active material for the Crossroads tests. We carried 5 initiators in the three special shipping cases. Slotin had arranged for the three 49 [2] cores to be brought down that morning.

We arrived about 1:30 P.M. and found the multiplication measurements on the composite core, started that morning, still in progress. Since the source being used in this test interfered with our field-checking measurements we waited for about one hour to start our work. (It tumed out that one of the 25 [2] shells had been left out by accident during the morning measurements so part of the multiplication measurement had to be repeated.)

At about 2:30 PM, Perlman and I started the counts on initiator Au-18. Meanwhile, Graves came in. A half-scale shot was being fired by M-4 at the lower Pajarito Site. We suspended operations during the shot but finished our neutron and gamma counts about 3:15 PM. Meanwhile Graves and Slotin discussed the critical assembly work. In the course of the conversation, Graves asked Slotin to demonstrate a critical assembly since he (Graves) was planning to do some experiments during Slotin's absence and wanted some indoctrination. At first Slotin said that he didn't have the proper materials for one. Then he remembered that we had the 49 cores there so he said he would do one "in about two minutes" in a beryllium tamper after we (Schrieber and

Perlman) had finished our counts. I remarked that if he were going to do it in two minutes I was going to leave but would stick around if he took a half-hour for it. This was not intended seriously since we all had confidence in Slotin's ability and judgment.

We finished our counting at about 3:15 PM and I put on rubber gloves and started to take the initiator from its case to check the counting. The neutrons from the driving source to be used by Slotin during the assembly would not affect this check so Slotin started his experiment. I was working on the initiator so did not pay close attention to Slotin's operations since I assumed he had done this before and knew how far he could go safely. I did, however, glance around at intervals so the following is my observation and is not based on subsequent conversation. I cannot swear to all the details but state what I believe to be true.

The beryllium tamper was set up on a low steel table near the north end of the room. Slotin stood before the table facing south and Graves stood behind him to his right. Perlman was working with me at a bench along the east side of the room about 15 ft. away. Kline, Young, Cieslicki and Cleary (SPO Security Guard) were around the assembly table at various distances but I do not know their precise positions.

The table on which Slotin was working was fitted with various detectors, some operating counters and others driving Esterline-Angus recorders. I believe that these were tested before the assembly was started. Kline and Cieslicki were running these so could give definite information. A strong Pu-Be source was used as a driving source. I do not know where it was put during the assembly.

I had assumed that the approach to critical would be rather slow so continued to work on the initiator, thinking that when the multiplication got to an interesting point I would tum and watch. It could not have been more than two or three minutes after the start that I tumed because of some noise or sudden movement. I saw a blue flash around the Be tamper and felt a heat wave simultaneously. At the same instant, Slotin flipped the outer top tamper shell off (The tamper was made of two concentric shells, 9" and 13" O.D., I believe). This stopped the reaction.

The blue flash was clearly visible in the room although it (the room) was well illuminated from he windows and possibly from the overhead lights. I believe that the flash appeared only around the hole in the upper tamper hemisphere and around the equatorial gap. Slotin's left hand, which was holding the top hemisphere, was definitely in the glowing region. The total duration of the flash could not have been more than a few tenths of a second. Slotin reacted very quickly in flipping the tamper piece off. The time was about 3:00 PM.

A few seconds after the accident, only Slotin, Graves, and myself were left in the room. Perlman had run up the corridor a few steps and was waiting, the other four had gone out the east door or up the corridor. The rest of us left immediately, going up the corridor.

Slotin called for an ambulance and then prepared a sketch showing our positions art the time of the accident.

Slotin had picked up a Watts ionization chamber meter which must have been near the assembly. We attempted to measure the radiation from the various articles with this but it was so active itself (about 15 div. on the 10^{10} scale) that nothing conclusive could be found out.

After about 5 minutes, at Slotin's suggestion, I took a handful of film badges and put them on the tamper. I carried the Watts meter. The room was quite hot, the meter going over full-scale near the assembly, so I did not linger.

After about 12 or 15 minutes, I went down again. The meter had meanwhile cooled down to about 5 divisions on the 10^{10} scale so was fairly usable. The reading about 10 ft. from the assembly was about 20 divisions on the 10^{10} scale but again off-scale nearer. I tried the G-M counter in its Columbia shield which was under the bench near the east door. It had been left turned on but with the "Counts" off during the accident. It was working and clicked at about 4 or 5 scales per second. The Super-Zoute on this same bench had been left on and was jammed at full-scale. I did not explore further because the room was too "warm" to stay long safely. I took Slotin's and my jackets back up the corridor as I left. I do not believe that I was in the room more than a minute.

No one else entered the room after the accident before we left. Werner (machinist at Pajarito) was going to close the outside doors after we left. He was warned not to go inside nor to stay in the vicinity long.

P.F.C. Cleary (Security Guard) phoned for an emergency relief after the ambulance had arrived (about 15 minutes). We suggested that he ask for two men to come and he relayed by telephone our instructions that one should stay outside the building where he could watch the laboratory outside door and the other stay at the end of the corridor furthest from the hot lab. They were told to stay out of the room under all circumstances.

Incidentally, the boys leaving via the east door had warned the MP's so the gates were opened and all personnel had gone perhaps 50 yds. up the exit road. They remained there until we called them back about 15 minutes after the accident.

The foregoing is my recollection of what happened. I repeat that my observations may not have been correct as to what happened during the few seconds following the accident.

The following section is an attempt to give an impersonal analysis of the accident with the sole purpose of trying to analyze the causes and so help prevent its re-occurrence.

1. Slotin was not, by any possible interpretation, guilty of what legal minds like to call "criminal negligence". The monitors were set up and running, an adequate number of observers were present who, by their silence, agreed to the procedure, and he had provided a safety device in the form of wedges to keep the tamper from dropping if it slipped. The fact that this safety device failed does not alter the situation as far as this point is concerned.

I feel emphatically that there should never be an attempt to establish legal responsibility for the accident. If this should be attempted, it is my opinion that, excepting Perlman and Cleary, all should be held equally responsible since the rest of us knew enough about critical assemblies to voice a protest if we objected to the procedure. No such protest was made.

2. The assembly was made too rapidly and without adequate consideration of the details of the method. A "dry run" without the active material to check the details of the mechanical operations should have been

made.

3. Only those persons actually concerned with the assembly should have remained in the room.

4. No conventional safety devices operating from a neutron monitor could have prevented the accident. The neutron rise was too rapid to have the reaction stopped by any of the devices I have seen used at Los Alamos.

5. While operation of such an assembly by remote control would have eliminated the hazard from this particular "burst", it might well have become a real explosion with equal or greater damage to personnel in spite of shielding walls unless a positive and fast-acting safety device were a part of the assembly. In this case, Slotin was that safety device.

I do not know what safety recommendations for future assemblies will evolve as a result of this accident. There are several points I should like to make.

1. The formulation, approval and publishing of a new set of rules will not prevent more accidents. As stated in item (1) of the preceding section, the existing rules were nominally complied with. In addition to the restatement of rules, there must be a continuous and vigorous campaign to keep the people participating in this work aware of the potential danger in every assembly. Perhaps the work should be rotated among a number of people. As soon as a person ceases to be nervous about the work he should be transferred to another job.

2. Any new assembly should be planned in detail a considerable time in advance. The plan should be sent to several responsible people, any one of which could veto the plan or ask for a clarification.

3. Every new assembly should be attended by one or more observers whose job would be to stop any procedure which they consider hazardous.

4. Wherever feasible, an assembly should be done by remote control provided that this control incorporates safety devices guaranteed to stop the reaction in the shortest possible time.

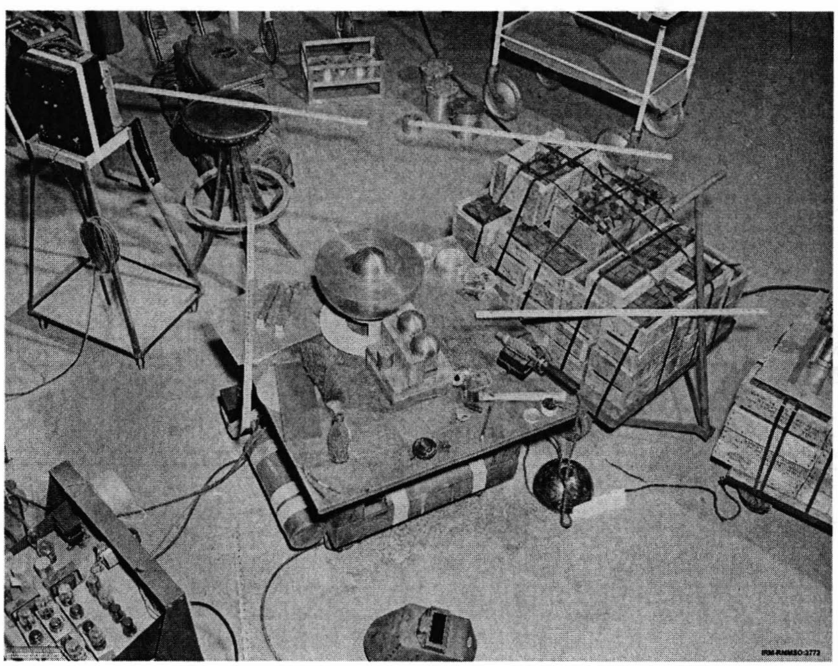
5. A complete account of each assembly should be kept, possibly with a running commentary fed into a wire recorder and either a movie camera or an automatic still camera.

6. New critical assemblies should never be reduced to a routine matter to be "run through before lunch".

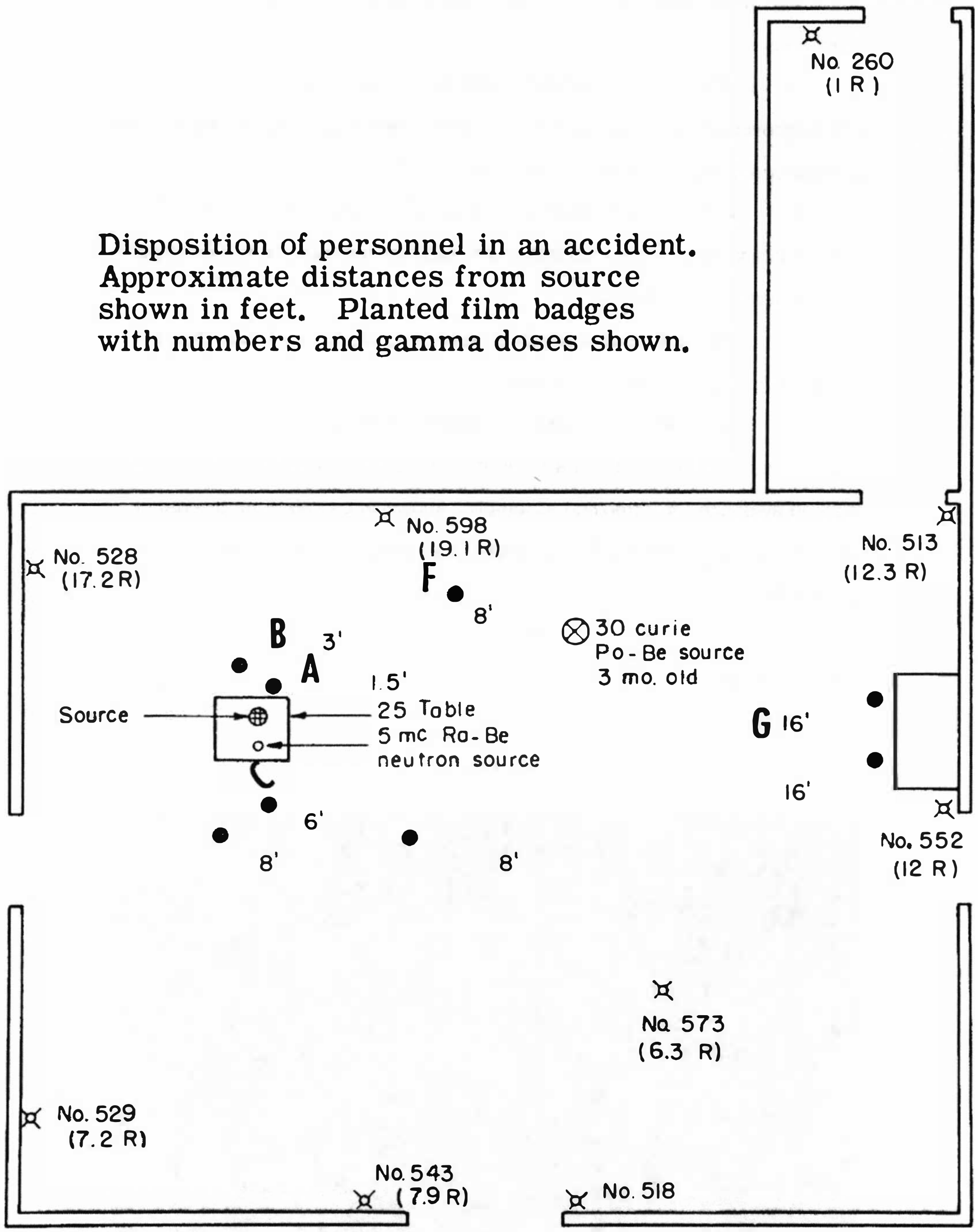
7. A detailed file of all critical assemblies should be kept up do date. This file would be valuable as a guide in making future assemblies and could also be evidence for removing assemblies known to be safe from the rather severe restrictions which will undoubtedly be imposed on all untried assemblies.

Cc: Froman
File

(LANL)



This Slotin accident reconstruction photo shows the position of the objects in the room. (LANL)



In this diagram from Los Alamos report TID-5360, figure "A" represents the position of Slotin. (LANL)

Figures 5, 6, and 7 show the distribution of all neutrons absorbed by the foils. The circles represent the measurements with gold, indium, and manganese foils all normalized to unity at the point .480" from the center. There were no significant differences found in the distribution curves given by these three detectors. The triangles show this distribution as measured with 25 foils, normalized to unity at the first point. In all cases this distribution falls off more steeply at the center than does the other.

The squares are the hypo-cadmium neutrons. This data was obtained by subtracting the activity induced in indium foils in cadmium from the total activity. These points are normalized so that the <u>total</u> activity (no cadmium) is unity at .480" from the center. They show, therefore, the ratio of the activity induced in indium by cadmium absorbable neutrons to the total activity induced in indium at that same place. The + 's are the distribution of neutrons producing the (n,p) reaction in phosphorus (threshold ~ 1.5 Mev).

Figure 8 shows the distribution in the 13-11/16" beryllium sphere, of neutrons producing fission in 28, (n,p) in phosphorus and (n,p) in sulphur. Also plotted (x's) is the phosphorus activity times r^2. The positive attenuation shows that the loss of these high energy neutrons by absorption and slowing down is not made up for by (n,2n) in beryllium under these conditions.

Figure 10 shows the value of $\frac{\text{Flux Barns}}{\text{Source}}$ measured .480" from the center of beryllium spheres with various detectors plotted against the sphere diameter.

Figure 11 shows the distribution of neutrons measured with gold detectors in a 3.62" diameter 49 sphere inside a 9" diameter beryllium sphere. A mock-fission source was at the center of the 49 sphere.

This excerpt from Los Alamos report LA-555 published three weeks before the Slotin accident describes the components used in the accident. The last paragraph specifies the exact diameter of the Pu sphere used in both accidents. It was the same size as the core used in both the Trinity and Nagasaki implosion devices. (LANL)

II-B. Metal Assemblies in Air

1. Los Alamos, New Mexico--August 21, 1945[1,5,21]
   (Plutonium core reflected with tungsten carbide, hand assembly)

2. Los Alamos, New Mexico - May 21, 1946[1,5,21]
   (Plutonium core reflected with beryllium, hand assembly)

These two accidental excursions occurred in the same core and were, in several respects, quite similar. The core consisted of two hemispheres of delta-phase plutonium coated with 5 mils of nickel. The total core mass was 6.2 kg, and the density was about 15.7 g/cm^3.

In the first incident a critical assembly was being created by hand stacking 4.4 kg tungsten-carbide bricks around the plutonium core. The lone experimenter was moving the final brick over the assembly for a total of 236 kg when he noticed from the nearby neutron counters that the addition of this brick would make the assembly supercritical. As he withdrew his hand, the brick slipped and fell onto the center of the assembly, adding sufficient reflection to make the system superprompt critical, and a power excursion occurred. As quickly as possible, he pushed off the final brick and proceeded to unstack the assembly. He died 28 days later as a result of radiation injuries. The exposure

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These two pages from Los Alamos report LA-3611 <u>A Review of Criticality Accidents</u> state that the same Pu hemispheres were used in both criticality accidents, were coated with 5-mils of nickel, weighed 6.2 kg, and had a density of "about 15.7." (LANL) was about 800 rep.

The yield of this incident was 10^{16} fissions.* An Army guard assigned to the building, but not helping with the experiment, was irradiated in the amount of 20 rep. The nickel canning on the plutonium core did not rupture.

In the second incident, the techniques involved in creating a metal critical assembly were being demonstrated to several people. The system consisted of the same plutonium sphere, reflected in this case by beryllium. The top and final hemispherical beryllium shell was being lowered slowly into place; one edge was touching the lower beryllium hemisphere while the edge 180° away was resting on the tip of a screwdriver. The person conducting the demonstration was holding the shell with his left hand with his thumb placed in an opening at the polar point, while slowly working the screwdriver out with his right hand. At this time the screwdriver slipped from under the shell and the shell fell completely on to the lower hemisphere. A burst occurred at once, the shell was thrown to the floor, and all personnel left the room.

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*The Los Alamos archives include some data and comments about a "rerun"(5,22) on October 2, 1945, performed to determine the radiation dose received in the incident of August 21, 1945. The yield of this "rerun" was about 6×10^{15} fissions, but the prompt critical state was not reached. The maximum reactivity of the system during this experiment was about 60 cents above delayed critical.

critical assemblies (Flattop and Jezebel).

During the 22 years since LA Accident No. 2, calculations have been developed to obtain the leakage neutron spectra from critical assemblies, and these calculations have recently been used to determine the leakage neutron spectrum from the critical assembly involved in LA Accident No. 2. The results from the Y-12 assembly mockup and the information obtained from the new blood-sodium activation study are applied to the calculated leakage neutron spectrum to obtain revised neutron dose estimates from the blood-sodium activity measurements made following the excursion.

Calculated Leakage Neutron Spectra

The critical assembly involved in LA Accident No. 2 was a 6.19-kg sphere of δ-phase plutonium alloy reflected on top by a 9-in.-o.d. hemisphere of beryllium and on the bottom by a 13-in.-o.d. hemisphere of beryllium. A screwdriver was used as a wedge between the upper and lower hemispheres to adjust them to the desired critical configuration. The excursion resulted from an unexpected movement of the screwdriver which allowed the upper beryllium shell to fall into place.

The neutron leakage for the assembly has been calculated by Hansen, and is given in Table I. A detailed description of the calculation is given in the Appendix.

The data in Table I are plotted in Fig. 1 relative to the calculated spectra of four critical assemblies used in a recent study of blood-sodium activation.[3] The spectrum in LA Accident No. 2 does not agree well with any of the spectra of the critical assemblies studied. It has a peak at about 2.5 MeV and a steady decrease in neutrons as the energy decreases.

TABLE I

COMPUTED NEUTRON LEAKAGE PER FISSION NEUTRON FOR THE LA ACCIDENT No. 2 CRITICAL ASSEMBLY

Group	Energy	Neutrons
1	3 MeV-∞	0.0404
2	1.4-3 MeV	0.1259
3	0.9-1.4 MeV	0.0606
4	0.4-0.9 MeV	0.0884
5	0.1-0.4 MeV	0.1109
6	17-100 keV	0.0763
7	3-17 keV	0.0561
8	0.55-3 keV	0.0398
9	100-550 eV	0.0288
10	30-100 eV	0.0158
11	10-30 eV	0.0115
12	3-10 eV	0.0098
13	1-3 eV	0.0071
14	0.4-1 eV	0.0048
15	0.1-0.4 eV	0.0055
16	Thermal	0.0176
Sum		0.6993

In Fig. 2, the calculated leakage neutron spectrum for LA Accident No. 2 is compared to that for the Y-12 accident assembly mockup. Since these spectra agree reasonably well, the blood-sodium activation obtained in the Y-12 assembly mockup studies can be used. The small differences between the spectra would result in calculation of only a slightly higher dose (<2%) than that actually delivered.

Blood-Sodium Activation

The blood-sodium activation as a function of distance has been obtained for several critical assemblies.[3] As shown in Fig. 3, the blood-sodium activation from 1 rad of fast neutrons varies from 1 pCi for a near-fission spectrum (Jezebel) to 12.5 pCi for a heavily moderated fission spectrum (Yugoslav). The amount of ^{24}Na produced per rad of fast neutrons varies because high energy neutrons deliver more dose per neutron than do low energy neutrons although the blood-sodium activation

This excerpt from Los Alamos report LA-3861 Revised dose estimates for the critically excursion at Los Alamos Scientific Laboratory, May 21, 1946 states the Pu sphere used in the Slotin accident weighed 6.19 kg. This report also mis-identifies the 13-11/16" Be sphere identified in LA-555 as "13-in.-o.d." when it should have read "14-in.-o.d." (LANL)

SECRET

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4000 SERIES - PIT TOOLS AND HANDLING EQUIPMENT

			No. per kit
PC4000	A*-	Geometry, paraffin, for live plug multiplication	1 each
PC4001	A*-	Hypodermic wire, maganese .040" dia. 32" long	6 per kit
PC4002	A*-	Hypodermic wire, Tu-Al standard (10% Tu; 90% Al, made by Seybolt)., .039" dia., 13" long	3 per kit
PC4003	A*-	Lead mounting plate for standardization of G-M counter	1 each
PC4004	B -	Pit cradle, for 18½" sphere, Y-2015, Issue A	1 each
PC4005	B -	Pit cradle, (doughnut) for 9" sphere, Y-1981-C2, Issue A	1 per kit
PC4006	A*-	Screw driver for aligning plug screw, dwg.Y2013B31 Issue B	
PC4007	A*-	Shims, preformed .0005" gold, for jet ring	20 each
PC4008	A*-	Shims, gold, .0005", flat 2.75" O.D. x 1.375"I.D.	20 each
PC4009	A*-	Tu plug lifting tool, Y-2013C8, Issue A	1 per kit
PC4010	B -	Al trapdoor lifting tool, Y2013B7, Issue B	1 per kit
PC4011		Trapdoor plug lifter, Y2013B13, Issue A	1 per kit
PC4012		Tu plug lifter, Y2013C5, Issue A	1 per kit
PC4013	A*-	Tu plug carrying case, Y2013C14, Issue A	1 per kit
PC4014	B -	Al disassembly tool, lock cup puller, #1, Y2013A6, Issue A	1 per kit
PC4015	B -	Al disassembly tool, lock cup puller #2, Issue A	1 per kit
PC4016	A*-	Tu ½ plug carrying tool, short	1 per kit
PC4017	A*-	Template for 18½" spheres Y2013A26, Issue A	1 per kit

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This is the last page of LAMS-381 Pit Catalog: Destination Kit and lists all of the pit tools used on the F-31 Nagasaki bomb. It lists tools (PC 4005) for the 9" diameter boron-covered tamper sphere and (PC 4004) 18.5" aluminum pusher sphere along with the (PC 4008) gold foil shims used with the 2.75" Pu hemisphere jet ring. (LANL)

TOP SECRET

OUTLINE FOR STOCKPILE REPORTS
TO BE RECEIVED BY MLC

All figures to be in terms of number of weapons
as of 31 December 1947

	Accepted	Under Test
A. F M WEAPONS		
1. Fissionable material		
a. Pure "49" Christy	9	2
b. Composite Christy	36	9
c. Leviated Composite	5	0
	50	11
2. Initiators		
a. Class A, 25 curies or over	50	22
b. Class B, 12 to 25 Curies	13	-
3. H. E. Components		
a. Assemabled	44	(4)
b. Unassembled	28	
4. Other Components (In terms of complete assemblies)	104	54
5. Current Critical Items (Items which were available in less than the quantities prescribed in Stockpile Directive, 4 Sept 47. Show number on hand and number short of prescribed level)	Pits below stockpile directive. Al pushers short 63 on hand. Detonators 156 against 160.	
6. Estimated dates that items in Par 5 will be removed from critical status.	Pits this month Detonator March	
B. L B WEAPONS		
1. Fissionable Material	-	10
2. Initiators		6
3. Other components (In terms of complete assembles)	-	-
4. Current Critical Items (Items which were available in less than the quantities prescribed in stockpile Directive, 4 Sept 1947. Show number on hand and number short of prescribed level)	None. Program is ahead of schedule.	
5. Estimated dates that items in Par 4 will be removed from critical status.		

DECLASSIFIED BY/ DNA, CHIEF, ISCM
SIGNATURE [signature] 17 Sep 91

TS CONTROL SYMBOL
DASA/ 61-47

This document gives the quantities of LB and FM stockpile components and materials in the US inventory as of 31 December 1947. Note that they were using solid, composite, and levitated cores for FM weapons. (Courtesy of Clay Perkins)

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Endnotes

[1] Junior scientists, graduate students, skilled mechanics, machinists, electronic technicians, and other technically adept personnel were subject to the wartime draft or were already in uniform. A way had to be found to put their enormous pool of talent to good use. The 9812th Technical Service Unit (TSU) of the Manhattan Project Special Engineer Detachment was established in May 1943 and by the end of the war almost 3,000 of them were hard at work in places like Los Alamos, Oak Ridge, and Hanford. People such as General Groves often referred to them anonymously in reports simply as "GI's". Although subject to Army rules, regulations, inspections, calisthenics, discipline, etc, they worked alongside the scientists and made invaluable contributions to the Manhattan Project. For example, most of the people at the Los Alamos 'S-Site" were SED personnel and responsible for the development of the explosive lenses used in the implosion device exploded at Trinity. After the war, many of them went on to very successful careers in science and industry. Countless held important patents and one of them, Val Fitch, even went on to win the Nobel Prize.

[2] Personal communication to the author dated 3/23/98. S-10,000 referred to the area that was 10,000 yards south of ground zero.

[3] "Trinity," LA-6300-H, Kenneth T. Bainbridge, May, 1976, p. 30.

[4] As anyone familiar with military slang knows, Fubar stands for Fucked up beyond all recognition; *The Skeptical Inquirer*, Rolf Sinclair, Fall 1993, Vol. 18, No. 1, pp. 63-67. This article concerns one of the most famous urban legends surrounding the test. According to this legend, a totally blind eighteen-year-old University of New Mexico student riding in a car 50 miles away "saw" the flash of the explosion and exclaimed to her sister and brother-in-law, "What's that?" The girl, Georgia Green, was actually only totally blind in one eye. Although she had lost most of her sight in the other eye from an accident at age seven, she could, however, distinguish light and dark. It is therefore completely plausible that she, as well as the other sighted passengers in the car, saw the pre-dawn flash.

[5] "EYE WITNESS REPORT OF NUCLEAR EXPLOSION, July 16, 1945, O.R. Frisch, VFA-470, LANL.

[6] *Ibid.*

[7] Personal communication to the author dated 3/23/98.

[8] Interview with the author on 6/16/02. An extremely rare 2" x 2" x 6" block of this original graphite was presented to the author during a 2/26/05 visit to Argonne National Laboratory.

[9] The laboratory, started on the isolated plateau site of the former Los Alamos Ranch School, was originally called the Los Alamos Scientific Laboratory (LASL) but was renamed Los Alamos National Laboratory (LANL) on 1/1/81.

[10] "The Los Alamos Primer," Robert Serber, LA-1, April 1943, LANL.

[11] On 8/4/01, during the 56th reunion of the 509th held at Wendover, the author was one of a group of seven people who, because they "have worked very hard during the past years to try to perpetuate the image of the 509th, and continue to keep what we did in the public's mind," were the first to be made permanent honorary members of this most elite WWII air group.

[12] *Return Of The Enola Gay*, Paul W. Tibbets, (Mid Coast Marketing, Columbus, OH, 1998), p. 190.

[13] Personal communication to the author dated 3/4/95.

[14] *B-29 Superfortress*, Alwyn T. Lloyd, (Tab Books Inc., Blue Ridge Summit, PA, 1987), p. 10; *A Brief History of the Enola Gay*, Richard H. Campbell, (The National Museum of Nuclear Science and History Foundation, 1998), pp. 3-4. Campbell had done remarkably thorough research documenting the history of each individual *Silverplate* B-29. He supplied numerous photos and documents contained in this book and his help and research were critical. Campbell had also compiled much valuable historical information pertaining to all of the Pumpkin missions. Campbell's definitive history of the 509th B-29's is called *The Silverplate Bombers* (McFarland & Company, Inc, NC, 2005). Sadly, Campbell passed away on Jan 20, 2011.

[15] Tibbets' decision to pick Sweeney as commander of the second atomic mission remains controversial. When asked by the author on 7/11/98 why Tibbets choose Sweeney, *Enola Gay* bombardier Tom Ferebee replied, "Friendship." Although involved extensively in testing and crew training, Sweeney had zero combat time. Other 509th Pilots, including Fred Bock, Tom Classen, Jim Hopkins, and Jim Price, had previous

invaluable combat experience. Of these, many in the group felt the well-liked 509th Deputy Group Commander Classen should have been chosen, instead of Sweeney, to command the second most important combat mission of World War II. The decision to bypass Classen, whom the men respected and trusted, reportedly left him embittered.

[16] Interview with the author on 8/10/95. Brixner's truck became mired down in mud and he reasoned that, since he never saw them hit it, the safest place to be was in the middle of the bullseye until the test was over. He became worried as he looked through the viewfinder and saw the bomb coming right at him. His nervousness subsided when he saw the side of the bomb's tail because this meant the bomb would hit off-target.

[17] Personal communication to the author dated 3/4/95.

[18] Ashworth was a spit-and-polish, by-the-book, naval aviator who oft-times viewed the 509th as a "bunch of playboys" and "Tibbets' Rowdies." He never hesitated to call things the way he saw it. As such, he rubbed some of them the wrong way, including both Tibbets and Sweeney. However, in a 7/11/98 interview with the author, Tom Ferebee admitted he always genuinely admired and liked him. "We really were a bunch of playboys. The reason he wasn't liked was because he was the only guy I knew who always tried to tell the truth and a lot of people don't like to hear that!" Unlike some other people involved with the wartime atomic missions, Ashworth never asked for, or received compensation of any kind for granting interviews or signing autographs. He always considered it to have been part of his service to his country. He also taped 20 hours of oral history for the Naval Institute at Annapolis in 1991. After the end of the war, Ashworth went on to a distinguished career in the Navy. In January 1951, he became Executive Officer of the USS *Midway*. He went on to become CO of the USS *Corson*; Commander of Naval Ordnance Station, China Lake, CA; CO of the carrier USS *Franklin D. Roosevelt*; Commandant of Midshipmen at the US Naval Academy in Annapolis, MD; Commander, Anti-Submarine Warfare, Carrier Division Eighteen in the US Atlantic Fleet; Commander of Attack Carrier Division One, in the US Pacific Fleet; Deputy Chief of Staff, Headquarters, US European Command in Paris; Commander of the US Sixth Fleet; Deputy and Chief of Staff, US Atlantic Fleet, and Chief of Staff and Aide to the Commander in Chief, US Atlantic Fleet/Commander in Chief, Western Atlantic Area until his retirement in 1968. In wartime reports, postwar articles, and in interviews, including those with the author, Ashworth has stated he always had nothing but the highest respect for the flying abilities of both Tibbets and Sweeney. However, as someone with extensive experience in making tough command decisions, Ashworth has also never hesitated in expressing his criticism of their command abilities. Ashworth died 12/3/05.

[19] *Hirohito, Emperor of Japan*, Leonard Mosley, (Prentice-Hall, Englewood Cliffs, NJ, 1966), p. 286; *Japan's War*, Edwin P. Hoyt, (McGraw-Hill, NY, 1986), p. 385.

[20] *B-29 Superfortress*, Curtis LeMay and Bill Yenne, (McGraw-Hill, NY, 1988), p. 123.

[21] Personal communication from Alvarez to author Max Morgan-Witts dated 4/20/76. Copy provided to the author by Morris Jeppson.

[22] Interview with the author on 9/6/95.

[23] There are those who insist *Little Boy* and *Fat Man* were really named for President Roosevelt and Winston Churchill, respectively. This theory is discounted by both Los Alamos archivist Roger Meade and by Vice Admiral Fred Ashworth U.S. Navy (Ret.). In his autobiography *Peace & War* (Columbia University Press, NY, 1998, p. 104), Robert Serber stated that he named the bombs. Serber wrote that *Thin Man* was taken from the title of the Dashiell Hammett detective novel and *Fat Man* referred to Sidney Greenstreet's role in *The Maltese Falcon*. *Little Boy* was also sometimes referred to as *Thin Man Junior*.

[24] Gunnar Thornton interview with the author on 5/23/96.

[25] *The Curve of Binding Energy*, John McPhee, (Farrar, Strauss, and Giroux, NY, 1973), p. 136.

[26] *Dark Sun: The Making of the Hydrogen Bomb*, Richard Rhodes, (Simon & Shuster, NY, 1995), p. 17; "Report of Gun Assembled Nuclear Bomb," A.F. Birch, 6 October 1945, pp. 24-25. This long-compromised document was openly available to the general public in the Correspondence ("Top Secret") of the Manhattan Engineer District, 1942-1946, Record Group 77 at the National Archives until it was withdrawn from general circulation 1/13/72. According to this document, the weights for the active material in the target insert and projectile were 25,616.44-g and 38,531.12-g respectively. Given a density of 18.8 g/cm^3, the 64,147.56-g core of beta-stage enriched uranium was probably (when fully assembled) 6.25" in diameter and 6.75" long. The 6.5" bore of the gun barrel fixed the maximum diameter of the bomb core. Because nobody knew for sure exactly how much or the enrichment rate of the HEU that would finally be available from Oak Ridge

(later Oak Ridge National Laboratory or ORNL) for use in the L-11 combat unit, simply adjusting the length of both the target insert and the projectile could easily accommodate any last-minute changes. Declassified records indicate the only complete HEU core ever made was used in L-11, although there are some reports that state a few were at least partially manufactured and tested for the relatively small handful of postwar stockpiled *Little Boy* weapons. In keeping with measuring systems in use during this period, all weights for fissile materials, as well as densities for materials, are specified in metric. All physical dimensions for components are specified in English (SAE).

[27] "Report of Gun Assembled Nuclear Bomb," p. 6.

[28] "Production of Hemispheres of Uranium and 25 by Hot Pressing," LA-198, January 13, 1945, LANL, p.3: *The Swords of Armageddon* CD-ROM, Chuck Hansen, (Chucklea Publications, Sunnyvale, CA, 1995), VI-73. Through his use of the Freedom of Information Act (FOIA), Hansen amassed the largest collection of declassified nuclear weapons information in existence anywhere. This remarkable CD-ROM is the result and it should be considered as the single most definitive resource tool for anyone interested in studying nuclear weapons technology. Sadly, Hansen died from cancer on 3/26/2003; "Uranium Seizures Heighten Terrorism Concerns," *Aviation Week & Space Technology*, April 3, 1995, p. 63. This article claimed the uranium enrichment rate for *Little Boy* was less than 87.5%. The enrichment percentage indicates how much of a given quantity is U-235. The balance is normal U-238. Criticality experiments conducted at Los Alamos in early 1945 utilized enrichment rates in the 70% to 73% range. Experiments done in October 1945 used U-235 with an enrichment rate of 76%. Oralloy with an enrichment rate of 93.18% has a density of 18.45; "The U.S. Calutron Program For Uranium Enrichment: History, Technology, Operations, And Production," A.L. Compere, W. L. Griffith, ORNL, October 1991. This report states the total amount of Oralloy produced at Oak Ridge by 7/28/45 was 74.68 kg at an average enrichment rate of 82.68%. It shows the enrichment rate had been steadily increasing since 6/24/44 and by the time the Oralloy for *Little Boy* had been shipped to Tinian the rate was up to a high of 88.38%. Most of the amounts produced in a two-week period up to 6/16/45 were only about 3 kg. The large 22.28 kg batch produced between 6/16/45 and 7/28/45 had a rate of 85.01%. This report also shows that amounts produced by Oak Ridge meant that another *Little Boy* would not have been available until late September or early October 1945. The scientists used a system of code numbers to describe fissile material in all reports. They utilized both the atomic number and mass of the element. U-235 had an atomic number of 9<u>2</u> and a mass of 23<u>5</u> so it had the code number 25. Pu-239 had an atomic number of 9<u>4</u> and a mass of 23<u>9</u> so the code number was 49.

[29] *Critical Assembly*, Lillian Hoddeson... (et al.), (Cambridge University Press, Cambridge, 1993), p. 410. This book is highly recommended. It details the remarkable technical history of Los Alamos from 1943 to 1945.

[30] Interview with the author on 4/1/95.

[31] *The Manhattan Project: Making the Atomic Bomb*, United States Department of Energy, 1994, p. 51; The *Little Boy* weight range has been specified in various publications as anywhere between 8,900 and 9,700-lb. In May 1981, three *Little Boy* training dummies and one drop dummy were "unexpectedly uncovered" in storage at Los Alamos. The drop dummy did not simulate the full bomb weight, but did simulate its ballistic characteristics. The training dummies, however, were correct as far as all internal components (except fissile material). One of these four units was cut in half and subsequently utilized for testing at Los Alamos in 1982. A report issued in conjunction with these tests stated that the *Little Boy* weighed 9,500-lb. According to a 5/20/96 interview with the author, Los Alamos scientist Richard Malenfant stated "the 9,500-lb. figure was the approximate weight of the training unit intact as it would have been carried by a B-29." Since a training unit would not have contained fissile material or cordite propellant, the actual L-11 combat unit weighed closer to 9,700-lb. A photo of test unit L-1 sitting on a skid in the assembly building at Tinian had a lighter weight of "8,555#" written on the nose although this Y-1792 unit contained a clock box, Brode Informers and battery box, Archies and batteries, Yagi antennas, baro switches, target case, 150 lb. projectile, cordite powder bags, and MK XV primer. This lighter weight was also because it did not contain a K-46 liner or any heavy WC tamper rings inside the target case.

[32] Unless specifically attributable to cited sources, the author made all external and some internal measurements of both *Little Boy* and *Fat Man* casings and components. Access to casings, components (some in private collections), blueprints, drawings, and measurements was provided through the gracious permission and kind cooperation of the staffs at the Experimental Aircraft Association (EAA) Museum in Oshkosh, WI; Harry S. Truman Library in Independence, MO; Imperial War Museum (IWM) in London and Duxford, UK; The National Museum of Nuclear Science and History in Albuquerque, NM; National Museum

of Naval Aviation in Pensacola, FL; Norris Bradbury Science Museum in Los Alamos, NM; Smithsonian Institution National Air and Space Museum (NASM) in Washington, DC; U.S. Air Force Museum in Dayton, OH; U.S. Navy Museum in Washington, DC; and the West Point Museum in West Point, NY.

[33] Gunnar Thornton interview with the author on 8/10/95.

[34] In interviews with the author, Weaponeer Leon Smith stated he designed the FTB for both weapons over a 30-hour period. Smith died 10/14/12.

[35] The description in this section of the clock box, baro switches, and radar components of the fuzing systems was provided to the author by both interviews and personal communication with G.C. Hollowwa.

[36] "Report of the Ordnance Division," LAMS-94, May 15, 1944, LANL, p.26. This report states that Mark 111-A mechanical flare fuse-clocks were modified into clock switches. Later, M-127 clocks were used.

[37] Alvarez letter to Morgan-Witts. The four Archie 9A6 units used in L-11 were numbered 5763, 5790, 5700, and 5708. 9A7 units were used in F-31.

[38] According to an 8 August 1945 memo from Colonel Kirkpatrick to Major Derry indicated the battery box "heaters did not operate at any time during the mission. The lowest bomb bay indicated temperature was plus 4 degrees centigrade [39° F] since the doors were open just for the final minute."

[39] Beser made a wire recording of the *Enola Gay* inter-phone conversations during the strike phase of the Hiroshima mission. This priceless, historical recording of all crew comments was handed over to an information officer after the plane landed at Tinian and then mysteriously disappeared forever.

[40] Although used on the earlier *Little Boy* test units, photos of L-11 underneath the *Enola Gay* in the loading pit on Tinian do not show the presence of any clips. However, clips were used on the F-31 *Fat Man* several days later.

[41] Jeppson kept both the original green plug and a spare red arming plug (with signed tags). On 6/11/02, Butterfields Auctioneers Inc. in San Francisco put Jeppson's plugs up for auction. These were purchased for $167,500 by 68-year-old retired physicist-turned-developer Clay Perkins. The federal government then immediately moved in to block the sale claiming, according to San Francisco federal prosecutor Steven Saltiel, "Their design is classified as secret, restricted data, and has never been declassified." The defense introduced an earlier draft version of the author's book (Exhibit K) to show the court that information about the plugs was commonly available. Despite a last-minute government request to delay the hearing, U.S. District Judge Susan Illston dismissed the case of United States v. Butterfields Auctioneers 02-2776 (in part based on this book) on 6/14/02. The actual plugs used in *Little Boy* were staked on the sides to prevent the plugs from being unscrewed after final inspection. However, the plugs used in *Fat Man* F-31 (on display at the Truman Library and the West Point Museum) were not staked. During the process of restoring the *Enola Gay* at the NASM Paul E. Garber Restoration Facility in Suitland, MD, spare green and red plugs were discovered by veteran restoration expert Richard Horigan. These plugs had fallen behind some equipment in the radio compartment area where Weaponeer Morris Jeppson sat during the mission. As of this writing, these plugs are on display at the NASM Udvar-Hazy Center in the same area as the *Enola Gay*. A green plug was in the possession of Weaponeer Leon Smith, but his plug has no identification tag. In 1995, he told the author Jeppson gave it to him after the mission, something Jeppson has denied in statements made to the author and others. It was most likely one of the many spare plugs carried onboard the *Enola Gay* during the combat mission. However, since Smith was Weaponeer during Operation CROSSROADS, his plug might also have come from one of the *Fat Man* implosion devices used during that test series. Either way, his plug is also of significant historic importance. Another green plug is in the possession of the family of the late General Kenneth D. Nichols who served as General Groves chief aide and troubleshooter for the Manhattan Project. Red and green plugs are also in the possession of the Edward A. Ryan, Jr. family. Ryan was a member of the 1st Ordnance Squadron based on Tinian and helped in the bomb assembly.

[42] *The Best-Kept Secret*, John Purcell, (The Vanguard Press, NY, 1963), p. 177; Personal communication to the author dated 8/14/95. Contrary to some previously published accounts, it was actually Jeppson, not Parsons, who climbed back into the bomb bay and changed the plugs.

[43] Personal communication to the author dated 4/17/95.

[44] Personal communication to the author dated 8/10/95.

[45] "Report of Gun Assembled Nuclear Bomb," p. 5; *Project W-47*, James Rowe, (JA A RO Publishing, Livermore, CA, 1978), p. 63. Rowe only mentions a 24.0" target case. His *Project W-47* book deserves some explanation at this point. According to Rowe, he was "the Project Officer of the military detachment responsible for the modification and assembly of the flight test units and the final assembly of the A-bomb during the last 107 days of the war, at Wendover Base, Utah." The book is filled with fascinating descriptions

of bomb assembly and drop test programs carried out at W-47 (Wendover). It graphically illustrates the enormous time pressures placed on Rowe's teams to assemble and test the continuously changing bomb designs. Much of the information in the book has been cited over the years as source material by numerous authors. However, Rowe had access to only a small portion of atomic bomb development and in many instances, to put it mildly, made incorrect assumptions and conclusions based on insufficient data. Although involved with the flight test units, he was not involved in any capacity with "the final assembly of the A-bomb." Rowe claimed in his book that both of the *Little Boy* and *Fat Man* combat bombs were assembled by his 1st Ordnance crews at Wendover, flown to Tinian, and then dropped on Japan. This is completely false. One Los Alamos source refers to the book as "seriously flawed." The information contained in his book should therefore be viewed with caution by researchers. During an interview with the author on 8/4/01, one of Rowe's assembly team members, Joseph A. Badali, adamantly insisted that the combat units were assembled at Wendover and flown directly to Tinian. He, like Rowe, claimed that Los Alamos did not want to give them the credit they deserved. The bomb assembly area at Wendover was quite some distance across the hot, wind-swept, salty desert away from everyone else stationed at the base. It was an isolated secure area totally surrounded by tall barbed wire fences, guard towers, and security checkpoints. Although they were housed at the same base, this tight-knit group worked in almost complete isolation from the 509th personnel. After assembly, they would bring the completed test units out to the loading pits adjacent to the taxi strip for loading into the planes. Some of these historic assembly buildings and loading pits remain intact at Wendover. The author was graciously allowed access to them on 8/5/01, 4/6/05, 6/13/07, and in 2015. The three loading pits are 126" x 216" x 73" deep, 102" x 179", and 129" x 254".

[46] "Report of Gun Assembled Nuclear Bomb," pp. 20, 24.

[47] Thornton interview on 8/10/95.

[48] It should be mentioned at this point that all front-to-back target case component dimensions cited here are approximations based on a 22" core center.

[49] *Project W-47*, p. 64; *Project Y*, p. 194. A basic cross-section drawing (OVA-54 *Fatman/Little Boy* Prints) of *Little Boy* was supplied to the author by LANL on 8/14/95. This drawing included the target-case to gun-tube adapter as well as a section showing the internal bore of the aft end of the target case and adapter. During the testing phase, this adapter allowed barrels of different diameters to be attached to the same size target case. The shock of firing was absorbed by the adapter during testing and many times had to be replaced along with the nose nut after the test. While no dimensions are specified in this illustration, the proportions shown are consistent with the actual 6.5" bore and 13" diameter tamper. The adapter appears in this illustration to be 8" to 9" thick and about 12" to 15" in diameter. Through close physical examination of several postwar *Little Boy* casings in 2005 and 2008 (with the full assistance and cooperation of museum curators who, in one instance, performed a partial disassembly to aid in the inspection process), the author was able to determine the adapter was 9.25" in total length, extending 4.25" from the back of the target case, 5.0" in front of the gun tube, was 12.25" in diameter at the point where it surrounded the gun tube behind the target case and 16.5" in diameter where it contacted the interior surface wall of the target case (the WC with liner had already been removed) at the aft end of the target case, and had a centrally-located 6.5" diameter hole. By utilizing a Rigid SeeSnake® micro inspection color TV camera in May 2008 to create digital still and video images of the inside of the target case in a publicly-displayed LB at the IWM (again with the full cooperation and assistance of the museum staff), the author was able to observe and then measure that the forward surface of this adapter was set back 31" from the front of the target case, the aft surface was 34.75" from the front, and it had four 1" deep and 1" wide vent channels machined into the surface radiating outward from the central 6.5" diameter hole equally spaced at 90° intervals like clock hands. At the outer end of each slot, where it contacted the interior wall of the target case, an additional vent channel was machined that extended each front vent slot rearward to the back of the adapter. The Acme threads on the interior surface of the target case at the point where the adapter was secured can be seen inside these channels. These deep channels allowed some of the air pushed by the exploding projectile to escape and also served to disrupt any developing shockwave produced by that rapidly moving projectile. Birch's 17 July 1945 memo to Parsons mentions "that a leak might by-pass the seals through the interrupted threads of the adapter" and these side channels in the adapter are the "interrupted threads" to which Parsons was referring. Although Rowe states the muzzle was threaded for "approximately eight inches," the three inches of muzzle threads in the actual gun tube were placed roughly in the center of a stepped-down lip section with a shoulder or "lip" that was 5" in length. *Project Y* refers to "the target case, its adapter to the muzzle threads...", however Rowe makes no mention of this adapter in his book. He points out that where the threads ended back from the end of the barrel, there

was a shoulder or a step in the diameter. Rowe states the barrel was screwed into the target case (actually the adapter) until this shoulder came in contact with the target case. The adapter is barely visible in several photos of L-11 inside the Tinian assembly building. The four battery cases were attached to short lengths of angle aluminum screwed into two collars that were clamped to this adapter. Though not specified by Rowe, a "square type of thread" mentioned by him was the Acme standard thread commonly in use at that time cut at the normal rate for that diameter of two threads per inch for maximum strength. A special wrench was developed to attach/remove this adapter from the target case.

[50] *Manhattan District History, Project Y, The Los Alamos Project*, David Hawkins, (Tomash Publishers, Los Angeles, CA, 1984), p. 193. This book is an extensively declassified version of the original Los Alamos report LAMS-2532 written in 1946 and 1947. This report was also the basis for part of the book *The Secret History of the Atomic Bomb.* In *Project Y*, the author explained that the Los Alamos engineers had "developed a tapered assembly that could be pushed apart hydraulically so that the outer cases of high-alloy steel could be reused." (see K-46 below) According to the author interviews with Gunnar Thornton, because it was so brittle, most of the WC tamper material placed inside the target case usually fractured during testing. What little remained intact was removed from the case hydraulically. Both bombs utilized conservative designs and were overbuilt since Groves felt it absolutely necessary to err on the side of caution. In reality, the massive target case could have been made much smaller, or even eliminated, since subsequent postwar gun-assembled weapons did use smaller, lighter cases. All measurements on the interior of the target case were made by the author. According to a chemical analysis made for the author in 2013, the standard 4340 steel alloy used on all the targets cases consisted of Fe and 1.79% Ni, 0.8% Cr, 0.71% Mn, 0.38% C, 0.3% Si, 0.28% Mo, 0.033% S, 0.027% P and the hardness was 31 HRC.

[51] Thornton interview on 8/10/95.

[52] "Martempering of K-46 Tool and Die Steel," LAMS-309, 7 January 1946, LANL; "Production of *Little Boy* Components," 5 December 1945, General Groves to Rear Admiral W.S. Parsons. This document mentions the "K-46 liner assembly." K-46 was one of several proprietary tool and die steels manufactured by the Jamieson Steel Corporation. According to the postwar Z-Division Progress Reports, this liner material was later changed in 1947 to Midvale Constant manufactured by Midvale Steel. This liner was placed between the tamper rings and the target case. In postwar stockpile units this liner sleeve was stored before assembly as a complete unit with the three large target rings of WC pressed inside. A precision measurement of the WC diameter (13.1513" ± 0.0004") was made by the author in 1995 utilizing a computerized Coordinate Measuring Machine (CMM) on a machined tamper ring fragment recovered by a source from Anchor Ranch in 1945. This diameter is consistent with proportions shown in the above-mentioned target case cross-section drawing supplied by LANL. According to a 7/27/96 interview with the author, machinist Ralph Sparks stated, "I worked over in the V-Shop for a while. They came in one day with a great big hunk of tungsten carbide. It was a big tubular shape...about 12 to 14 inches in diameter, with about a 6 or 8 inch hole in it." He also indicated the sleeve might have been only about 10"-12" in length. If these lengths were true, it would have meant a weight of about 600-lb. However, an 18" long tamper assembly with a 6.5" hole would have weighed about 970-lb. In a recent limited edition, personal book, one source described how the WC powder was put into a mold, "encased in an electric heating coil and heated to 2,300 degrees centigrade and put under 125 tons per square inch pressure. The idea was to cause the tungsten carbide powder to adhere to itself and make a solid ring 13 and ¼ in diameter, 4 inches thick and with about an 8 inch hole in the middle." This larger diameter 13.25" ring was "ground to size on a horizontal cylindrical grinder using diamond-impregnated wheels" and then pressed inside the K-46 liner sleeve. "Special Materials Report of Group CMR-6 for the Period Dec. 20, 1946-Jan. 20, 1947," January 24, 1947, p. 2, "Ten tungsten carbide rings, thirteen inches in diameter, were produced this month. At this time, the total number of rings produced is 26." That is enough for almost 9 complete target units. This chart (below) appears in the DOE document "Restricted Data Declassification Decisions 1946 to the Present" (RDD-8) released on January 1, 2002. It states that no "Nuclear Components" for Gun-Type (LB) weapons were made and only two "Non-Nuclear" components. This CMR document, and other documents reproduced in this book, clearly refutes this chart!!

	Fiscal Year			
Number of non-nuclear components	1945	1946	1947	1948
1. Gun-type	0	0	(0)	(2)
2. Implosion	2	9	(29)	(53)
Number of nuclear components				
3. Gun-type	0	0	0	0
4. Implosion-type	2	9	13	50

Addressing possible security concerns, the DOE has subsequently removed these WC tamper pieces from all units on public display along with most of the gun tubes (see below).

[53]*Project Y*, p. 224; *Project Alberta: The Preparation of Atomic Bombs for use in World War II*, Harlow Russ, (Exceptional Books, Los Alamos, NM, 1984, 1990), p. 10. The Russ book is an engaging description of his involvement with the engineering of the barometric fuzing and other assemblies used in both *Little Boy* and *Fat Man* weapons. It detailed daily life at both Los Alamos and Tinian. However, his own vivid personal recollections of events at Tinian were interspersed with descriptions drawn from Hawkins' *Project Y* book as well as other sources. This occurred when he described occurrences and procedures with which he had no direct involvement. As such, his narrative differed occasionally from what actually occurred at Tinian.

[54] "Integral Experiments I, Tamper Reflections and Distributions," E. R. Graves and J. H. Manley, June 15, 1945, LA-304. This report mentions a WC density of ≅14.8 with a cobalt content of 6% by weight. However, the criticality experiments carried out with Pu spheres at Los Alamos on 8/21/45 by Harry Daghlian showed later the WC bricks had an actual higher density of 14.952 (8.643 oz/in²). Both experiments were conducted with surface ground bricks measuring 2.107" x 2.107" x 4.170".

[55] "Report of Gun Assembled Nuclear Bomb," p. 4; "Production of *Little Boy* Components;" Although the *Little Boy* gun bore dimension is mentioned on this postwar document, which has been available to the public on microfilm since 1982 from the National Archives (MED Record Group 77), even after more than half a century the gun bore is still considered classified by the Department of Energy (DOE). This document calls the gun barrel "Exp. [Experimental] Gun, 6 ½", Type B, Mod [Modification] 0." As of this writing, Type B, Mod 0 is stamped into the nose nut of the postwar stockpiled *Little Boy* on display at The National Museum of Nuclear Science and History, Imperial War Museum, and the Smithsonian NASM while Type A, Mod 0 is on the *Little Boy* at the Navy Museum. The Navy Museum is located in a building at the Washington, DC Navy Yard that originally served as the Naval Gun Factory. The term's "gun", "barrel", and "tube" were all used to describe the same object. In 1986, NASM's Paul E. Garber Facility restoration expert Richard Horigan removed the 17" diameter perforated back plate on the *Little Boy* AAA491. After removing the 15" armor plate inside, he noted that part of the breech had been removed and he could look inside the bore of the gun barrel. During a subsequent tour a few days later, Horigan again removed the plate, showed the interior to the tour guests, and briefly explained the bomb's operation. It turned out that several of the tour members had been in the military. Even though this LB had been at the NASM, and on public display at various times since 1965, the DOE finally became concerned that (no matter how impossible or improbable) the LB might somehow be stolen and possibly converted into a crude nuclear device. Because it still contained the gun tube and the interior tamper assembly, within a few days representatives from Army Intelligence and the DOE showed up on June 12, 1986 in force and heavily armed, moved the current tour group into an isolated room, interrogated the incredulous NASM staff, and confiscated (or in the words of one DOE source, "kidnapped!") *Little Boy*! It was immediately shipped to a secure DOE facility, "archived", and reluctantly returned over seven years later on August 2, 1993 with all of the original Yagi antennas and clock box missing, a new solid rear plate, and the interior armored plate now welded to the 15" tube inside the 17" tail tube. After the terrorist attacks on 9/11, the *Little Boy* at The National Museum of Nuclear Science and History was removed, gutted, and finally returned to public display in September 2003. The original LB on display at the Wright-Patterson USAF Museum was removed and "restored' before being returned for public viewing in July 2004. This LB now has three female electrical sockets on the top plate, three red arming plugs with clips, and replica Yagi antenna (for some as yet unknown reason, the original Yagi antennas have now been removed from all LB and FM units on public display). At about the same time, the DOE also removed the *Little Boy* from the Bradbury Museum. According to several sources, it was moved to a location in a secure underground weapons storage bunker located some 300 feet below the

McDonalds restaurant in Los Alamos. It has since been moved to the classified weapons training facility at Los Alamos and a non-classified replica was fabricated by an outside contractor to replace the original and put on public display at the Bradbury in 2005. Caution is one thing, but it is difficult to imagine a scenario whereby the 9,500-lb LB's on public display at the secure Bradbury, The National Museum of Nuclear Science and History, and the W-P USAF museums could somehow have been removed without anyone noticing, or stopping, the theft in-progress! All units now on public display have had their gun tubes and tamper assemblies removed and replaced with a length of 8" steel pipe. In order to keep these cases from literally falling apart, new bushings and collars had to be fabricated for the target case, bulkhead, and tail tube to fill in the gaps between this pipe and the original 10.5" diameter gun tube.

[56] *Project Y*, p. 193; LAMS-2532, p. 223; *Project W-47*, p. 63. With the target case adapter in place, the front of the gun was almost even with the aft end of the target case. If the gun was "about a half a ton", then it would have been about 66" long. Conversely, if it "was 6 ft long," then it would have weighed around 1,091-lb. If the aft end of the gun were flush up against the rear interior plate inside the tail tube, which is 16" from the end of the tail tube, this would have meant the gun was no more than 69" in length weighing in the neighborhood of 1,036-lb. However, the aft end of the actual gun tube was most likely 107.5" from the nose of LB and 12.5" from the rear tail plate making it about 72" long. The gun tubes were "proof" tested with 200-lb projectiles.

[57] Exterior barrel measurements made by the author. Postwar guns for the handful of stockpiled weapons were made at the Pocatello Naval Gun Factory in Idaho.

[58] *Project W-47*, pp. 63-64. Rowe states the gun barrel was tapered (p. 63). Discarded standard tapered naval guns were used for some of the drop tests at Wendover (*Project Y*, p. 193). This is probably one of the guns Rowe described. The actual combat *Little Boy* gun had parallel sides, as do the guns in postwar stockpiled weapons on display in museums. There were six Acme threads at the front of the gun tube machined at the rate of two threads per inch.

[59] *Critical Assembly*, p. 117.

[60] *Critical Assembly*, p. 83.

[61] Thornton interview on 8/25/96.

[62] Personal communication to the author on 12/1/05.

[63] *Project Y*, p. 116; "Report of the Ordnance Division," p. 46. This report says they were testing a 60 pound projectile that could be fired at a velocity of more than 3,000 fps.

[64] *The Swords of Armageddon*, VI-71; Thornton interview on 8/10/95. Research has indicated boron-10 was initially incorporated as part of the safety sabot used in the plutonium gun. Although subsequently utilized in the implosion design as a neutron absorber, Thornton claimed a boron-10 safety sabot was not used in the final *Little Boy* gun bomb. In communications with the author, author Richard Rhodes wrote that during interviews with Los Alamos scientist Robert Serber, he "did mention sabots."

[65] Thornton interview on 8/10/95.

[66] "Report of Gun Assembled Nuclear Bomb," p. 26.

[67] Thornton interview on 8/10/95. Thornton recalled it could have been either 11-kg or 11-lb of Cordite. However, File No. 17 of the Tinian Files at the NARA mentions "4 - 2 pound charges of Cordite" in conjunction with test unit L-6. Eight of these bags (four backup bags) were carried in a standard BuOrd (Bureau of Ordnance) M7 powder can. According to the postwar Los Alamos Z-Division progress reports, the stockpile "Road" units also used the four-bag system. The July schedule for drop tests at Kingman (Wendover) mentions (p. 5) that a "unit will have a 9# charge."

[68] "Breech removal, etc," W.S. Parsons, 25 May 1945; "Vent Seals for LB," F. Birch, 17 July 1945; *Project Alberta*, p. 59; *Project W-47*, p. 93. The entire breech assembly weighed about 75-lb. The original plans called for Parsons to remove the heavy breech plug in-flight, insert a single powder bag, and then reinstall the breech plug. However, because the breech was recessed so far inside the tail area of the bomb, it proved to be almost physically impossible for even the strongest person to hold it for more than a few moments at arm's length, let alone successfully screw it back into the barrel. Rowe described an interrupted thread breech plug with alternating lugs and spaces at 120° intervals. For speed in loading, this type of plug can be inserted in the breech and given a slight clockwise twist to seat it tightly. When the breech was redesigned into a two-piece unit, the outer bushing of this plug contained about 3.5" of continuous threads, while the inner plug, according to Parsons, required "about 16 turns" with the breech wrench to seat it properly. *Z-Division Progress Report*, LAMS-621, p. 59, October 13, 1947, mentions, "Chase out Acme thds. on Breach Plug for L.B." If the inner plug was also threaded using Acme standard threads, then it would have been cut at two

threads per inch and 16 turns would have moved the plug eight inches. However, it might also have been cut at a finer four threads per inch and, if so, would have meant the threaded portion occupied only the back half of the plug with the forward portion stepped down slightly like the outer bushing. According to the author interview with Gunnar Thornton on 8/10/95, the scientists sometimes also referred to the primer as a detonator. In keeping with the need for redundancy, each of the safing plugs was connected to one of the three separate primer circuits.

[69] *Project Alberta*, p. 7; *Project Y*, p. 193; *Project W-47*, p. 93. Rowe described the use of one-pound powder bags in *Little Boy*. This was probably a guess on Rowe's part since the previously mentioned Tinian Files mention larger two-pound bags. Parsons' log from the Hiroshima mission mentions four bags. However, four one-pound powder bags would probably not have even budged the massive projectile used in *Little Boy*. Each of the four bags might have been about 2.5" or less in diameter. The eight pounds of cordite (if solid) would have occupied a volume of 133 in^3, which is about a quarter of the volume of the 15.5" long empty cavity between the rear of the projectile and the breech plug. Although Birch had redesigned the breech, Parsons, Oppenheimer, and Groves had previously vetoed the idea of in-flight powder loading. However, once Parsons arrived at Tinian and personally witnessed a number of B-29 takeoff crashes, along with the resulting spectacular fiery explosions, he quickly changed his mind. In interviews and communications with the author, Jeppson stated that he never witnessed any ordnance exploding during these fires and (in hindsight) disagreed with the need to load the powder bags after takeoff. Nonetheless, had the *Enola Gay* also crashed and burned on takeoff, the fire *might* have ignited the powder, resulting in a high-order nuclear detonation. Almost the entire island of Tinian would have been obliterated along with the hundreds of B-29's stationed there. Many thousands would have been killed including all 1,800 members of the 509th, the *Project Alberta* scientists, and, in addition, the plutonium core for *Fat Man* would have been lost. Depending on the wind direction, the massive fallout resulting from the thousands of tons of coral sucked up into the fireball would undoubtedly have contaminated LeMay's entire remaining fleet of B-29's stationed at neighboring Saipan and Guam. Fearing he might be overridden, Parsons simply decided not to inform Groves and Oppenheimer until the last possible moment. As an extremely professional and meticulous person, Parsons left nothing to chance. Because the breech opening was so small, and the 17" diameter tail-section fairly cramped, he practiced loading and unloading the powder bags in and out of *Little Boy* in the days before the mission. After the bomb had been loaded into the *Enola Gay*, Parsons continued practicing for several more hours in the tight quarters and stifling heat of the bomb bay. He had also practiced this procedure while flying test missions. According to a 5/12/04 Leon Smith interview with the author, Parsons practiced this loading procedure inside the bomb bay on a test flight to Iwo Jima in the week before the Hiroshima mission. Even though the slippery surface on the silk bags helped them to slide in and out fairly easily, Parsons' hands became so cut and scratched on the sharp, graphite-coated breech threads that General Farrell offered him a thin pair of leather gloves. He refused them because he said he needed to feel what he was doing. Farrell had drafted a memo earlier in the day ½ hour before *Fat Man* test unit F-18 was dropped in the ocean off Tinian. He held off sending this memo until that evening. This APCOM 5195 message started out by saying "This message to Director (Oppenheimer), Groves, and Bradbury from Farrell, Parsons, and Ramsey. Status of *Little Boy* is awaiting only for weather. It has been decided that *Little Boy* will be loaded by Parsons immediately after the B-29 leaves Tinian. Birch's double plug will be used." This memo was received in Washington at 050917Z (5:17 AM EWT) and delivered at 051207Z (8:07 AM EWT). Groves clearly had a chance to act on this information for several hours until the *Enola Gay* took off at 051645Z (12:45 PM EWT), but there are no records in the Tinian Files that showed any messages from Groves back to Farrell overriding this decision to arm the *Little Boy* in-flight.

[70] "Report of Gun Assembled Nuclear Bomb," pp. 6, 24; *Project Y*, p. 193. All previous authors have stated that the solid (male) projectile fissile mass was driven into a hollow, cup shaped (female) target fissile mass at the front of the bomb. In actuality, it was just the opposite. The front of the projectile was hollow (female) and it slid over the solid (male) target cylinder. The target fissile cylinder was therefore referred to in reports as the "target insert" or simply "insert" because it inserted into the center of the hollow projectile during final critical assembly. This unique design feature was first revealed by Los Alamos engineer Harlow Russ who told the author in 1994, "You knew the projectile was hollow didn't ya?" He then went on to fully describe how it functioned. After the war, Russ was placed in charge of the Z-11 Division at Sandia Base in Albuquerque tasked with manufacturing *Little Boy* stockpile units for the fledgling postwar nuclear arsenal. In a 10/19/96 phone interview shortly before he died, Gunnar Thornton also confirmed the "hollow projectile" design to the author. The target discs and projectile rings were composed of a total of 15 pieces

of fissile material, which were formed by centrifugal casting. This quantity was confirmed in *Critical Assembly*, p. 264, when the authors quoted from an undesignated classified document, which stated, "15 castings were made without failure." In a 7/11/98 interview, *Enola Gay* bombardier Tom Ferebee stated he saw them in the Tinian assembly building and that these castings were "very highly machined." Because the target mass was surrounded by the WC tamper material, it contained a lesser amount of fissile material than the projectile. The projectile could contain a larger amount of material because the steel gun barrel that surrounded it was not as effective a tamper as WC. There was sufficient untamped surface area (about 100 sq in) on both the target and projectile to permit neutrons to escape, thus allowing these relatively large fissile masses to safely remain subcritical even though there was over four "crits" of U-235 in the weapon. A "crit" of U-235 was 13 ± 2 kg. The "Tinian Files" at the NARA describe a "150 pound projectile" (propelled by "4 – 2 pound charges of Cordite") that was used in the L-6 test unit dropped on July 25 at Tinian. This was a solid steel projectile since a projectile of this size would have weighed considerably more if it contained any amount of WC and/or surrogate fissile material (Tuballoy). In postwar reports the projectile is often referred to as the slug and was both forged and cadmium plated.

[71] "Gun Fabrication Plan-Second Supplement to Memorandum of June 13, 1945," C.S. Smith and I.C. Schoonover, July 3, 1945. This Los Alamos document confirms the Harlow Russ "hollow projectile" design.

[72] *Project W-47*, p. 76; Thornton interview on 8/10/95; *Critical Assembly*, p. 117.

[73] *Critical Assembly*, p. 259; LANL archivist Roger Meade interview with the author on 11/15/94; *Dark Sun*, p. 278. These stoppers, along with the heavy projectile mass, allowed the rapidly burning cordite to buildup to peak pressure before the projectile started to move. This allowed the projectile to attain the desired 900 fps to 1,000 fps velocity in such a relatively short barrel. This effect is similar to what occurs when the driver of a dragster revs up to maximum engine speed before releasing the brakes.

[74] Thornton interview; "Considerations Affecting Use of Impact Switch for LB.", 17 July 1945, F. Birch to Captain W. S. Parsons, A-84-019, 18-2. Actually, the projectile would seat in any drop made from above 15,000 feet. Since L-11 was dropped from over 30,000 feet, if the fuzing and firing mechanisms had failed, it would have struck the ground at a speed of over 1,100 fps.

[75] The aft end of the target insert was probably rounded, beveled, or tapered to ensure it would seat properly into the 4.0" diameter projectile opening in the event there was any possible misalignment. The projectile rings and target discs were also probably machined so that there was a slight air gap between them, which would have been necessary in order to allow a trouble-free high-speed assembly.

[76] Thornton interview. There were a total of three bomb assembly buildings constructed on Tinian. All three were identical and could have been used to construct both types of weapons. The final designs for these buildings were based on the first-hand experiences of using the assembly buildings at Wendover in the spring of 1945 and the test building that was constructed at Inyokern during the same time period. According to Harlow Russ in *Project Alberta*, these buildings were about 80% completed when he arrived on Tinian in late June 1945. He told the person in charge of the construction, Col. Kirkpatrick, that the *Little Boy* building "must be completed by July 1, and the *Fat Man* facility by July 7." These buildings were spaced about 1,100 feet apart and situated fifty yards from the cliffs overlooking the Philippine Sea on the west side on the island just north of the *Project Alberta* Tech Area (see aerial photos). These were surrounded on three sides by a 25' high earthen berm "with five machine guns emplacements on the top of the berm." By July 5, all the necessary equipment had been moved into the *Little Boy* building (Bldg. #1 closest to the Tech Area). The *Fat Man* facilities were completed on July 7. The Summary of Special Meeting for Project Technical Committee dated July 27, 1945 stated "In view of the expediting of the FM program and consequent requirement for additional assembly building space, it was agreed that all active material for the LB should be stored in Assembly Building No. 1." Accompanying this report was the LB and FM test unit "Schedule of Events" that said the LB units were all assembled in "Assembly Bldg. No. 1" and the FM test units were assembled in "Assembly Bldg. No.2." Photos taken on Tinian at that time suggest the FM combat unit F-31 was assembled in Bldg. #3. Russ mentioned (p. 66) in his book *Project Alberta* that F-31 was assembled "at the special assembly building that was the most distant from the Tech Area, along the northwest coast of the island." Since no more LB units could have been used in combat until late Fall due to the lack of U-235, Bldg. #1 was also supposed to be utilized to construct the *Fat Man* test units after the Hiroshima and Nagasaki missions in case the Japanese did not surrender.

[77] "A Critical Commentary On Dose-Rate Evaluations," E.J. Dowdy, R.E. Malenfant, and E.A. Plassmann, Los Alamos, Proceedings of the 17th Midyear Topical Symposium of the Health Physics Society, Pasco,

WA, February, 5-9, 1984, p. 8.46. This article states the core center was about 50 cm (19.6") from the front of the target case, although all of the cross-section illustrations in this report show the core center to be about 22" from the front. The report also states, "30° corresponds to the maximum diagonal thickness of the steel case", which would also be consistent with the 50 cm (19.6") distance. However, the later 1985 report ORNL/TM-9439 says the core center was 31 cm (12.2") from the aft end of the target case and 60 cm (23.6") from the nose. This discrepancy can possibly be explained due to the greatly decreased core size used in some of these replication experiments and that it was therefore positioned further back in the target case. Gunnar Thornton told the author during one of the interviews that the core was set back from the center of the target case in the combat units because the scientists felt extra space was needed to accommodate any possible movement of the impact-absorbing anvil. When the NASM LB was returned in 1993 after the "kidnapping" episode, the DOE inadvertently left numerous cryptic "Magic Marker" markings they had drawn on the exterior surface during their "declassifying" process, markings not present before the LB removal in 1986. The markings drawn on both sides of the tapered tail tube (also present on the casing during the entire period of time when this LB was included in the NASM *Enola Gay* public display in 1995-98) indicated the exact likely position of the projectile after loading. Taking into account the position of the target case WC tamper and target-case to gun-tube adapter, one of the DOE markings left on the port side of the target case suggests the core center might have been 26.5" from the front of the target case. However, based on the IWM LB inspection by the author in May 2008 and the subsequent 2013 "Nuclear Archeology" expedition examination of an actual Y-1852 target case interior, if the WC-filled tamper liner assembly occupied the back 18" of this entire 22.0" long cavity in front of the GTA in the target case, and the core center was positioned exactly in the middle center of this cavity, then this core center would have been 22" from the front.

[78] Thornton interviews with the author on 8/10/95, 8/25/96, and 10/19/96; *Critical Assembly*, p. 84. This book mentioned the anvil only once and no explanation of it was provided. Its mere existence was one of the most closely guarded secrets of the gun-bomb. The anvil may have been about 4" long and 6.5" in diameter. Thornton recalled he thought the diameter was wider than the length. When the projectile slammed into the target insert, WC tamper base, and anvil, it was traveling at almost 1,000 fps. At the instant the projectile and target were assembled into a critical mass, there would have been a momentary delay in time before the anvil absorbed most of the kinetic energy. The scientists reasoned this millisecond delay was sufficient for the HEU to be held together long enough in a supercritical assembly for a nuclear chain reaction detonation to occur. This is analogous to what happens when a billiard ball strikes another ball or a hammer hits a nail. At the instant it strikes the nail, the hammer stops for a split second before the kinetic energy is transferred to the nail and the nail starts moving. In actuality, however, the anvil was a superfluous design feature necessary only to keep components intact during repeated testing. In terms of time and distance, after the projectile fully seated around the target insert and a super-prompt critical mass was achieved, the extremely brief amount of time (0.00000081 sec) it then took for the entire core to fission meant the bomb had already exploded in a rapidly expanding nuclear fireball traveling at millions of feet per second long before the combined projectile-target assembly lumbering along at the relatively slow speed of 1,000 fps had applied any pressure whatsoever on the anvil. *Z-Division Progress Report,* LAMS-713, p. 73, 29 March 1948, states "Enlarged hole in three anvil shims per instructions." Since they were enlarging an existing hole in the shim, it would seem to indicate that the shim was probably slid over the draw bolt in front of (or behind) the anvil itself and the quantity of shims ordered for manufacture in other Z-Division Progress Reports would also seem to indicate that only one anvil shim was used in conjunction with each anvil.

[79] Thornton interviews on 8/10/95 and 8/25/96.

[80] *Critical Assembly*, pp. 119, 125, 126; Roger Meade interview on 11/15/94. Meade referred to these initiators as "Squabs." Other sources have nicknamed them "Abner." Tinian test Event Number A-5 involved LB test unit L-6, which took place from 25-29 July 1945. This was the final full-scale LB test and it meant loading the test unit in a B-29 and flying it to Iwo Jima where they simulated both battery charging and initiator changing. *Z-Division Progress Report*, LAMS-681, p. 92, 27 January 1948, states that orders were received for an "initiator cartridge", "plug", and "driving head."

[81] Thornton interview on 8/10/95. He stated he would go into the lab in the evening and assemble the initiators. Because of the short half-life of the polonium, they had to keep careful records of each initiator to make sure of its "freshness."

[82] Author interviews with Harlow Russ on 8/9/94, 2/9/95, 8/10/95. Russ described the nose nut as between "5 to 6 inches thick" and weighing about "250 lb to 300 lb." In actuality, the thickness of the nose nut is

9.25" in the postwar unit on display at the IWM and in pre-deployment test units. At the back end, the last 0.75" of this nut was 14" in diameter (with a slight chamfered end), then it was threaded 15.0" in diameter with square-cut threads at the rate of two threads per inch for the remainder of the distance to the front end (about 7.5") and lubricated with zinc oxide grease. Russ said they used a large, wide leather belt looped over a special nose nut handling pulley attached to the ceiling. They first carefully balanced the heavy nut on this belt, slowly raised it up until it was even with the opening in the target case, and then carefully rotated it as it was screwed into the target case. After the war, a nose nut pulley was designed to assist in the removal process. The opening in the center of this nose nut (to accommodate the 1.0 inch diameter cadmium-plated draw bolt) was threaded at the rate of 12 threads per inch. Several Los Alamos CMR reports mention "bolts were cast...and machined" so it is entirely possible this draw bolt itself, or the portion of it in contact with the discs, was also made out of tuballoy and not steel. A heavily redacted July 26, 1945 memo "Gun Fabrication Plan – Target" from C. (Cyril) S. Smith to Oppenheimer mentions an earlier July 6 document "outlining specifications and a schedule for casting the rings and bolt for the target assembly." *Z-Division Progress Report*, LAMS-582, p. 78, June 24, 1947, states, "Dollies were built for handling the nose nut, cavity ring, and washer." The "cavity ring, and washer" probably filled a gap in the target case between the nose nut and the tamper-filled K-46/Midvale Constant liner assembly. The ring might have had a 10" I.D. and fit snugly against the 14" diameter interior wall. The same report also mentioned that "A unit can be cleaned and assembled, without painting, in approximately 4 hours by a four man crew plus foreman."

[83] Thornton interview on 8/10/95.

[84] Thornton interview on 8/25/96.

[85] The four initiators were attached to front of the tamper filler plug inside the projectile.

[86] Author interviews with Russ. *Enola Gay* bombardier Tom Ferebee observed the L-11 during the assembly on Tinian and told the author the same thing.

[87] *Nuclear Weapons Engineering and Delivery*, LA-1161, Vol. 23, Norman Ramsey and Raymond Brin, Los Alamos Scientific Laboratory of the University of California, July 1946, p. 103. A newly declassified version of this report was released on 7/17/02 as a result of a FOIA request filed by the author over seven years earlier on 4/18/95.

[88] *Project Alberta*, p. 21.

[89] Blueprints supplied to the author courtesy of The National Museum of Nuclear Science and History.

[90] All measurements on the 1852 and dummy units were made by the author.

[91] "Report of Gun Assembled Nuclear Bomb," p. 24.

[92] *Swords of Armageddon*, VI-75. When one kg of U-235 fissions completely, it is equivalent to the release of 17 Kilotons of energy. One Kiloton equals 1,000 tons of TNT. Therefore, if *Little Boy* contained 64.14756 kg of U-235, then a 15 Kiloton yield meant that only 1.38% (0.88 kg) of the uranium actually fissioned. If all of the uranium in *Little Boy* had fissioned at 100% efficiency, it would have released over one Megaton (million tons) of energy.

[93] "The Yields of the Hiroshima and Nagasaki Nuclear Explosions," LA-8819, John Malik, LANL, September 1985. *Reflections of a Nuclear Weaponeer*, Frank Shelton, (Shelton Enterprises, Inc., Colorado Springs, CO, 1988), p. 2-28;

[94] *Day of Trinity*, Lansing Lamont, (Antheum, NY, 1965), p. 149.

[95] "Report of Gun Assembled Nuclear Bomb," p. 26. "Rammed home" meant that the projectile was pushed forward in the gun until it was stopped by the detents. The scientists always used the term "active" to describe the use of actual, rather than surrogate fissile material in any critical assemblies.

[96] Thornton interviews on 8/10/95 and 8/25/96.

[97] "Report of Gun Assembled Nuclear Bomb," p. 26. Although the Archies had been installed, the Archie batteries and antennas were not.

[98] Communication to the author on 6/24/02. The large wooden crate containing the *Little Boy* L-11 destined for Hiroshima measured 138" x 44" x 47" and weighed some 10,000 pounds.

[99] Interview with the author on 8/2/01.

[100] *Ibid.*

[101] *Ibid.*

[102] Thornton interview on 8/10/95. While standing together inside the truck on 10/09/04 containing the LB replica destined for the Historic Wendover Airfield Museum, the author asked Tibbets to sign it in the same place he signed the original. Tibbets immediately responded that he never signed that one. However, as he walked slowly around the front of LB, his hands caressing the painted surface, a glimmer of remembrance

struck him. "I saw Luis Alvarez sign it just after it was removed from the Tinian assembly building." He continued, "If he could sign it then it was ok for me to do it also. I signed it with the tail on the right side and looking up at it", which meant he was kneeling down and signed it in the area near the safing plugs. The author quickly handed him a pen and he signed the L-11 replica in the exact same place as the original. After finishing, he turned and added, "I hope they realize what you've done here!" The author also had *Indianapolis* survivor Mike Kuryla sign the L-11 replica earlier that same day inside the Wichita Boeing hanger. In addition to his name, he added, "For the Boys of the *Indianapolis*." Kuryla told the author a few months before he died on 10/10/09, that after doing that, he was so shaken that he had to step outside the hanger to regain his composure.

[103] Ray Gallagher quotes are from a first-person audiotape he made entitled, *WAR ENDS With Atomic Bomb*, in which he describes both missions. Reproduced with permission. Mission narrative was drawn from several sources including Gallagher interviews on 11/30/94, 12/18/94; Parson's log; Van Kirk's log; Lewis's diary; and interviews conducted with surviving crew members during the 1994, 1995, 1997, and 1999 509th reunions.

[104] Reprinted courtesy of Michael Vickio. Vickio started the *Children of the Manhattan Project* Internet web site. His mother was a nurse at Los Alamos during the Manhattan Project and this very important web site has become the main repository for MP related information. Unfortunately for all of us, Michael died on 9/25/05 after a brief illness.

[105] Lewis wrote these thoughts down on a tablet of Army Air Force (AAF) Line of Position pages. A lot of the descriptions were somewhat jocular, until the bomb exploded. Then the tone of his comments changed dramatically and became quite sober. The actual diary was eventually purchased at auction decades later by millionaire publisher Malcolm Forbes. According to one source, such was the incalculable value of this historic document, that when a courier brought it to the Truman Library for inspection, he arrived with it locked in a briefcase handcuffed to his wrist. It was sold again at Christies Auction on 3/27/02 for $350,000.

[106] *The Men Who Bombed Hiroshima*, Coronet, August, 1960, p. 81-82.

[107] During the 2005 509th reunion in Washington, DC, the author was taken on a scissors lift up inside the *Enola Gay* bomb bay at the Smithsonian National Air and Space Museum (NASM) to experience first-hand where Parsons and Jeppson walked and stood/crouched to perform their respective duties that morning. The original removable aluminum catwalk was missing and had been replaced by a wood replica constructed by the Bernie Poppert, the NASM Deputy Chief of Restoration. Carefully standing, kneeling, and sitting on this replica platform allowed the author some idea of exactly where the rear of LB was relative to Parsons' position on that original platform and how Parsons moved while performing those duties. The author then did the same for Jeppson's movements relative to the performance of his duties that morning. Based on this examination of the bomb bay, and the author's construction of the L-11 replica in 2004, it is most likely that Parsons was lying down on this platform during most, if not all of the loading and arming process. The author was subsequently allowed to assist Poppert in manually closing the bomb bay doors.

[108] Personal communication to the author dated 7/26/05.

[109] Personal communication to the author dated 10/2/07.

[110] Personal communication to the author dated 9/21/01.

[111] 509th Reunion, Albuquerque, NM, 8/7/95.

[112] "The Yields of the Hiroshima and Nagasaki Nuclear Explosions," p. 8. The altitude was reported in the strike report as 30,200 ft, 509th archives as 31,600 ft, and Parsons' log as 32,700 ft. According to a 10 June 1945 letter from Colonel E.E. Kirkpatrick to General Groves, "...the weapon would destroy a plane using it at an altitude of less than 25,000 feet."

[113] *The Men Who Bombed Hiroshima*, p. 84-85.

[114] *Seven Hours to Zero*, Joseph Marx (G.P. Putnam's Sons, NY, 1967), pp. 168-169. This book maintained that the *Enola Gay* turned right and *The Great Artiste* turned left. This same series of turns was also mentioned in *Enola Gay*, Gordon Thomas and Max Morgan-Witts (Stein and Day, NY, 1977), p. 257 and *No High Ground*, Fletcher Knebel and Charles W. Bailey II (Harper & Brothers, Publishers, NY, 1960), p. 173; "Escape Maneuver For Atomic Mission," R.A. Lewis, Major U.S.A.F., August 1, 1945. This drawing clearly shows a specified right turn of 150° for the first plane (*Enola Gay*) and the same 150° turn, but to the left, for the second plane (*The Great Artiste*); The FIELD ORDERS NUMBER 13 specify a breakaway "Right turn of at least 150 degrees 3400N – 13334E;" In his autobiography *The Tibbets Story*, Tibbets indicated *Enola Gay* turned right and *The Great Artiste* turned left, while in his book *Wars End*, *War's* (Avon Books, NY, 1997), Chuck Sweeney maintains he also made a right turn. Sweeney's co-Pilot Don Albury recalled in a

10/15/99 interview with the author that, although he really couldn't remember exactly which way they turned, they would have turned in opposite directions to avoid colliding with each other.
[115] Interview with the author on 8/9/95.
[116] *Reflections of a Nuclear Weaponeer*, p. 2-28; "The Yields of the Hiroshima and Nagasaki Nuclear Explosions." The angle from vertical at the time of explosion was 15°. A joint U.S.-Japan Working Group, chaired by Dr. Robert Young and Dr. Hiromi Hasai, has undertaken a comprehensive evaluation of the calculations that comprise the RERF dosimetry system and the measurements that are used to verify these calculations. At a meeting in Tokyo on March 14-15, 2003, a Joint U.S.-Japanese Senior Review Group, chaired by Dr. Warren Sinclair and Dr. Wataru Mori, approved DS02 (Dosimetry System 2002), which was developed by the Joint Working Group. A report issued by this group revised the height-of-burst from 580m to 600m and the yield from 15 kt to 16 kt.
[117] Interview with the author on 4/1/95. The aircrews had been instructed to wear their American Optical Company polarized goggles. These variable density goggles have a knurled knob on the front. The lenses are normally a light amber color, but when the knob is rotated they turn a dark magenta. This may have been one of the reasons some of the observers described the fireball as pinkish in color, even after these goggles had been removed.
[118] *How to Drop an Atom Bomb*, Col. Paul W. Tibbets, Jr. and Wesley Price, Saturday Evening Post, June 8, 1946, p. 136. This was certainly a natural reaction to the shock wave impact. It was identical to normal flak buffeting routinely experienced during previous combat missions. The authors of the book *Enola Gay* also stated it was Tibbets who shouted "Flak." However, Tibbets later claimed in his book that it was Parsons. Both Tibbets and the scientists already knew a shock wave would accompany the blast. After all, that was the primary reason for the diving 155° turn. As someone intimately involved with the entire *Manhattan Project* from the beginning, but unfamiliar with flak concussion, it therefore seems highly unlikely Parsons would have misinterpreted the shock wave as flak. In an 8/14/04 speech at the USAF Museum, Tibbets stated that he had accelerometers onboard and these registered 2.5 G's as the shock wave struck the plane. He called it, "A real kick in the pants!" He also stated the scientists later calculated the *Enola Gay* was 10.5 miles from LB when it exploded.
[119] Personal communication to the author dated 8/14/95.
[120] Personal communication to the author dated 7/26/05.
[121] *How to Drop an Atom Bomb*, p. 136. Tibbets subsequently maintained that he also tasted the lead.
[122] *The Japan Times*, August 7-13, 1995, Vol. 35. This article also stated 522,664 people were affected and that a total of 246,726 have so far died. This statistic citing the amount of affected people seems to be a somewhat inflated figure because less than half that number has been estimated to have actually been in Hiroshima at the time of the explosion. The Japanese government has always included anyone who has died from any of what they consider bomb-related diseases in the total number of deaths. This includes deaths due to illnesses such as cancer and leukemia, even though these illnesses occur naturally in both the bomb and non-bomb affected Japanese general population.
[123] *The Men Who Bombed Hiroshima*, p. 87.
[124] Lewis diary; *How to Drop an Atom Bomb*, p. 136. Crewmembers later recalled that what Lewis said over the planes' intercom was "Look at that son of a bitch burn!" In the Post article, according to Tibbets, "I remember Lewis pounding my shoulder, saying 'Look at that! Look at that! Look at that!' "
[125] *The Men Who Bombed Hiroshima*, p. 88.
[126] Although both Tibbets and Ferebee knew it was atomic, Tibbets had been very careful not to mention this to any of the crew beforehand in case the mission had to be aborted before the drop.
[127] Personal communication to the author dated 4/12/95.
[128] Interview with the author on 4/1/95.
[129] *LaCrosse Tribune*, August 28, 1999, p. A-8.
[130] 509th reunion, Dayton, Ohio, 8/2/97.
[131] *Code-Name Downfall*, p. 272.
[132] *The Japanese Monarchy*, Nakamura Masanori, (Armonk, NY: M.E. Sharpe, 1992), p. 140.
[133] Gallagher interview 12/18/94.
[134] Part of Gallagher interview that was presented at the 1994 509th Chicago reunion.
[135] It was also called *Fat Boy* or *Large Boy*. One document even referred to it as *Little Boy's* "corpulent cousin." In several blueprints drawn 4/13/45 by Ray Brin showing the *Fat Man* version Y-1740 as it would have appeared in the B-29 bomb bay, the bomb is referred to as *Big Joe*. *Big Joe* is also stenciled on the

shackle assembly inside the restored *Enola Gay* at the NASM.

[136] *Reflections of a Nuclear Weaponeer*, p. 2-28.

[137] The standard AN-M64 500-lb GP (General Purpose) bomb used during the war contained 262-lb of either Comp B or Comp D high explosive.

[138] "Trinity: Getting the Job Done," New Mexico Public TV, KNME, 1995, Douglas Ballard statement.

[139] "Pit From FM 32," R.E. Schreiber, November 5, 1945, A-84-019, 17-2; "Plastic Bonding of Boron Powder," L. Haye and J.E Burke, October 4, 1944, LA-151. This document describes the method of "bonding boron powder by wet tamping it with methyl methacrylate monomer and polymerizing the monomer to produce a finished, handleable piece which has a density of at least 1.6." This technique required a temperature of about 50°c for at least 48 hrs. to polymerize the material. One source told the author, "It looked and smelled like bakelite plastic and brown color." *Dark Sun*, pp. 194-196; *Project Y*, pp. 71, 146; *Soviet Atomic Espionage*, Joint Committee on Atomic Energy, U.S. Government Printing Office, April 1951, p. 91; *The Rosenberg File*, Ronald Radosh and Joyce Milton, (Holt, Rinehart, and Winston, NY, 1983), p. 437; Raemer Schreiber interview with the author on 2/14/96 (2-3 mm thick); James Osborn (.109"); Ralph Sparks interviews with the author on 7/1/96 and 7/27/96 (0.125"-0.1875" thick); According to Sparks, "The plastic shell was a last minute addition.... one of the guys over in the chemical department worked for about two days straight making that shell...he was a GI [SED] and a pretty sharp guy. He worked day and night, literally!"; Shell #1 was probably used in the Trinity device, #2 in unit F-31 (Nagasaki), #3 in unit F-32; Document #13, Moskovskaya Pravda, "Hunters of Nuclear Secrets," Mikhail Makhlin, June 1991, with additions from Visgin, V.P., ed. 1992. At the source of the Soviet atomic project: the role of espionage, 1941-1946. Problems in the History of Science and Technology 3:97, pp. 126-129. This document (available on the Internet) contains information obtained from Soviet spies (Fuchs, Greenglass, Hall, "Perseus", and et al.) at Los Alamos and was presented to the infamous People's Commissariat of State Security of the USSR, Laverentia Beria, in October 1945. However, it contains numerous errors and should be considered by researchers as a questionable document. While it is clear from the two different English translations of this document in the author's possession that some of these are errors in translation and/or SAE to metric conversion, others are descriptions of components or assembly procedures not used in either the final Trinity or Nagasaki implosion devices. There were many parallel development programs in place at Los Alamos, and elsewhere, during this period (levitation, composite cores, beryllium tampers, etc.) and not all were successful. Some data derived from these programs was later incorporated into postwar weapon designs. It seems probable that information pertaining to several different implosion devices and components, either in production or development, were combined to construct this document. This author cites the document only when the information mentioned has been corroborated by documentation and sources that worked at Los Alamos on the original *Fat Man* implosion development program.

[140] Visgin, V.P.; *Critical Assembly*, pp. 307, 325, 326, 327; *Dark Sun*, pp. 168, 174, 193; *Project Y*, pp. 82-83; Leonard Della-Moretta personal communication dated 12/18/95; Della-Moretta interview with the author on 1/20/96; Leon Smith interview with the author on 8/7/95. According to British physicist Geoffrey Taylor, there was instability in the interface between heavy and light materials. This interface is stable if a heavy material is accelerated into a lighter material and unstable if a lighter material is accelerated into a heavy material. This phenomenon was later referred to as the "Raleigh-Taylor instability." The aluminum pusher was used to smooth out these instabilities. The high-pressure detonation shock wave produced by the spherically imploding HE liquefied the aluminum pusher, uranium tamper, and plutonium as it passed through these solid materials. According to *Critical Assembly*, p. 307, in fall of 1944, the scientists were "exploring the idea of inserting a 'pusher' into the implosion assembly to replace a portion of the high explosives as a possible means of smoothing out jets [of molten material] and avoiding the Taylor instability." Lightweight beryllium is used as a tamper in contemporaneous implosion designs, thus eliminating the need for an additional aluminum pusher. Continual wartime pressures on the scientists to produce a reliable implosion device also led to the conservative design and usage of solid, rather than hollow, levitated pit components for both the Trinity and Nagasaki devices. Although it was under study during the war, according to one source, "levitation was just a dream, even by fall of 1945." The use of levitated components in postwar weapons, however, greatly reduced the amount of fissile material needed to produce the same yield. Levitation meant having airspaces between pit components, such as initiator and core, core and tamper, and/or HEU shell and Pu sphere in a composite core. The airspace was utilized to prevent the deceleration of the shockwave as it proceeded from one component into another during implosion. A hammer that simply pushes on a nail is not nearly as effective as one that strikes it from a distance. Small, frangible aluminum cones or brackets were sometimes used in levitating components. Levitation also created additional

engineering challenges. For instance, if an initiator was placed inside a two-piece Pu hemisphere, which in turn was levitated (nested) inside of another two-piece HEU hemisphere, then a means had to be devised to hold the Pu hemisphere halves tightly together. The use of small, figure-8 shaped pins pressed into circular holes bored into both halves of each hemisphere at the parting line ingeniously solved this problem. This design is based on the Double-Dovetail, or Butterfly, joinery technique commonly used in woodworking. The only difference was the use of circular, rather than the typical dovetail wedge shaped keys

141 *Critical Assembly*, pp. 164-169, 299; *Project Y*, p. 213. Code names were frequently used in communications, particularly those between Tinian and Los Alamos. HE was sometimes referred to in those memos as How Easy.

142 *The Curve of Binding Energy*, p. 82.

143 The number designations were simply drawing numbers. Changes in the numbers meant a design change. These changes ranged from major re-designs to something as simple as a difference in bolt sizes. Even though the *Fat Man* came to be known simply as the Y-1561, the drawings sometimes showed different numbers, such as 1560 or 1562. After the war, R. A Bice formalized the Mark numbering system and the Y-1222 design turned into the Mark I, *Little Boy* was designated the Mark II, and Y-1561 *Fat Man* became the Mark III. Postwar weapon designations utilized English numbers rather than Roman numerals. The probable dimensions (in inches) for the Y-1561 implosion design are as follows:

	Radius	Diameter	Thickness
Initiator	0.4	0.8	0.4
Plutonium	1.81	3.62	1.25
Tamper	4.375	8.75	2.565
Boron	4.5	9.0	0.125
Pusher	9.25	18.5	4.75
Felt	9.28	18.56	0.03125
Inner Charge	18.16	36.31	8.875
Felt	18.19	36.38	0.03125
Outer Lens	27.19	54.38	9.0
Cork	27.69	55.25	0.5
Dural Sphere	28.625	57.25	1.0

144 According to *Critical Assembly* (p. 139), the pit volume, HE volume, and overall bomb size was frozen in early 1944. The Y-1222, Y-1291, and Y-1561 designs were in simultaneous development after the pit volume freeze. By late 1944, the Y-1222 had been dropped, in part, because of time-consuming assembly difficulties and the simpler Y-1291 and Y-1561 became the final designs. No interior photos of the Y-1561 sphere have ever been declassified. The photo of the Y-1222 can also be seen in the *Making of the Atomic Bomb*, *Dark Sun*, and *Critical Mass* CD-ROM (Corbis). The 24.5" aluminum pusher is clearly visible with its thin felt covering held in place with tape. Although most of the charges shown in this photo were irregularly shaped pentagons, each contained the same amount of HE. These charges were made of solid Comp B and were not explosive lenses. The Y-1222 and Y-1291 designs relied unsuccessfully on 72 points-of-ignition to achieve adequate core compression. The scientists also tested a 1560 design (with the redesigned 7-piece Dural sphere) using 72 detonators, and even a 1562 design, which used 132 detonators. However, by April 1945, the 32 detonator Y-1561 was the main design. The 72 detonator Y-1291 backup design was drop tested concurrently with the Y-1561 at Tinian. Except for minor changes, the Y-1560 Dural sphere remained essentially the same for the Y-1560, 1561, 1562, 1563, and 1564 implosion designs. According to a chemical analysis made for the author in 2013, the Dural used in all these spheres contained aluminum, 7.04% Si, 0.47% Fe, 0.27% Mg, 0.07% Ti, 0.04% Cu, 0.02% Mn, and less than 0.01% Ni, Zr and Zn.

145 Personal communication to the author dated 10/3/95.

146 Personal communication to the author dated 12/5/95.

147 *Ibid*.

148 *Ibid*.

149 "Allocation of Large Lenses," G.B. Kistiakowsky, 14 April 1945, A-84-019, 13-3.

150 Some sources indicated the inner hexagonal charges weighed between 50 and 60-lb. and the outer hexagonal lenses weighed between 120 and 130-lb. On p. 214 of *Project Y*, a maximum lens weight of 120-lb. is mentioned. Both Ed Wilder and Al Van Vessum cited larger weights of 125-lb. and 130-lb. respectively. A 9" thick hexagonal lens (without the Baratol insert) would have weighed almost 130-lb., so it is probable

the lenses weighed even more than that since Baratol is over 50% denser than Comp B. The pentagonal blocks were 0.662 the size and volume of the hexagonal blocks. The total weight of the HE has been quoted in various sources as 5,000-lb. General Groves mentioned an HE weight of "some 5,000 lb." Both the military and scientists frequently used rounded-off numbers when discussing weights. An implosion sphere consisting of 12 pentagonal lenses each weighing 86-lb., 20 hexagonal lenses weighing 130-lb., 12 pentagonal inner charges weighing 31-lb., and 20 hexagonal inner charges weighing 47-lb. would have had a total HE weight of 4,944-lb. However, the *Sandia National Laboratories: The Postwar Decade* book (pp. 74, 79) mentioned a larger HE weight of 5,300-lb. Chuck Sweeney's book *War's End* (p. 2) also mentioned 5,300-lb. If the lens weight is increased to accommodate the Baratol inclusions, then the total HE amount was almost certainly closer to the 5,300-lb. figure. Based on the 5,300-lb weight, the Comp B/Baratol ratio used in the lens portion of the Y-1561 assembly was probably equal to around 75%/25% by volume. According to weights painted on the nose of the *Fat Man* on display at the Navy Museum, a completed implosion sphere (minus such items as detonators, tuballoy capsule, Pu core, and initiator) weighed 7,160-lb. If the empty Dural sphere alone weighed 1,146-lb., then the remaining 6,014-lb. represented the weight of the cork lining, HE, felt pads, 18.5" pusher, boron shell, and 8.75" tamper sphere. The final lens design was based on Los Alamos drawing number 32L90N.

[151] *Critical Assembly*, p. 300.

[152] While the size of nuclear devices has shrunk dramatically over the last half century, the amount of plutonium/HEU used in the cores has remained fundamentally the same. Tremendous advances in HE technology and the use of beryllium tampers, beryllium/Pu bonded pits, levitation, composite Pu/HEU cores, valve-controlled tritium gas "boosting" (known as DAY or "Dial-A-Yield"), external initiators ("zippers"), and solid-state detonators have greatly downsized the dimensions of the so-called "physics package." Sizes of less than 12" in diameter, and in some cases 6" or smaller, are possible. For example, the MKB-61 thermonuclear weapon currently in the US stockpile is 13.3" in diameter. The yield of this weapon when it was first introduced was reportedly as high as 900 kt. Although almost 50 times more powerful than the original Trinity implosion device, the warhead portion of this weapon could easily fit into a car trunk, large suitcase, or even a duffel bag. The yield range of the current Mod-11 variation of this warhead is sub-kiloton to 350-kt. Present-day implosion devices use less than 1% of the approximately 5,300-lb. of HE needed in the original WWII *Fat Man*. For safety purposes, some implosion devices even store the HE as a paste until it is extruded around the pit just before detonation. This type of HE, however, has a shelf life of only six to eight months. According to a 9/25/97 report aired on National Public Radio, a technician at the DOE Pantex facility in Amarillo, Texas, claimed the explosive force of the bowling ball-size charge of HE used in some present-day nuclear devices would be similar to the ammonium nitrate terrorist bomb that destroyed the Oklahoma City Alfred P. Murrah Federal Building on 4/19/95. This was an exaggeration since the most advanced IHE is only about 60% more powerful than TNT. According to the FBI, the Oklahoma blast was equivalent to about 5,000 pounds of TNT making it about the same size as the amount of HE used in *Fat Man*. To illustrate just how small an implosion sphere can be, *The Undeclared Bomb*, Leonard S. Spector, (Ballinger Publishing Company, Cambridge, MA, 1988), p. 194, gives a graphic example. This book contains a photograph of a full-size mockup of the 4-kg plutonium core (encased in a thin copper shell), 4.5" diameter two-piece beryllium tamper sphere, and 10" diameter HE hemisphere of the spherical implosion primary or "trigger" for an Israeli two-stage thermonuclear (TN)/low-yield neutron bomb (dimensions are approximate). A neutron weapon produces a maximum amount of lethal neutron radiation, which kills anything living within a limited range while generating only minimal physical property damage. It uses as much as 20-g of tritium gas boosting in the fission primary. The tritium is released into the primary by means of an electro-explosive squib controlled valve. This very expensive gas must be renewed frequently because of its short 12.3-year half-life.

[153] Personal communication from McAllister Hull to the author dated 11/12/96. Hull had successfully employed this technique when he worked as a soda jerk in the local drug store in college, where he was renowned for making the smoothest malts on campus. The stirrer motor was air-driven since electrically-driven motors were never permitted near explosives due to sparking.

[154] Personal communication to the author dated 10/3/95.

[155] *Ibid.*

[156] Personal communication from Edward Wilder to the author dated 2/5/96; Visgin, V.P. The Visgin document incorrectly states the lenses were cast in special casings made of cellulose acetate. It also incorrectly states there were special slots in the external surface of the inner charges that provided for the

insertion of the outer lenses.

[157] According to a 1/20/05 interview with SED John Weil, the heavy Baratol settled while cooling and any irregularities in the mix rose to the surface and were removed when the riser was machined off the top of the casting. The forming cutter not only removed the riser, but also machined the proper curved surface to the Baratol casting. The machine that performed this procedure was operated remotely using an ingenious series of mirrors so the operator could view the procedure from a distance behind a safety barricade.

[158] *Manhattan District History: Nonscientific Aspects of Los Alamos Project Y 1942-1946*, Edith Truslow, (Los Alamos Historical Society, Los Alamos, NM, 1991), Appendix, Early S-Site Experiences by Edward Wilder, Jr., pp. 109-110.

[159] 14 November 1986 letter from Luis Alvarez to Edmund V. Sawyer, president of Crescent Engineering & Research Company.

[160] Ralph Sparks interview with the author on 7/1/96.

[161] The detonation velocity ratio was computed by using the formula V1÷V2. V1 represented the detonation rate (velocity) of Comp B and V2 was the rate of Baratol. This ratio varied from 1.59 to 1.63 with 1.6 considered normal. However, since detonation wave shaping was not a fully understood phenomenon in 1945, the only way to determine the actual refractive index was for the scientists to conduct exhaustive testing with full-size explosive lenses. The so-called "normal" refractive index was considered 2.0 with a refracting angle of 60° although an October 1945 X-2 Progress Report mentions an index of 7800/5250 (1.49) as being the "present lens design." The final velocity of the lens was therefore 5250 m/sec.

[162] *Dark Sun*, p. 119; According to one source, the subcritical plutonium quantity was at "0.995 of critical mass."

[163] 02/08/04 communication to the author from Steve Bice. However, unlike U-235, U-238 was not a neutron multiplier and would therefore not release any additional neutrons during fissioning.

[164] Leonard Della-Moretta interview with the author on 1/20/96.

[165] The total amount of WC in the assembly, not including the last brick, was 236-kg. These figures are based on a WC density of 14.

[166] *Critical Assembly*, p. 341; *Project Y*, pp. 300, 301, 325; "A Review of Criticality Accidents," Thomas P. McLaughlin...(et al), LA-13638, May 2000, pp. 74-76; "A History of Critical Experiments at Pajarito Site," Hugh C. Paxton, LA-9685-H, March 1983, pp. 1-3; "Report on Accident of August 21, 1945 at Omega Site," LAMD-120, August 26, 1945, pp. 1-4; "Neutron Experiments Done With Beryllium Spheres," E. Creutz (et al), LA-555, May 1, 1946, p. 9; Louis Hempelmann (et al), *Annals of Internal Medicine* 36, 1952, pp. 279-510; "Operational Accidents and Radiation Exposure Experience Within the United States Atomic Energy Commission, 1943-1970," TID-5360, United States Government Printing Office, 1971, p. 2; *Picturing the Bomb*, Rachel Fermi and Esther Samra, (Harry N. Abrams, Inc., NY, 1995), pp. 111, 113, 115. The report in *Annals of Internal Medicine* contains graphic photos of both Daghlian's and Slotin's bodies and swollen hands. *Picturing the Bomb* also shows a photo of Daghlian's right hand as well as photos of both the Daghlian and Slotin critical assembly accident re-constructions. The Slotin reconstruction photo is quite interesting. The scientists had just finished a series of experiments in the weeks prior to May 21, 1946, involving the use of 3.0", 4.5", 6.0", 9.0", and 13.6875" diameter beryllium spheres. A table in the background contained storage cases for HEU and Pu hemispheres, while the table in the foreground showed what appeared to be Pu (possibly Be) hemispheres sitting on top of several 2' x 4" x 8" lead blocks. Perhaps indicative of the casualness with which the scientists sometimes treated the fissile material was the presence of an empty Coke bottle on the same cluttered table with the plutonium. When the test assemblies were very close to criticality, sometimes the addition of a few extra people in the room was enough to initiate a chain reaction. In effect, their bodies became part of the bomb. Also, by simply moving their hands closer to an assembly that was just short of criticality, the physicists could play melodies on the speaker attached to the neutron counter. According to one source, they would occasionally utilize this effect to scare already jittery visitors. The physicist would nonchalantly move his hand closer to the assembly, which dramatically increased the clicking sound, then look startled and say "Uh Oh! What's going on here?"

[167] *Picturing the Bomb*, p. 113; *U. S. Nuclear Weapons*, p. 216; "Revised Dose Estimates for the Criticality Excursion at Los Alamos Scientific Laboratory May 21, 1946," Dale E. Hankins and G.E. Hansen, LA-3861, April 25, 1968, pp. 4, 11, 12. According to numerous Los Alamos reports, the same plutonium hemispheres were used in both the Daghlian and Slotin accidents. The individual cores were supposed to be between 0.94 and 0.97 "crits" or critical masses. This was determined by the enrichment rate of each batch of plutonium received from Hanford. Although machined to the same dimensional specifications as the Trinity and

Nagasaki cores, the core used in both accidents was out-of-spec because it was slightly above the desired enrichment rate. Thus the scientists felt any criticality tests done with this core would insure that the actual pit assemblies would remain safely sub-critical.

[168] Personal communication to the author dated 11/12/96. Health Physics scientists now think that Slotin actually received about a 2,100 rem radiation (neutron/gamma) dose, while Graves received a dose estimated at 360 rem. The six remaining people in the room received doses of about 250, 160, 110, 65, 47, and 37 rem. In 1993, a park was dedicated to Slotin's memory in his hometown of Winnipeg, Canada. The text of the plaque in Dr. Louis Slotin Park reads as follows. "This park is dedicated to the memory of Dr. Louis Slotin who willingly and heroically laid down his life to save seven fellow scientists during an experiment May 21, 1946 at the Los Alamos atomic research project in New Mexico, USA. As the laboratory was being swept with deadly radiation, Dr. Slotin spontaneously leaped forward covering the experiment with his body. Dr. Slotin was taken to hospital where he died nine days later. His seven co-workers survived. Dr. Slotin and his family had resided at 125 Scotia Street, just a short walk north of this park. Descendents and family members of the late Dr. Slotin still reside in Winnipeg." On May 20th, 2000 (Armed Forces Day), a memorial stone was dedicated in New London, CT, to the memory of Daghlian. The stone reads, "In memory of Harry K. Daghlian jr. 1921 – 1945, a brilliant scientist on the Manhattan Project. His work involved the determination of critical mass. During an experiment gone awry, he became the first American casualty of the atomic age. Though not in uniform, he died in service to his country."

[169] United States Strategic Bombing Survey (USSBS), "The Effects Of The Ten Thousand-Pound Bomb On Japanese Targets," May 1947, pp. 13, 36, 37, 50, 63, 206. This report does not specifically use the term "pumpkin." Instead, it referred to it as a 10,000-pound, special, LC (light-case), high-explosive bomb, with a 51% charge-weight ratio utilizing three AN-MK219-2 instantaneous nose fuses. This report would seem to indicate pumpkins were filled with about 5,100-lb. of HE. However, the pumpkins actually contained 6,300-lb. (net weight) of Comp B. The total weight of the pumpkin was supposed to be as close as possible to the *Fat Man* weight of 10,265-lb. The pumpkins were filled with either Comp B or cement (for dummy drop tests). The cement used in the 1560 sphere was carefully formulated using 1 bag of cement, 1 bag of plaster of paris, 240-lb. of sand, and enough water to result in a final concrete density to exactly match the 1.67-1.68 g/cm³ density of Comp B. At least 1,000 pumpkins were ordered for manufacture during the war, although only several hundred were actually produced. These were sent to Wendover, Inyokern, and Tinian. The Naval Magazine at Inland Storage Area at Cowell, California was referred to with the code name Three Igloo Job (TIJ) on all shipping documents. After the war, some 2,500 pumpkins were ordered. However, because of the postwar redesign of the Mark III *Fat Man* into the Mark 4, it is unlikely that very many of these were actually manufactured. The pumpkins, although similar in size and shape to the *Fat Man*, did not have the exact same ballistics. For instance, these units had three nose fuses compared to the four on the *Fat Man*. The pumpkins also did not have the eight bathtub fairings around the waist portion as well as raised mounting plates for the antennae. These items all had serious affects on the ballistics.

[170] "Disassembly of 1560 Sphere After Overseas Shipment," R.A. Bice, November 1, 1945, A-84-019, 17-2, p. 1.

[171] "Memo to Group Leaders, Subject: Trinity test," J.R. Oppenheimer, June 14, 1945, A-84-019, 54-15.

[172] "Los Alamos Science," Winter/Spring, 1983, pp. 144-145.

[173] *Critical Assembly*, p. 330; *Project Y*, pp. 222, 223, 228; *U.S. Nuclear Weapons*, p. 123.

[174] *Plutonium Handbook: A Guide to the Technology, Vol. 1*, O.J. Wick, (Gordon and Breach, Science Publishers, Inc., NY, 1967), p. 82; *Dark Sun*, p. 194. Weapon-grade plutonium is defined as Pu 239 which is contaminated with no more than 6% of the neutron-rich isotope Pu 240 whereas reactor-grade contains at least 12% Pu 240. This isotope emits too many neutrons and would predetonate the plutonium core long before the chain reaction reached its peak. Irradiating uranium fuel elements in a nuclear reactor for a period of time creates plutonium. However, the longer the uranium is irradiated the more Pu 240 it contains. Depending on the size and power output of the reactor, it takes about five weeks worth of irradiation to produce weapon-grade plutonium and three months for reactor-grade.

[175] *U.S. Nuclear Weapons*, pp. 21, 26, 212; *Dark Sun*, p. 194; Raemer Schreiber interview with the author on 2/14/96. He was one of the scientists who had been in the room during the ill-fated criticality experiment that killed Louis Slotin in 1946. After the death of Slotin, Schreiber became the Critical Assembly Group Leader. Also in 1946, he became Pit Assembly Team Leader for Operation CROSSROADS. He went on to become Technical Associate Director of LANL in 1962 and finally Deputy Director in 1972. Different Los Alamos reports published over the years pertaining to the Daghlian and Slotin criticality events state the core

used in both accidents was either 6.19-kg (LA-3861), 6.2-kg (LA-3611, LA-13638, etc.), or 6200 grams (LAMD-120).

[176] Harry S. Truman Library. One scientist stated jokingly "that if Truman had not been president, he would have been taken out and shot for leaking this information." General Groves was even more specific in describing the amount of plutonium used in the device. In an 18 July 1945 report to Secretary of War Henry Stimson, Groves wrote it contained "about thirteen and a half pounds of plutonium which was compressed by the detonation of a surrounding sphere of some 5,000 pounds of high explosives." According to sources, current plutonium pits weigh an average of 3 to 6-kg with some as small as 1-kg.

[177] *The Curve of Binding Energy*, p.163. This amount was arrived at by using Einstein's Relativity Theory $E=MC^2$. According to the law of conservation of energy, energy can never be lost, just converted into other forms of energy. In 1905, Einstein proposed that energy could be converted into matter and matter into energy. A free neutron or proton weighs slightly more than when inside the nucleus of an atom. When converted to energy, this tiny difference in mass becomes the tremendous force that holds the nucleus together. It is known as binding energy. When one kg of Pu239 fissions completely (100% efficiency), it releases 19 Kilotons of energy. Therefore, based on 6.19 kg and a 21 Kiloton yield, only 17.9% (1.1 kg) of the plutonium actually fissioned. If it had fissioned at 100% efficiency, it would have released about 118 Kilotons of energy.

[178] *Critical Assembly*, pp. 284, 285, 290, 292; *Los Alamos Science*, Vol. 4. No. 7, Winter/Spring 1983, pp. 144, 145.

[179] *Project Y*, p. 223; Philip Morrison interview with the author on 5/31/95; Roger Meade interview with the author on 11/15/94. The plutonium hemispheres and thin hemispherical HEU shells of modern-day nuclear devices are machined to tolerances of less than ± 0.0005" or about one-sixth the diameter of a human hair. After disassembly at the DOE Pantex Facility in Amarillo, Texas, pits removed from nuclear devices are stored encased in their beryllium shells or thin stainless steel cladding. As of this writing, Pantex stores in excess of 10,000 pits.

[180] Interview with the author on 6/16/02.

[181] Personal communication from Raemer Schreiber to the author dated 1/22/96 (1.9 cm or 0.7" diameter); Visgin, V.P. The Visgin document stated the initiator diameter to be 2.0 cm (0.79"). Robert Christy told the author on 6/16/02, "Everything was made to be a good fit." A source told the author that postwar LANL documents mention a "standard 0.8-inch diameter ball-polonium" initiator. The May 1, 1946 Los Alamos report LA-555 mentions that the thin-walled beryllium neutron source-sphere used inside the Be hemispheres had a 0.830" O.D. The *Monthly Progress Report of the Chemistry and Metallurgical Division*, LAMS-352, February 1, 1946, p.17, mentions that "Molds are being prepared for casting 0.8 inch diameter spheres of various metals, to be used for nuclear measurements." The interior cavity in the Pu hemispheres was about 0.85" in diameter. Since both the Urchin and the Pu core thermally expanded due to the heat generated by their alpha-particle emissions, the slightly smaller 0.8" diameter initiator (according to sources) "fit snugly" inside the Pu core. Current nuclear devices utilize external neutron initiation, which allows the plutonium core to be machined shapes such as a sphere, cylinder, or ovoid. The dimensions specified in the Visgin document for the Urchin initiator are as follows:

Radius of the hollow beryllium sphere	1.0 cm (0.39")
Radius of the base of the wedge-shaped groove	0.40 cm (0.157")
Radius of the top of the wedge-shaped groove	0.609 cm (0.24")
Radius of the solid beryllium ball	0.40 cm (0.156")

However, one source disputed the Visgin description and told the author on 5/19/08, "The urchin is machined from two beryllium hemispheres. The inside is hollowed out by boring steps of decreasing radius using a series of end-mills. The result is what looks like a 'theater in the round,' with the circular steps cut in each hemisphere. The beryllium is then flash-coated with Po-210 on the steps." Yet another source confirmed to the author in 2015 the Visgin descriptions are accurate.

[182] "Neutron Experiments Done With Beryllium Spheres," E. Creutz (et al), LA-555, May 1, 1946, p. 9. A plastic hemisphere cast in 1945 in the same molds used for the Pu hemispheres was shown to the author in 2015 and it measured a smaller 3.55" diameter. The Trinity and Nagasaki Pu hemispheres were possibly 3.62" in diameter. It is unclear from this report if the 3.62" diameter mentioned already included the 5-mil (0.005") layer of nickel, but it probably did not; Visgin, V.P.; Raemer Schreiber interview with the author on 2/14/96; Personal communication from Philip Morrison to the author dated 1/10/96. Radium-beryllium (Ra-Be) initiators were also tested. A 5-microcurie Ra-Be initiator was present on the table during the Slotin

accident. A 30-curie polonium-beryllium (Po-Be) initiator was also on another table, which was behind and to the left of the first table. This was, in all probability, an "Urchin" initiator minus the 20-curie polonium-plated interior solid beryllium ball. A curie is a unit of radioactivity where 37 billion disintegrations occur per second. One source identified scientist Jim Tuck, part of the British team assigned to the *Manhattan Project*, as the person who named it "Urchin" because its interior ribbed surface resembled the interior of a sea urchin. Tuck had a whimsical sense of humor. When an atomic rocket engine was under development by the US in the Fifties, he nicknamed it "KIWI" after a flightless New Zealand bird. In 1952, Tuck proposed to the Atomic Energy Commission (AEC) that he construct an experimental, controlled nuclear fusion machine at Los Alamos. He named it the "Perhapsatron." However, a *Manhattan Project* scientist, who wished to remain anonymous, *strongly* denied this version. The source worked in the G10 Group at Los Alamos, which developed the initiator under the direction of Charles Critchfield. In a 1/10/01 communication to the author, the source stated, "My memory, for what it's worth, is that I gave it its name." The source continued, "I reviewed for the Group the 8 or more various devices being studied. They had names like Omega, Wedge, Grapenuts, Melon Seed, and even Nicodemus all of which were as unrevealing of their inner structure as the name 'Urchin'! I used the name 'Urchin' because I had once seen the globular spiked animal and it just popped into my head. I never saw the insides...I never saw the final design but if it had 'parallel' grooves they must have been like latitudes, the only way they could be machined to be parallel." Other designs named in the 1/20/45 Los Alamos document LAMS-198 are Gamma, Multigun, Wedge, Iron Maiden, Disc, and Cube (Little Joe).

[183] Visgin, V.P.

[184] This was referred to by various members of the assembly team as the "capsule," "plug," and "slug." These terms all refer to the same cylindrical object and were used interchangeably. Postwar stockpiled assemblies with plutonium cores were referred to as "hot plugs."

[185] U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, DC: U.S. Government Printing Office, December 1993), p. 133.

[186] Personal communication to the author dated 7/21/95.

[187] Interview with the author on 2/5/96.

[188] Personal communication to the author dated 1/22/96. In fact, in the short period of time between its assembly at the McDonald Ranch to the time it was inserted in the pit, the temperature of the capsule had risen from 102.2° F to 115.7° F.

[189] Personal communication to the author dated 1/10/96.

[190] Personal communication to the author dated 12/22/95.

[191] Interview with the author on 2/5/96.

[192] Personal communication with the author dated 9/19/99.

[193] The uranium wall was about 0.69" thick in the very middle of the capsule. Because it was relatively thin at this point, the heat transferred rapidly from the warm capsule to the cooler main tamper sphere, thus allowing the capsule to contract back down to its original diameter within just a few minutes. All subsequent capsules were machined to allow more clearance so this problem would not happen again. This same capsule design was maintained for many years and used in the In Flight Insertion (IFI) mechanisms prevalent during the 1950's and 1960's era nuclear weapons.

[194] Robert Alldredge and Ralph Sparks interviews with the author on 5/17/96 and 8/20/96 respectively.

[195] Raemer Schreiber interview with the author on 2/14/96.

[196] *Ibid*; Ralph Sparks interview with the author on 7/27/96; The Trinity gold foil gasket is on display at the Smithsonian Institution National Museum of American History in Washington, DC. The Nagasaki foil was cut up into pieces with a scissors and distributed to those present during an impromptu post-mission party at Tinian. The Trinity foil on display has a dimpled surface. The Nagasaki foil is smooth and, according to an anonymous source, "Is thick enough to be fairly stiff. It originally looked like a flat donut, with a hole in the center. The outer cut had several straight sections in it as if no attempt had been made to make it fairly round. Who ever made it must have been in a hurry."

[197] Case description based on Herbert Lehr, Raemer Schreiber, and Ralph Sparks interviews with the author dated 2/5/96, 2/14/96, and 7/27/96 respectively.

[198] Ralph Sparks interview with the author on 7/27/96.

[199] *Ibid.*

[200] Personal communication to the author dated 9/7/95.

[201] "Nuclear Naiveté," *Albuquerque Journal*, July 1995.
[202] Interview with the author on 8/9/95; Visgin, V.P. The Visgin document incorrectly states the active bomb components (plutonium core and initiator) temperature to be 90° centigrade higher than the temperature of the environment. It also incorrectly states these components were transported to the bomb assembly site in special containers fitted with cooling systems. The only "cooling system" on the magnesium case was a series of fins machined into the waist section.
[203] *U.S. Nuclear Weapons*, p. 124.
[204] Dural sphere measurements and photographs made by the author on a publicly-displayed postwar stockpile unit in the EAA museum with the full cooperation and assistance from the staff who, along with the author, performed the partial disassembly of the FM. Since these were virtually interchangeable, some polar caps on the stockpiled weapons in museum displays have Y-1560-6 stamped on them, while others show the design number Y-1561; *Dark Sun*, p. 174; Visgin, V.P.
[205] *Swords of Armageddon*, VI-85.
[206] "Nuclear Weapons Engineering and Delivery," p. 89.
[207] *Project Alberta*, p. 65. There is a possible problem with this story in the Russ book. If the F-31 preassembly was transported from Los Alamos to Tinian inside an armor ballistic case, then where did it go and why did not the assembly team members use this original case? Russ also described the F-31 HE sphere buildup as taking place at Tinian, when in fact it had occurred earlier back at Los Alamos. However, a July 27, 1945 Special Meeting for Project Technical Committee Tinian memo from Norman Ramsey to Capt. Parsons notes, "If the [armor ellipsoid] modifications are impossible, even the hot unit will be dropped without armor ellipsoids." This memo would seem to confirm they were prepared to drop the combat FM without the armor ellipsoids.
[208] Interview with the author on 5/31/95.
[209] *Ibid.*
[210] Harlow Russ interview 8/9/94.
[211] Personal communication to the author dated 11/12/96.
[212] *Manhattan District History: Nonscientific Aspects of Los Alamos Project Y*, p. 110; "Memo from Wm. Parsons to Lt. Benninghoff," 27 June 1945, LANL, A-84-019, 17-8. This memo states in part "Castings are to be coated with the new fast drying varnish and plastic coating shipped to McAlester via REA on 16 June. One coat each of the varnish and plastic coating are to be applied in that order. These may be applied either by spraying or painting, maintaining a total thickness of approximately 4 to 8 thousandths inches. Blotting paper and felt will then be applied as previously instructed. No tape to be applied until further notice."
[213] "Disassembly of 1560 Sphere After Overseas Shipment," p. 1; "Unit F-32 Disassembly, 25 October 1945," Capt. Schaffer, 8 November 1945, A-84-019, 17-2, p. 1.
[214] Interview with the author on 10/1/97.
[215] *Ibid.*
[216] *Critical Assembly*, p. 386; *Project W-47*, p. 128; "HE Assembly Problem," N.E. Bradbury, 11 May 1945. Norris E. Bradbury became second LANL Director in October 1945 after the postwar departure of Oppenheimer; Personal communication from William R. Stewart to the author dated 3/23/98. Stewart was a member of Captain Schaffer's assembly team.
[217] Visgin, V.P.
[218] Personal communication from Edward Wilder to the author dated 2/5/96; "TR Hot Run," Comdr. N.E. Bradbury, Memo to Personnel Concerned, 9 July 1945, p. 1.
[219] Visgin, V.P.; "TR Hot Run," pp. 1, 3; "Trinity," p. 39. This report states that there was "considerable controversy over the effect of small air spaces between castings. Grease was advocated by some to take care of the possible air voids left by the spacer materials." In the end, they decided not to use grease. This report also provides a description of the "Schaffer Shake Test." It reads, "On July 7 a mockup HE charge with four actual lens charges was delivered from S-Site for assembly. The charges were prepared and the assembly was made on July 8. On July 9 this unit was driven for 8h over a rough course to determine what effect transportation to Trinity might have on the actual lens charge...After 3-h driving time, the top polar cap was removed for inspection and the charge found to be in excellent condition." According to a 3/16/98 communication to the author, Schaffer described this unusual test. "We obtained a standard Army transport truck from the Motor Pool and rigged it out in a rough area of the mesa by securing the steering wheel so the vehicle could travel in a circle. I believe we also installed a post in the center of the circular path and tied the truck to the post by ropes to keep it from leaving the test site...It was then just a matter of starting the

truck and keeping it fueled for the duration of the test."

220 *Project W-47*, p. 132.

221 Early S-Site Experiences, Wilder, p. 109.

222 "Trap Door FM Assemblies," Captain Larkin memo to Lt. Col. R.W. Lockridge, 4 August 1945, A-84-019, 67-3; *Critical Assembly*, pp. 333, 334, 386, 387; *Nuclear Weapons Engineering and Delivery*, p. 97.

223 The information about the jigs and the vacuum cup was supplied by Steve Bice. For several decades he had been accumulating a long series of interviews with his father and other Los Alamos and Sandia pioneers in order to write a biography of his father. Unfortunately, he passed away suddenly in early 2006 before this could be accomplished. Used with permission.

224 Van Vessem interview 10/1/97.

225 Personal communication to the author dated 2/5/96.

226 The Visgin document gives the aluminum pusher and tuballoy tamper sphere diameters as 460 mm (18.1") and 230 mm (9.06") respectively. The beryllium tamper used in the 5/21/46 criticality experiment that killed Louis Slotin was also 9" in diameter. In *Project W-47*, James Rowe mentioned an 18" pit diameter and the use of explosive blocks for the units his crews assembled at Wendover (W-47) starting about the middle of July 1945. Up until that time, his crews had just poured cement into the Dural spheres, which were subsequently used for *Fat Man* drop tests. However, both Rowe and Visgin also described the use of levitated pit components, which were not used in either of the wartime Trinity and Nagasaki implosion devices. A 4 August 1945 memo from Lt. Col. R.W. Lockridge to Captain Larkin regarding trap door FM assemblies states "HE charges for *experimental* use at W-47 will be prepared at Y [Los Alamos] from McAlester HE blocks at the rate of at least one per week as long as needed (emphasis added)." McAlester referred to the Naval Ammunition Depot (now the Army Ammunition Plant) in McAlester, Oklahoma, which was one of several sites producing HE blocks. The pumpkin bombs were filled with Comp B at McAlester. A production bottleneck occurred there because it took such a long time for the 6,300-lb. of HE used in each pumpkin to cool properly. On p. 174 of *Dark Sun*, the tamper weight is given as "500 pounds" which would correspond to an 11" diameter tuballoy sphere. However, the original accompanying Russian text mentions a tamper weight of 50, not 500-lb. According to the declassified "PIT Catalog: Destination Kit," LAMS-381, pg. 12, May 7, 1946 (graciously supplied to the author by Steve Bice), one of the items listed was "Pit cradle, (doughnut) for 9" sphere, Y-1981-C2, Issue A," which confirms the actual 9" diameter of the tamper sphere covered with the boron shell. Including the capsule mass, this 8.75" diameter tamper sphere weighed a total of about 224-lb. The ventilated wood box containing the assembled Trinity capsule that Herb Lehr and Harry Daghlian placed into the back seat of the 1942 Plymouth sedan at the McDonald ranch was about 10" to 11" long. The thickness of the wood case sides easily accommodated the 8.75" long capsule. The same LAMS-381 also lists "Pit cradle, for 18 ½" sphere, Y-2015, Issue A," which confirms 18.5" as the final combat weapon pusher diameter. The Y-1291design pusher was 24.5" in diameter, which meant the tamper was also a larger diameter (probably 12"). In an interview with the author on 7/27/96, one source stated, "It was about an eleven to twelve inch plug." The source went on to state, "I wrestled with those aluminum spheres at the Ice House [assembly building] and they were two foot or a little better." In almost a dozen interviews with the author, this source was very steadfast in his assertion that the pusher was this larger size and not the smaller 18.5" diameter. Ralph Sparks said (2/22/97) that a wood cradle made from felt-covered 2 x 4's was installed in the back of a pickup truck so the completed spheres could be driven over to the HE assembly area at S-Site. He accompanied the spheres to make sure the HE assembly crews kept the brass trap-door plug in the proper alignment position. In 1945, Oppenheimer contracted with the California Institute of Technology (C.I.T. or Caltech) to create *Project Camel*. This group subsequently formed its own general implosion program, which pursued alternative, standby lines of development. Among its many accomplishments, they worked on the pumpkin bombs and the Y-1222 and Y-1291 non-lens implosion program. They also became heavily involved with detonator development. Their test site was near the Naval Ordnance Test Station or NOTS (now the China Lake Naval Weapons Center) at Inyokern, California. In May 1945, Caltech sub-contracted with Crescent Engineering & Research Company in Pasadena to design and manufacture the complex water-cooled molds necessary to produce explosive blocks. The first explosives blocks were cast at the NOTS Salt Wells Pilot Plant on 7/25/45. A 1996 Crescent company history report stated the pit was "*around 2 feet in diameter* – based on the radius of the lower shiny precision mold faces we handled (emphasis added)." The report also stated, "The upper and lower aluminum mold faces were hexagon and pentagon shapes with sloping sides. All front curved, and side angled faces were mirror polished." After the 16 July 1945 Trinity test firmly established the success of the Los Alamos implosion

program, with the exception of the Salt Wells plant, *Project Camel* was cancelled the very same day. Although most of the remaining molds were ordered scrapped, Crescent's founder, Edmund V. Sawyer, saved a few and eventually used one of them as a poolside garden gas torch at his home! It has since disappeared.

[227] Morrison interview 5/31/95.

[228] *Twilight Time*, Ralph C. Sparks, (Los Alamos Historical Society, Los Alamos, NM, 2000), p. 65.

[229] Sparks interview 7/1/96.

[230] Personal communication from Leonard Della-Moretta to the author dated 12/18/95. Both Della-Moretta and Sparks stated these cups were about 2" to 3" in diameter. Developments in early postwar levitated implosion designs also led to pushers with substantially thinner wall thicknesses of under 2" although the outside diameter remained about 18". One such pusher design started out as an 18.25" diameter casting with a 1.375" wall thickness. Some of the rough castings were manufactured at the Rock Island Arsenal and final machining was done at Los Alamos. A few residents living in the Los Alamos/Santa Fe area have used the large aluminum surplus rough castings as ornamental garden bells and birdbaths. One of these castings was used by artist Jim Sanborn in his *Critical Assembly* installation shown at the Corcoran Gallery in Washington, DC in late 2003 and early 2004. This exhibit, in part, reproduced the Y-1561 pit based on specifications and descriptions provided by the author who worked closely with the artist over a four year period.

[231] Sparks interview 7/27/96.

[232] Sparks interview 7/1/96.

[233] The Trinity plug had a machined brass top, which contained all of the necessary threading. The main body of the plug was made of wood, whereas the entire subsequent Tinian plug was hollow brass. The Trinity plug was discarded during the final assembly under the 100' shot tower. It was later recovered by Pit Team member Marshall Holloway and saved by him until his death in 1991. His son found it in his personal effects and donated it to the Bradbury Science Museum in Los Alamos. When Raemer Schreiber found out about this, he brought over the threaded brass top, which he had saved. The two pieces were then reassembled. The 2" diameter brass disk, or "key," remains in a private collection. The plug also has the long steel eyebolt, which was screwed into the top of the plug. With the bolt, it is about 12.5" long and weighs 10-lb. In early 1999, this plug was removed from the museum collection. As of this writing, it remains in the custody of the LANL Classification Office.

[234] Sparks interview 8/20/96.

[235] *Critical Assembly*, pp. 333, 368, 390; *Sandia National Laboratory: The Postwar Decade*, Necah S. Furman, (University of New Mexico Press, Albuquerque, NM, 1990), pp. 30-31; Personal communication from Raemer Schreiber to the author dated 9/7/95.

[236] Schreiber interview 2/14/96.

[237] Robert Bacher interview with Lillian Hoddeson and Gordon Baym at Caltech in Pasadena on 3/3/86 (p.8). Copy courtesy of Alex Wellerstein.

[238] Personal communication from Herbert Lehr to the author dated 9/20/96. During the assembly, the pieces of foil stuck out around the entire perimeter of the plug at the parting line. If the assembled plug diameter was too large, the plug was disassembled and some of the foil was removed. If they tugged on the foil and it came out, that indicated they did not have enough, so it was disassembled and more foil placed inside. This assembly/disassembly procedure progressed slowly for several hours until everyone was satisfied that there were no gaps and the plug diameter indicated that it would easily slide into the tamper sphere.

[239] Schreiber interview.

[240] Capsule assembly description based on interviews and personal communications with Herbert Lehr, Raemer Schreiber, Ralph Sparks, and Philip Morrison.

[241] Herbert Lehr interview 9/3/96; *Day of Trinity*, p. 172.

[242] Lehr interview 2/5/96.

[243] Morrison interview 5/31/95.

[244] Sparks interview 7/1/96. The silver layer was probably 2-mils to 3-mils thick.

[245] Visgin, V.P.; *Dark Sun*, p. 194. Because of this, the second and third sets of combat Pu hemispheres were re-designed to eliminate any possibility of jets causing premature initiator activation. A Pu ring, with a triangular cross-section, was inserted into grooves machined into the flat mating surfaces of each hemisphere. According to LAMS-381, 20 "Shims, gold, .0005", flat 2.75" O.D. x 1.375" I.D." were available for use in the Nagasaki hemispheres. This would seem to indicate the I.D. of the jet ring was probably 2.75" and the O.D was most likely the Pu sphere diameter of 3.62."

[246] Morrison interview 5/31/95.

[247] Thornton interview 8/25/96; Personal communication from Herbert Lehr to the author dated 9/20/96; Personal communication from McAllister Hull to the author dated 11/12/96.

[248] In April 2005, the author and Jim Peterson, the president of the Historic Wendover Airfield Museum, uncovered the remnants of this sub-floor design at the site where the final test bomb assembly buildings once stood out in the desert at Wendover. The crumbled remains of this floor consisted of scattered fragmented concrete chunks colored red from the rusted iron filings along with numerous lengths of 4 gauge copper grounding wire imbedded in them. These wires were anchored to the steel columns that once formed the 18' wide interior framework for the building. One small jagged-edge corroded piece of the original thin copper floor sheeting was recovered and that is now in the possession of the museum.

[249] Schreiber, 9/7/95.

[250] Personal communication to the author dated 8/11/04.

[251] Personal letter from Art Machen to Steve Bice dated January 1982. Copy graciously provided to the author by Bice.

[252] *Project Alberta*, pg. 17. With the exception of about one-half inch at the bottom, this funnel covered all of the HE.

[253] Sparks interview 7/27/96. None of the other *Trinity* or Nagasaki pit assembly people interviewed by the author recall seeing anything written inside the boron shell.

[254] Schreiber interview 2/14/96.

[255] Capsule insertion description is based on several sources including both interviews and personal communications with Herbert Lehr, Philip Morrison, Raemer Schreiber, and Ralph Sparks; *Sandia National Laboratory: The Postwar Decade*, pp. 30-31.

[256] *Nuclear Weapons Engineering and Delivery*, LA-1161, p. 73.

[257] Personal communication to the author dated 9/7/95; Boyce McDaniel performed this task at Trinity. "I would take the wire back to the McDonald ranch and count it in a leadshielded Geiger Counter. The lead shield was for cosmic rays, in order to minimize the background radiation to improve the sensitivity of the measurement." (Personal communication to the author dated 9/27/99.)

[258] Three different weights have been mentioned for the X-unit. Visgin, V.P. (180-kg/397-lb.); *Nuclear Weapons Engineering and Delivery*, p. 83, (300-lb., although this might have been the weight of just the Dural tub/firing circuit box); *Sandia National Laboratory: The Postwar Decade*, p. 270, (700-lb.).

[259] *Nuclear Weapons Engineering and Delivery*, p.83.

[260] Measurements made by the author.

[261] Personal communication to the author dated 7/11/00.

[262] *Ibid.*

[263] Personal communication from G.C. Hollowwa to the author dated 8/10/95; Because the batteries would be exposed to low temperatures at high altitudes, the specific gravity of the acid (12.35) was changed to 13.5.

[264] 5,600 volts was the optimum with 4,500 volts considered the "Disaster Chart" minimum at firing time. Description of the 1773 detonator was based on several sources including interviews and personal communications with Robert Alldredge, Leonard Della-Moretta, Sigmond Harris, G.C. Hollowwa, Larry Johnston, James Lyons, Sr., Harlow Russ, and John Tucker; all measurements made by the author with a Mitutoyo Digimatic digital caliper on an inert 1773 detonator; "1E23 Detonator Manual," Los Alamos Scientific Laboratory of the University of California, LA-1380, March 1952; *Critical Assembly*, pp. 169-173, 301-307, 321-325. One of the places contracted to help develop the detonator was Caltech. They referred to them as "sockets."

[265] After awhile, the silver in the wire underwent an unanticipated transformation from metal to crystalline structure as a result of long term-contact with the PETN. This resulted in some bridgewire breakage and the subsequent necessity of replacing all detonators in the entire US nuclear weapons inventory. Adjustments had to be made in the firing circuitry because the gold and silver/copper bridgewires had different electrical characteristics. In addition to silver, platinum was also tested for use as a bridgewire.

[266] Personal communication from John Tucker to the author dated 5/10/96.

[267] "1E23 Detonator Manual," p. 14; The recrystallization process determined the particle size, which in turn determined the threshold at which it would initiate.

[268] Tucker, 5/10/96. PETN has a crystal density of 1.77 g/cm³ and a pressed density of about 1.54 g/cm³ at 30,000 psi. The higher the pressed density, however, the harder it is to initiate the PETN. In Los Alamos report LAMS-198 dated 1/16/45, 500 psi was proposed as a standard pressure. The report also stated that the detonators would not fire at pressures above 1200 psi. Tucker went to Tinian as part of *Project Alberta*

Detonator/Firing Team unit. As a young Navy ensign, his first project at Los Alamos was building the prototype of the X-unit. He also helped build the *Fat Man* Flight Test Box (FTB) used by Philip Barnes aboard *Bockscar*. Tucker flew three or four stateside "missions" as weaponeer. His first view of San Francisco's Golden Gate Bridge "was through the bombsight of a B-29 at 30,000 feet." 509th crews frequently used San Francisco as a test target because, like both Hiroshima and Nagasaki, it was a port city that could be approached from over water. Before Captain Parsons, Tucker, Bernard "Barney" O'Keefe, and Bill Prohs left on 4 July 1945 to fly to Tinian, Oppenheimer told Parsons to send the others over to have a very brief meeting with him. Tucker remembered that Oppenheimer came into the room and had only six words to say to the small group, "We will tolerate no mistakes. Goodbye!" Before they departed, Tucker recalled, "We'd sent really fancy tool kits over to Tinian. I said, 'What if they don't get there?' Stevenson [Detonator/Firing Team Leader] allowed me to go to the warehouse to get some spares. I got a big box, put it on a dolly, and picked out stuff I thought we could use in the event our tools never showed up. Well, our tools never did show up until after the war was declared over. So we used the tools I had put in this box and sent over to Tinian on a Green Hornet [C-54 supply flight]. Later, the fancy tool kits were put on a LCT, taken out, and dumped overboard!"

269 Interview with the author on 4/22/96.

270 Tucker, 5/10/96.

271 "Explosives," G.B. Kistiakowsky, February 7, 1945, LAMS-202.

272 "1E23 Detonator Manual," p. 16.

273 *Ibid.*

274 Tucker, 5/10/96.

275 "Los Alamos Science," Number 21, 1993, pp. 56-57. Present-day implosion nuclear devices probably use this slapper detonator in the form of a thin multi-piece, laminated, multi-detonator printed circuit shell, which completely surrounds the hemispheres or cylinders of IHE. One later EBW detonator design was the SE-1, which is on display at the Bradbury Museum. The design specs were later furnished to the RISI Company in order for them to manufacture an inexpensive detonator (RP-1) that LANL and LLNL could use for various experiments, parameter studies, and tests. The actual detonators used in nuclear devices are still manufactured under the most stringent of quality control standards by LANL and LLNL

276 Personal communication to the author dated 9/14/95.

277 In a personal communication to the author dated 3/27/97, Robert Alldredge wrote, "I thought a heated bridgewire combined with an azide explosive would fire rapidly enough to make microsecond-assimultaneity detonators. They would require only a fraction of the current that exploding bridgewire detonators needed. Lead azide is too sensitive to shock, especially when the azide is compacted by compressing it.... However, thirty years later "airbags" for cars were developed. They use fast-firing sodium azide hot wire detonators. Sodium azide is "desensitized" as compared to lead azide. Unknowingly, the air bag designers adopted my concept of a hot bridgewire azide detonator."

278 Sigmond Harris interview 4/22/96.

279 *Critical Assembly*, p. 321.

280 Personal communication to the author dated 9/14/95.

281 Robert Alldredge interview with the author on 5/17/96. Personal communication to the author dated 3/27/97.

282 Personal communication to the author dated 3/27/97.

283 *Critical Assembly*, pp. 321-323. Companies, such as RISI, produce EBW detonators today with simultaneities that equal or exceed the original 1773. These detonators are still made by hand using precision assembly techniques pioneered by the South Mesa Detonator Group.

284 Interview with the author on 8/9/95.

285 Part of an unfinished manuscript by Lyons dated 11/15/93 and graciously supplied to the author on 4/3/96. A self-described "powder monkey," he also had been involved with R & D at the blasting cap and detonator labs at DuPont's Eastern Laboratory in Gibbstown, NJ, prior to arriving at Los Alamos in February 1945. Due to a mix-up after the war, his military records were accidentally switched with another soldier with the same name. Lyons spent the last few years of his life in an attempt to prove he worked at South Mesa. He even filed Freedom Of Information Act (FOIA) requests with the DOE. In interviews with the author, other surviving members of the South Mesa Detonator Group have confirmed Lyons' contributions to the development of both spark-gap and bridgewire detonators at Los Alamos. Shortly before his death in December 1996, Lyons loaned photos of himself and other South Mesa personnel to the author. These

personal photos depicted members of the Detonator Group and others not only working, but also enjoying camping, hiking, exploring, swimming, baseball, and horseback riding at Los Alamos.

[286] *Project Alberta*, pp. 55, 68, 72, 73. The brass "chimney" tube extended up about 1" from the surface of the lens.

[287] "Unit F-32 Disassembly, 25 October 1945," pg. 1; "H.E. Assembly with Condenser Spacers for Stress Measurements," R.A. Bice, August 30, 1945, A-84-019.

[288] There were many design changes made to the postwar stockpiled units. To ensure a less bulky cable routing system, cables of different lengths were utilized. Load coils (delay mechanism) for each cable connector at the X-unit load plate were used so the electrical current reached all of the detonators at precisely the same time. According to one source, "Much later on, cables were inductively matched by cutting to inductive length, rather than to specific lengths, to further improve simultaneity of the electrical pulse timing to the detonators." According to LA-550 "Cross-Roads Handbook of Explosion Phenomena," the time it took from the moment the firing signal was sent to the X-unit until the chain reaction started was a mere 0.115 milliseconds. After the chain reaction started, it was only another 0.005 milliseconds until the shock wave broke out through the bomb casing.

[289] In a 12/4/09 communication to the author, Project Alberta Firing Team member John Tucker disputes this. "The connectors at the ends of the detonator cable had no bends. If I remember right...the connectors were AN connectors." He also disputes the use of sparkplugs. However, a July 20, 1945 memo from Ed Lofgren to Oppenheimer states "We also believe that sturdier spark plugs...should be used."

[290] Personal communications to the author dated 10/11/99 and 10/12/99.

[291] Interview with the author on 10/94. James Rowe describes these contact fuzes on pp. 136-137 of his book *Project W-47*. On p. 169 he also states that both Art Machen and William Parsons told him after the war that the Primacord fuze trains to these detonators had been removed before the Nagasaki mission. In conversations with the author, both Harlow Russ and Frederick Ashworth denied the removal of the Primacord. However, in a January 1982 letter from Art Machen to Steve Bice (copy graciously supplied to the author by Bice), Machen states that "It was a last minute decision not to use contact fuzes (sic) for a backup destruct for reason that it would scatter plutonium all over the place." Bice went on to describe how he "went out in the boonies with a hacksaw and sawed off the swedged-on tube containing the primacord train to the tetral (sic) boosters on the sphere. I installed the modified fuses (sic) in the case during final assembly."

[292] *Project Alberta*, p. 24.

[293] *Ibid.*, pp. 32, 56-57.

[294] According to Ashworth's Assistant Operations Officer Don Mastick, the case warping problems also interfered with the mating of the tail to the F-31 bomb case. This problem was described in *War's End* (pp. 1-3).

[295] *Ibid.*, p. 12.

[296] *Ibid.*, p. 13.

[297] *Ibid.*, p. 56.

[298] "Sealing Of The 1560 Units at W-47," J.C. Batteiger, 29 June 1945, p. 2.

[299] *Project Alberta*, p. 68.

[300] *Ibid.*, pp. 65-66.

[301] *Critical Assembly*, p. 331.

[302] "3 B-29 specially modified bombers departed from Kirtland Field at 1250Z 28 July and carried 3 HE preassemblies of the implosion type bomb encased in the outer shell. All 3 B-29's arrived at Tinian at 0230Z 2 August and discharged project cargo safely," J.A. Derry, "Transportation of Critical Shipments," 17 August 1945; According to a 3/16/98 communication to the author from W.F. Schaffer, "I was responsible for getting 3 *Fat Man* weapons assembled and delivered to Kirtland field in Albuquerque for loading in the aircraft for delivery to Tinian." These units were loaded onboard the B-29's at Kirtland by using the same style loading pit with hydraulic lift that had been installed at Iwo Jima, Wendover, and Tinian. Rowe denied the existence of a wartime loading pit at Kirtland in his *Project W-47* book. However, in a 10/1/97 interview with the author, Al Van Vessem confirmed the presence of this pit. He personally signed for the F-31 unit at Los Alamos, accompanied it to Kirtland, and watched while it was loaded onto the B-29. It was enclosed by an armor ellipsoid case with a tail assembly. He stated the pit was "on the backside at Kirtland." Photos taken in 1945 and declassified in 1997 clearly showed both a loading pit and small turntable in operation at Kirtland.

[303] Personal communication from Herman (Stan) Zahn to Richard Campbell dated 2/4/97. Copy supplied to

the author courtesy Richard Campbell. In a 3/27/97 interview with the author, Zahn stated both the Costello and Hartshorn preassemblies were accompanied by a grey wooden box with rope handles. His preassembly did not have this extra box. In a 24 March 1959 letter to LOOK magazine author Fletcher Knebel, Costello wrote that he "was told this box contained '*Little Boy* Material' and was led to believe that it contained fissionable material for the bomb, which was dropped on Hiroshima." However, in all likelihood, these contained the tamper plugs (minus the plutonium) that were matched to the F-31 and F-32 units. Zahn probably carried the F-33 unit. Because this unit was going to be used as a final drop test of the X-unit, it did not need a tamper plug.

[304] John Downey interviews with the author on 11/8/94, 11/10/94, and 8/7/94. *Making of the Atomic Bomb*, p. 693.

[305] According to msg. TA-2324 from Oppenheimer to Maj. Derry (Groves' office) dated 9 August 1945, the active sphere for F-32 was scheduled to leave Kirtland the evening of August 12. On 13 August, all shipments to Tinian had been halted. A 16 August 1945 memo from Parsons to Oppenheimer states, "Although they are completely ready, F-101, 103 and 102 [test units] will not be dropped due to surrender agreement. An active sphere for F-32, it is also assumed, will not be sent." This would appear to indicate F-32 would have been the next bomb used against Japan had the surrender not taken place.

[306] *Nuclear Hostages*, Bernard J. O'Keefe, (Houghton Mifflin Company, 1983), pp. 98-102.

[307] Gallagher audiotape.

[308] The FIELD ORDERS, NUMBER 17 (see below) state "No friendly aircraft, other than those listed herein, will be within a 50 mile area of either of the targets for this strike [Kokura or Nagasaki] during a period of four hours prior to and four hours subsequent to strike time, except for one routine weather aircraft of this command." This Pilot might have accompanied later photo recon aircraft, but by that time the mushroom cloud would have long since dissipated. The earliest any photo planes arrived over Nagasaki was over four hours after the initial strike. At that time, the city was entirely covered by clouds, smoke, and dust.

[309] Sweeney interviews with the author on 3/28/95, 4/13/95.

[310] Gallagher audiotape.

[311] Personal communication to the author dated 2/1/95; In both a personal communication to the author dated 3/4/95 and in the reissue of his autobiography in 1998, Tibbets made it crystal clear he viewed Sweeney's complaints about the fuel problem as an example of his indecisiveness and failure to command.

[312] This information is based on a series of conversations and interviews conducted with members of ground and flight crews from the *Enola Gay*, *Bockscar,* and *The Great Artiste* conducted prior to and during the 1994, 1995, 1997, 1999, 2000, 2001, 2002, and 2004 509th reunions. This matter has been a source of friction between some members of these crews. Because these 15 special *Silverplate* B-29's were meticulously maintained, several of the original *Bockscar* ground and flight crew have stated to the author the plane was in absolutely perfect condition before Sweeney's crew took over. After both planes landed at Okinawa, *Bockscar* Flight Engineer Rod Arnold, who had been inside *The Great Artiste*, ran over to *Bockscar* and went inside to check out this problem "before the wheels even stopped turning." According to a 10/16/99 interview with the author, *Bockscar* navigator Len Godfrey stated that "Arnold came back and said 'My God! They've got 610 gallons of fuel in those rear tanks!' " In an interview with the author on 10/17/99, Charles Albury was adamant that the fuel was still in the tanks when they landed. He also stated that Kuharek told him later that the pumps were then removed and found to be defective. Both before the mission and immediately after returning to Tinian, Bock's crew chief Fred Clayton went over the plane thoroughly and had no difficulty transferring fuel. A subsequent test flight also confirmed a successful in-flight fuel transfer. Like any highly complex machine, each B-29 had its own idiosyncrasies. Some of Bock's crew have told the author that, if Kuharek had simply turned the fuel transfer switch on and left it on, the fuel would have transferred perfectly. In an 8/15/99 communication to the author, Fred Bock wrote, "My Flight Engineer, Roderick Arnold, and ground crew chief, Frederick Clayton, always maintained that inspection and tests of #77 after the mission did not reveal a faulty fuel transfer system and that the problem was probably procedural." However, *Bockscar* maintenance records dated 1 August 1945 on file at the USAF Museum at Wright-Patterson state "Check bomb bay hook-up, have to use upper tank switch to get fuel out of lower tank." The post-mission maintenance report dated 8/9/45 states, "Check bomb bay tank hook-up. Lower tank works erradict (sic), appears that booster pump is at fault." Sweeney flew *Bockscar* with Kuharek as Flight Engineer during drops of FM units F13, F18, F33, and F31 on 8/1, 8/5, 8/8, and 8/9 respectively. Some people have speculated that Kuharek might have actually used some of this extra fuel during the mission and that without it; they never would have made it back to Okinawa without ditching the plane in the ocean. If Arnold's statement is correct,

then Kuharek might have been able to transfer as much as 30 gallons of fuel. In an unpublished manuscript written in 1946 by navigator Jim Van Pelt, he stated that "John Kuharek couldn't transfer 300 gallons from the lower tank." He noted that Kuharek checked and found that "the transfer motor was inoperative." He also wrote that the fuel in "The upper bomb bay tank couldn't be transferred because of lack of pressure at altitudes." In interviews with the author on 10/16/99 and 7/26/04, Tibbets stated that he and Dutch Van Kirk went to see Kuharek in 1995 at the 509th reunion. "John Kuharek looked at me, he said 'If I hadn't been able to transfer that fuel, I wouldn't be here talking to you, we'd have gone in the water. Sweeney didn't listen to me! What I told Sweeney was I couldn't transfer it at normal rate, I had to milk it out a little bit at a time. I was afraid of burning out the pump.' " 509th B-29 Flight Engineers have told the author that the pump motor was designed for continuous and not intermittent use. They stated that turning it on and off frequently would probably have burned out the motor. Besides, fuel moving through the pump helped to keep it cool since the fuel at that altitude was already cold. The author re-examined the entire fuel transfer system during one of the 509th reunions in 2004 when he was allowed inside *Doc*, a B-29 being restored at Boeing Wichita. He was also given access to all the original B-29 fuel system technical drawings. He sat at *Doc*'s Flight Engineer's console with two of the original 509th Flight Engineers and worked out all the possibilities for the fuel system failures. We reasoned that the most likely scenario was that at least some of the fuel was transferred in-flight during that mission.

313 Personal communication to the author dated 3/4/95.

314 *Ibid.*

315 *Now It Can Be Told*, General Leslie M. Groves, (Harper and Brothers, 1962), p. 344.

316 *Ibid*, p. 344; *Wars End*, p. 200. Sweeney claimed that Admiral Purnell told him it cost "Two billion dollars." This was an exaggeration on Sweeney's part, since the entire *Manhattan Project* cost that much. Also, according to Groves (*Now It Can Be Told*, p. 342), it was Purnell who suggested that two bombs would be needed to end the war. Some historians have asserted that it was actually Groves who ordered the second bomb to be dropped *without* Truman's authorization.

317 According to interviews with the author, Olivi stated his notes were reportedly made within a few hours after he returned to Tinian following the mission while his recollections were still fresh. Copy supplied to the author by Olivi. A collector purchased the original diary. According to Olivi, all times mentioned in his notes were taken directly from Van Pelt's log. However, like Beser's wire recording, Van Pelt's log for this mission was handed over to an information officer and has never been located. In an interview with the author during the 2000 509th Reunion, *Bockscar* Pilot Charles Albury discounted the validity of Olivi's diary since the log was surrendered by Van Pelt immediately after landing. It has also been mentioned to the author by others that Olivi's so-called "diary" was actually written in the 1980's at the request of a collector.

318 Interview with the author on 5/3/95. Olivi normally flew in *The Great Artiste* as Albury's regular co-Pilot. When Sweeney was assigned as Aircraft Commander on both the Hiroshima and Nagasaki missions, co-Pilot Olivi was bumped from the C-15 flight crew. The same thing had happened a few days earlier to regular B-9 flight crewmembers co-Pilot 2nd Lt. Richard McNamara, navigator Lt. Harold Rider, and bombardier Lt. Stewart Willims when Tibbets, Van Kirk, and Ferebee replaced them in the *Enola Gay*. In a 1/26/01 letter to the author, *Bockscar* Pilot Charles Albury wrote, "Fred Olivi said he flew the aircraft while going up to the rendezvous at Yaku-Shima. Fred sat in Chuck Sweeney's seat and I flew the aircraft. The only time Fred flew the aircraft was on our way back to Tinian from Okinawa. He spent most of his time in the tunnel sleeping." In a 4/12/95 letter to the author, Albury wrote, "He was a passenger on the flight only because he came to me and asked if he could go along. I told him I would talk to Chuck Sweeney...I asked Chuck Sweeney if he could go along as he was my co-Pilot and Chuck agreed. At one session, he (Olivi) said he went to General Tibbets, which is untrue. Gen. Tibbets has said, if he had come to him, he (Gen. Tibbets) would have not let him go on the flight." Albury reconfirmed this account in an interview with the author during the 2000 509th Reunion in Kansas City. In numerous interviews with the author, Olivi strenuously denied this and stated it was actually the other way around. He said that, as a lowly 2nd Lieutenant, he was fearful of Colonel Tibbets and would therefore have never approached him to ask permission to go along on the mission. He claimed Tibbets approached him after Hiroshima was bombed and asked if he would like to go on the second mission. He readily agreed. Since Tibbets was present during the *Bockscar* pre-flight preparations and saw all of the crew before takeoff, it seems obvious he knew at that time Olivi was going on the flight. However, in a 7/26/04 interview with the author, Tibbets denied this account. He stated he did not know Olivi was on the mission and was unaware Sweeney had "turned it into a sightseeing trip." Had he known, he said he would not have allowed Olivi onboard.

[319] This "problem" has been described with varying degrees of detail and accuracy in many narratives of the mission. In a letter to the Truman Library dated 11/14/90, Barnes corrected some misinformation that had been printed in *NAGASAKI: The Forgotten Bomb.* The author, Frank Chinnock, had written that Barnes' grandfather had been a country doctor and that this helped Barnes "diagnose" the electrical problem. Barnes wrote (11/14/90), "Both paragraphs are misrepresentations of fact; My grandfathers were farmers, neither was a doctor. In addition, my father was a barber, and a very good one." Copy of the letter supplied by the Truman Library and reprinted with permission of Philip Barnes.
[320] Personal communication to the author dated 1/26/01.
[321] *History of Project A*, Norman Ramsey, 27 September 1945. Los Alamos Archivist Roger Meade supplied this copy to the author on 8/10/95. It was copied from the original onionskin carbon paper copy stored in the LANL archives and contains numerous handwritten revisions. The rendezvous time has always been a source of discussion. When shown a copy of Ashworth's log by the author on 4/19/95 at the USAF Museum in Dayton, Sweeney indicated to the author he had never seen it before. A surprising statement considering it the only mission log cited in the Manhattan District History at the National Archives and has been reprinted in countless publications over the past half century. When he read the part about arriving at the rendezvous point at 0900 and that the second plane was sighted at 0920, he looked up and angrily stated, "He's full of shit!" He went on to say that it was just a minute or two before the second plane was sighted. On pp. 210-211 of *War's End*, Sweeney claimed "We arrived at the rendezvous at 7:45 A.M. [0845 Marianas Time] on the button" and "spent 40 minutes at the rendezvous point." This meant a 0925 departure time from the rendezvous point, yet both Ashworth and Olivi wrote in their logs that they left at 0950. However, Ashworth does not recall ever keeping a log. In a personal communication to the author dated 11/29/98, he wrote, "I'll be perfectly frank with you about the Ashworth log. I can't recall that I ever wrote one during the mission. If I did not, this was a grave error on my part. If it wasn't mine, I suspect that it was really Phil Barnes'. I know there is much argument as to when the first aircraft arrived at the rendezvous. If I am supposed to have said, '9:20', so be it, how should I have known when it arrived. It was of no particular interest to me except, as I have said, I wanted the instrument plane to be with us. Everyone else seems to have known just which aircraft it was and when."
[322] Personal communication to the author dated 11/24/95.
[323] *We Dropped the A-Bomb*, Merle Miller and Abe Spitzer, (Thomas Crowell Company, NY, 1946), p. 99. This was the first book published by any of the crewmembers that detailed the atomic missions. Miller had been editor of Stars and Stripes during the war. When asked later by at least one of his fellow crew as to why many details about the mission and crewmembers seem to have been fabricated, Spitzer replied defensively that he just told what happened and Miller decided after the interviews to, as he put it, "Hollywood it up!" However, it is clear from both Spitzer's book and Olivi's diary the *Bockscar* flight crew knew immediately that it was Bock's instrument plane that had joined them at the rendezvous. According to a 1/10/99 interview, Ashworth stated he was probably the only one on the plane who did not know it was Bock's plane. "I was way back in the bilge of the plane and could not tell which plane it was that joined with us."
[324] 509th Reunion speech, Albuquerque, NM, 8/9/95.
[325] Gallagher audiotape.
[326] Sweeney interviews; According to comments made later by Stan G. Steinke (Hopkins' navigator) to Olivi, Hopkins was actually flying at 35,000 feet; In comments made to the author at the 2000 509th Reunion in Kansas City, one of the *Bockscar* Pilots stated "Hopkins was a screwup"; Sweeney's book, *War's End*, expands on the story of Hopkins and his failure to rendezvous with Sweeney and Bock. Highly decorated veteran RAF Group Captain Leonard Cheshire, one of two British observers on the plane, later told Sweeney that he knew Hopkins was flying at the wrong altitude for the rendezvous, but did not feel it was his place to point that out to Hopkins. The sole reason for Hopkins' flight was so that Los Alamos scientist Robert Serber could operate the specialized high-speed Fastax instrumentation movie camera. Before the flight, Serber had mistakenly grabbed a life raft instead of a parachute. Hopkins stubbornly refused to allow him onboard without a regulation parachute and took off without him. An hour later, radio silence had to be broken so Serber could instruct one of the crew in how to operate the camera. However, both the camera and instructions proved too complex and it was not used. In his autobiography *Peace & War* (p. 113), Serber wrote, "This was truly idiotic: he forgot that he wasn't on a joy ride, the plane was supposed to have a mission. The mission was to take pictures, and I was the only one aboard who knew how to run the camera...Of course, Tibbets threw a fit when he heard what happened, and...gave the Pilot a piece of his mind." It has been suggested by some that an electromagnetic pulse (EMP) from the earlier *Little Boy* explosion interfered

with the timing of the Fastax camera during the first mission and, because of this, the scientists did not obtain any Fastax camera footage. It was therefore vital that they get some from the second mission. Later, when Hopkins could not locate Sweeney and Bock at the rendezvous, he violated orders and broke radio silence over enemy territory by asking, "Has Sweeney aborted?" All the people back at Tinian heard was "Sweeney aborted." This caused near panic and resulted in the recall of all rescue planes and ships. When General Farrell was at breakfast and heard the mission had aborted, he ran out of the tent and threw up. It would be over two hours before they finally knew the mission had actually been successful. However, the 1997 publication of Sweeney's popular book stirred up a veritable hornet's nest of criticism resulting in several personal confrontations between some members of the 509th and Sweeney. It almost seems as if Sweeney had dropped *Fat Man* on the 509th instead of Japan. Some of the 509th have even suggested the book more properly belonged in the fiction category. A good-natured, affable character, Sweeney laughed off such criticism. On 10/29/97, Ashworth wrote a three-page letter to Sweeney's editor at Avon Books detailing numerous mistakes. Ferebee, Olivi, and others also made comments regarding inaccuracies. *Enola Gay* navigator Dutch Van Kirk told the author in an interview on 10/4/02 that all of the things mentioned in Sweeney's book probably happened to the 509th, but that not all of them happened to Sweeney. He added, "Historically, it's a bunch of crap!" The errors range all the way from simply misspelling *Bockscar* throughout the entire book (a common error that Tibbets repeated in his autobiography) to outright falsification. For example, on pp. 115-116, Sweeney vividly described Piloting a B-29 pumpkin test flight that went awry with Tom Ferebee acting as bombardier. In a 7/11/98 interview with the author, Ferebee explained the actual Pilot of that test was Stan Shields and that Sweeney was not even in the plane, let alone flying it. During the Saturday afternoon briefing on Tinian, before the Hiroshima mission, the crews were supposed to view movie footage of the Trinity test. Previously published accounts of this briefing have all described, sometimes humorously, how the projector malfunctioned and the footage could not be shown. Still photos were shown instead. At the 1997 509th reunion, those present during the large group question and answer session were asked if anyone remembered seeing this footage. The collective answer was negative, yet in *War's End* (p. 153), Sweeney described viewing this footage during the briefing. Ben Jordan organized Flight Engineer training for the 315th Bomb Wing. He also was Staff Flight Engineer for General Curtis LeMay on Guam. As part of a scathing critique of Sweeney's book supplied to the author, he wrote on 8/9/98 that "Sweeney documents so many of his violations of Air Force Regulations and so much stupidity as to justify his and Tibbets' recall to active duty to face court martial." After publicly holding his tongue since the end of the war, Tibbets' response to Sweeney's book was especially severe. In a 7/11/98 interview with the author, Tom Ferebee told the author Tibbets got through the first 60 pages of the book and was too disgusted to go any further. Ferebee was also present during a car ride in Wendover with Sweeney and Tibbets when "Paul turned around and let him have it" for a full half-hour. Ferebee added, "He just sat there and took it." Partly due to the release of Sweeney's book, Tibbets reissued his autobiography in 1998, adding a new section on the Nagasaki mission. He bluntly criticized both Ashworth's and Sweeney's actions and added that, after *Bockscar's* return to Tinian, he was considering "if any action should be taken against the airplane commander, Charles Sweeney, for failure to command." He added that General LeMay later decided any investigation would serve no useful purpose. Sweeney died on 7/16/04. In a 7/26/04 interview with the author, Tibbets stated that you can never tell in advance how someone will act under fire. When asked, in hindsight, if he would pick Sweeney again for the mission. He snapped, "No! Absolutely not! I should have chosen Marquardt since George was a good Pilot, he had a good crew, he had been shot at, and nobody could BS him." In an 8/14/04 speech at the USAF Museum, Tibbets stated, "That airplane flew around for an hour and a half without anyone commanding it." He added, "I didn't have that much to do with Sweeney [after Nagasaki] because he was the only bad mark on the whole 509th all the time it existed."

327 Personal communication to the author dated 4/12/95.

328 *The Atomic Bomb An Account of British Policy in the Second World War*, John Ehrman, (Cabinet Office, London SW1, 1953).

329 Personal communication to the author dated 11/29/98.

330 *Now It Can Be Told*, p. 344.

331 Personal communication to the author dated 2/1/95. In the 1998 reissue of his autobiography, Tibbets mistakenly claimed the missing plane was the one carrying the instruments and again directly blames Ashworth for the delay. In a personal communication to the author dated 3/4/95, Tibbets charged, "Sweeney's first mistake was wasting time attempting to assemble his element. From this point on 'confusion reigned' in the cockpit. He was listening to Ashworth and consequently gave up 'command' of his plane.

Nobody was really in command until Kuharek made it clear they were critically short of fuel." Ashworth took a lot of criticism over the years from many, including Tibbets, who incorrectly assumed he was the person responsible for the delay at the rendezvous. Ashworth wrote to the author on 11/29/98, "I had absolutely nothing to do with the rendezvous nor the time expended there, Tibbets' comments notwithstanding." In comments made to the author and in his autobiography, Sweeney accepted sole responsibility for the delay and never claimed Ashworth had anything to do with it.

[332] Ferebee interview with the author 7/11/98. He stated he was present when Tibbets told Sweeney to wait no more than 15 minutes and then head on to the primary target; *War's End*, p. 211; In a 4/13/95 interview with the author, Sweeney admitted "When I got back that night, he (Tibbets) said to me, 'Do you remember when I said don't wait more than 15 minutes?' I said, 'Jeez, I do now.' Well, I just forgot about it...I screwed up." He added defensively, "But, that doesn't mean I didn't have every intention, in fact, every knowledge that I was going to deliver that goddamn bomb...I did wait longer than I should have."

[333] "Use of Gadget in Rain or Fog," W. G. Penney, February 6, 1945, LA-217; John Tucker interview with the author on 8/9/95. This is believed to be the first time this story has surfaced in print. When the author asked Ashworth on 8/10/95 if this could have been one of the reasons for the lack of visibility over Kokura, he responded affirmatively. He also added, "if the Japanese really did that, then they were damn clever!" In 1945, onboard radar was still in its infancy and notoriously inaccurate. Because of this the military felt the bombardier needed to see the target clearly through his Norden bombsight crosshairs before he dropped the bomb. In reality, of course, it did not matter that much because of the tremendous destructive radius of the weapon. Dropping the bomb in rain or fog, however, did pose a significant problem. This is because dispersed water droplets will absorb much of the shock wave and thermal output energy of a nuclear weapon within a radius of just a few miles!

[334] Sweeney interviews; Personal communication to the author from Fred Ashworth dated 2/1/95. He discounted Sweeneys' description of flak. "As for all the anti-aircraft fire over Kokura, I don't agree with that at all. I am sure that it was only on the third run into Kokura that we detected any flak and that it was way behind us and below." Others on board were not so nonchalant about the flak. In an interview on 8/4/01, the widow of *Bockscar* navigator James Van Pelt told the author that, because of the flak, "Jim was so frightened he couldn't talk."

[335] Personal communication to the author dated 2/1/95.

[336] *Ibid*. However, in an interview with the author, veteran *Enola Gay* bombardier Tom Ferebee stated that if they could not get it by the second run, then they definitely should have gone on to the secondary at that point. In his 3/4/95 personal communication to the author, Tibbets asserted "At the risk of 'Monday morning quarterbacking' any other airplane commander would have aborted the mission after the first aborted attempt on a bomb run; told Ashworth to shut up; and asked his navigator for a 'heading home'." However, in the 1998 reissue of his autobiography, he changed his mind and wrote he would have broken off after the *second* pass and then proceeded to Nagasaki. He also blames Ashworth for the third run at Kokura. In a speech at Los Alamos on 3/3/04, Ashworth admitted Sweeney should have told him to shut up about the couple of approaches at Kokura. He also stated the reason he was up there talking to Sweeney in the first place was because he felt Sweeney was not thinking of these things himself and should have been. Ashworth stated it was not something that was his responsibility. His responsibility was the bomb. Tibbets insisted the mission should have been scrubbed after the third pass and that the bomb did not have to be dropped. In a 10/16/99 interview with the author, Tibbets stated, "When Sweeney hit the second situation with the bad weather, he should have aborted and gone back, especially if he thought they couldn't get fuel out...There was a failure of communication...I just couldn't understand why Sweeney didn't realize he was the commander of that airplane and he risked peoples lives with what he did!" As it turned out, however, if the second bomb had not been dropped when it was, the entire sequence of events for the end of the war would have been severely affected. News of the Nagasaki attack, just three days after Hiroshima, reached Emperor Hirohito when he was in the middle of a critical meeting with his War Council. History has clearly shown that the timing of this second attack, along with Russia's simultaneous invasion of Manchuria, played the pivotal role in Hirohito's face-saving decision to override his military and bring an immediate end to the war by accepting the exceedingly generous terms of the Potsdam Declaration.

[337] Personal communication to the author dated 11/29/98.

[338] Personal communication to the author dated 1/26/01.

[339] Ashworth interviews with the author on 2/8/95, 7/31/95, and 8/10/95. In separate interviews with the author, both Sweeney and Ashworth each claimed to have made almost the exact same statement. In *War's*

End, p. 217, Sweeney stated, "I'll take full responsibility for this." He then wrote, rather dismissively, that the only reason for even consulting Ashworth was his interest in preserving interservice harmony. In interviews and communications with the author, Ashworth freely acknowledged that as Aircraft Commander, Sweeney was in complete control of the mission. However, as Senior Project Officer on the mission, the final responsibility for the bomb, including where, when, and how it was dropped, was Ashworth's. In his 10/29/97 letter to the editor of Sweeney's book, Ashworth wrote, "Sweeney consulted with me because he knew full well that the question that we were discussing was my responsibility." As proof, Ashworth went on to cite a portion of General Leslie Groves' 1968 book, *Now It Can Be Told*, detailing a June 1945 letter from Air Force Chief of Staff General Lauris Norstad to General Curtis LeMay which clearly and unmistakably defined Ashworth's (and Parsons') authority to "render final judgment in the event that an emergency requires deviation from the tactical plan. (original emphasis)" In the 1998 reissue of his book, it is clear Tibbets still disagreed that this letter gave Ashworth any such authority. One can only speculate as to what imbroglio might have occurred if some event aboard the *Enola Gay* during the Hiroshima mission had forced Parsons to override Tibbets. The author broached this question in an interview with Tibbets on 10/16/99. He bluntly stated, "No, there wouldn't have been [a problem] because I would have aborted and gone back." Undoubtedly prompted by political fallout from the Nagasaki fiasco, Brigadier General T. F. Farrell sought to further clarify the situation in what can best be described as a classic CYA memo written to General Groves over two months *after* the missions on 22 October 1945. This memo pointed out that the subject of command authority had been discussed in conferences between Generals Groves, LeMay, Farrell, and Norstad and in field discussions between General Farrell, Colonel Blanchard (LeMay's staff), Tibbets, Parsons, Ashworth, and Sweeney. It stated "There was agreement between Commodore Parsons and Colonel Tibbets, and similarly between Commander Ashworth and Major Sweeney as to methods of operation....In case of disagreement the [senior] project officer [Parsons/Ashworth] would have final decision. It was recognized that the plane commander did not have sufficient detailed knowledge of the bomb and its operation to render final judgment in these matters." The questionable decision from Washington to place both Army and Navy officers in the same plane surely must have also added to the confusion as to who had ultimate authority. Both Colonel Tibbets (Army) and Captain Parsons (USN) were of equal rank. On the other hand, Ashworth's Commander (USN) rank placed him senior to Major Sweeney (Army). In an 11/29/98 communication to the author, Ashworth disagreed and sought to clarify his role as Senior Officer Specialist. "Let's face it, somebody had to be aboard to monitor the bomb and the [Army] Air Force had no one capable of doing that. Phil Barnes, an army officer, I believe, was the technical advisor to me as to the actual condition of the bomb. It just happened that General Groves selected two naval officers for this duty, Captain Parsons and me. My rank as being above Sweeney's is immaterial since I had no responsibility for the operational aspects of the mission. That was Sweeney's, as far as I am concerned he was the boss, except for the technical aspects of the bomb."

[340] Personal communication to the author dated 4/12/95.

[341] Sweeney interviews.

[342] Olivi interview.

[343] *Now It Can Be Told*, p. 343; According to Groves, Tibbets, Sweeney, and Ashworth, the original AP had been the dock and harbor area close to the city center. The FIELD ORDERS NUMBER 17 (Copy 25 of 32) in the Air Force Historical Archives state "Secondary target: 90.36 NAGASAKI URBAN AREA. (a) Aiming Point: 114061. Reference: XXI BomCom Litho-Mosaic NAGASAKI AREA, MITSUBISHI STEEL and ARMS WORKS, No. 90.36 – 546." Ashworth supplied this copy of the orders to the author. However, there is some reason to believe these orders were faked and the original orders were changed after-the-fact to reflect where the bomb actually exploded. In an 11/29/98 communication to the author, Ashworth wrote, "At the interview at the Smithsonian, I verbally raised the question with Sweeney of the aiming point, and pointed out to him that it was generally accepted that the aiming point was more or less in the center of the city and in the vicinity of the dock area. I told him that the Mission Order now in circulation designated the aiming point as the Mitsubishi Arms and Steel works. His immediate answer was, 'It's a fake'."

[344] The time has been cited differently in numerous sources over the years. The official detonation time is 11:02 AM (Nagasaki Time). This time was cited in "The Yields of the Hiroshima and Nagasaki Nuclear Explosions" (p. 4) and the USSBS, 30 June 1946, "The Effects of Atomic Bombs on Hiroshima and Nagasaki," (p. 8). *Bockscar* radio operator Abe Spitzer claimed in *We Dropped the A-Bomb* (p. 111), "We let go with the bomb at 12:01." This time is also cited by William Laurence in *Dawn Over Zero* (p. 236) and by Chuck Sweeney in *War's End* (p. 218). However, Commander Ashworth's log states, "At 1150 the bomb

was dropped after a twenty second visual bombing run." This could have been a simple error on Ashworth's part since he also stated in his log that they arrived in the Nagasaki target area at 1150. Norman Ramsey later changed the 1150 drop time in Ashworth's log to 1158 in the rough draft of his *History of Project A* (p. 16) that he sent to General T. Farrell on 27 September 1945. The information contained in this rough draft, including the 1158 drop time, was then used by Farrell in his *Report on Overseas Operations – Atomic Bombs* sent to Major General L. R. Groves the same day. The 1158 time remained in the final version of *History of Project A*, *Project Y*, and LAMS-2532. Olivi's diary also cites the 1158 release. The Office of Air Force History book *The Pacific: Matterhorn To Nagasaki, Volume Five,* cites both the 1058 release (p. 720) and an 1101 explosion (p. 724). "The Nagasaki Strike Report" written 10 August 1945 states, "Time Bombs Away First: 090158Z [1158 Tinian Time] Last: 090201Z [1201 Tinian Time]." Since Olivi told the author the times cited by him in his diary where taken directly from Van Pelt's missing flight log, and since Ashworth, Van Pelt, Olivi, Spitzer, and Ashworth's assistant Phil Barnes (possible source for Ashworth's log) were all within a few feet of each other in the extremely cramped rear compartment of the flight deck, it is conceivable the time error occurred when someone must have said it was 1158 at some point in the tension-filled flight deck during the actual drop and this was the time recorded.

345 "The Yields of the Hiroshima and Nagasaki Nuclear Explosions," pp. 4, 8, 9, 10, 33; *Reflections of a Nuclear Weaponeer*, p. 2-28.

346 "Thoughts Concerning the Nagasaki A-Bomb Mission", Kermit K. Beahan, 12 December 1984. At the urging of *Enola Gay* bombardier Tom Ferebee, historian Joseph Papalia, and others, Beahan made this hand written description of the mission six years before his death in 1990. Copy supplied to the author by Fred Olivi.

347 Personal communications to the author dated 8/13/94 and 2/1/95.

348 Ashworth interviews.

349 *Ibid.*

350 Personal communication to the author dated 2/1/95.

351 Ashworth interviews. By "missing" the original target, the casualties were also far less than at Hiroshima. This later proved to be quite beneficial from a public relations point of view when criticism started to mount regarding the high civilian casualty figures in Hiroshima. This also might help explain a possible rationale for faking the orders, if that did indeed take place. During interviews with the author, Sweeney claimed General Spaatz told him that a lot of the top brass breathed easier because they wound up dropping the bomb where they did instead of the original AP. A few days after the mission, gruff, no nonsense, 20th Air Force Commander General Curtis LeMay asked to see Tibbets and Sweeney in his office. In a 3/4/95 letter to the author, Tibbets wrote, "The old man looked at Sweeney and said, 'Chuck, you fucked it up didn't you?' " When asked by the author about this in a 4/13/95 interview, Sweeney explained chuckling, "What he actually said was worse!...He just looked up at me, didn't return my salute. He simply said, 'You missed the target, didn't you!' I said, 'Yes Sir.' He didn't say, 'Won't you sit down and have a cup of coffee.' That was the same as if you had been condemned to death!" Tibbets has always maintained that if a third mission had been necessary, he would have commanded it. Tibbets claimed to the author that LeMay told him he (Tibbets) would fly the next mission because LeMay "didn't want another screw-up like Nagasaki." This statement strikes at the very heart of whether or not LeMay had confidence in any of the other airplane commanders under Tibbets' command and certainly calls into question Tibbets' standards for their training. It calls into question Tibbets' own confidence in those other commanders under his control and certainly his questionable choice of Sweeney for the second mission. It also indicates Tibbets' own authority to make that important decision had been abrogated at that point by LeMay. Sources have told the author the other airplane commanders were not happy back in 1945 when Tibbets announced he would be commanding a third mission, if it was needed.

352 Personal communication to the author dated 4/12/95.

353 Olivi interview.

354 The FIELD ORDERS NUMBER 17 specified a breakaway "Left turn of at least 150 degrees 3137N – 13128E." William Laurence was inside *The Great Artiste* and wrote in *Dawn Over Zero* (p. 236) that they turned in the opposite direction from *Bockscar*. In an 11/2/99 interview with the author, *The Great Artiste* navigator, Len Godfrey, recalled that *Artiste* made a right turn. He stated that he distinctly remembered people looking out the right side of their plane and taking pictures as they circled the mushroom cloud. In a 9/23/00 interview with the author, *The Great Artiste* Pilot Hugh C. Ferguson confirmed that they made a right turn immediately after the instruments were dropped. He also stated that *Bockscar* made a left turn.

[355] Personal communication to the author dated 8/15/99.
[356] Gallagher interviews.
[357] Personal communication to the author dated 1/26/01.
[358] Olivi interview.
[359] *Ibid.*
[360] Gallagher audiotape.
[361] *We Dropped the A-Bomb*, pp. 112-113.
[362] Personal communication to the author dated 4/12/95. This is, of course, after Sweeney made the corrective diving right turn. From his position in the co-Pilot seat, Albury has stated that he could easily see out Sweeney's window during the turn. Gallagher, Olivi, and Spitzer all stated the rising cloud was directly under their plane. In Van Pelt's unpublished 1946 manuscript, he stated, "The airplane was supposed to turn left at a sixty degree bank but it was a much slower forty-five degrees making it unable to clear the danger area specified by the scientists." After describing the mushroom cloud and the five shock waves, he continued, "At the end of our turn, our assistant Flight Engineer, Ray Gallagher, called up informing us the cloud was coming up under us. After describing what it looked like, they decided it was the shock waves."
[363] *Ibid.*
[364] *The Atomic Bomb An Account of British Policy in the Second World War.*
[365] Olivi interview.
[366] *War's End*, Charles Sweeney, video, (Kinsale Enterprises, Malden, MA, 1995).
[367] Sweeney interview with the author 4/13/95.
[368] Olivi interview. Both Olivi (who passed away in 2004) and Van Pelt (who passed away in 1994) have been credited with firing the flares. While seemingly a minor point, it is nonetheless highly important to those anxious to secure their place in history. During a videotaping session on the eve of the 50th anniversary of the mission, it led to a very heated argument as to which one of them actually did it. According to an 9/22/00 author interview with *Bockscar* Pilot Don Albury who was present at the taping, when Van Pelt casually stated that he fired the flares, Olivi exploded in a fit of anger, let loose with a string of expletives, and stormed out of the room saying that "I only did one thing on that flight and now they want to take that away from me!" Since there was only one flare gun and one porthole, it would have been impossible for both to fire them. In an interview with the author on 8/4/01, Van Pelt's widow stated her husband did not have a distinct memory of who fired the flares. She said her husband recalled that he probably just handed the flares for Olivi to shoot. She said, "Jim considered it such a minor thing and not worth all the fuss." The question was perhaps best answered by Spitzer who wrote back in 1946 in his book *We Dropped the A-Bomb* that Sweeney called back to Olivi "Get out the goddamned flares and start shooting them when I give you the signal." Spitzer also wrote in his own diary at the time that "Olivi started shooting off the flares--red, green, and white, any one that was available was shot into the sky." He continued, "Olivi kept sending off those flares." However, this account is contradicted by Van Pelt's unpublished manuscript, which was also written in 1946. In it, Van Pelt states that since Sweeney "couldn't contact the tower, he called back to Spitzer and me to shoot flares." The flare gun was attached to a bracket fixed to the B-29 fuselage about a foot behind and above the navigator's station window. At one point in time, the flare gun (donated by Olivi), as well as other mission artifacts, were on display underneath *Bockscar* in the USAF Museum at Wright-Patterson AFB in Dayton, OH.
[369] Gallagher audio tape.
[370] Personal communication to the author dated 1/26/01.
[371] Olivi interview.
[372] Sweeney interviews.
[373] Gallagher audio tape.
[374] Communication dated 10/29/97 from Frederick L. Ashworth to Stephen Power, Editor, Avon Books.
[375] Personal communication to the author dated 4/11/1995.
[376] National Archives.
[377] *The Smithsonian Institution Management Guidelines For The Future*, p. 6.
[378] Jeppson interview.
[379] *Toyota: Fifty Years in Motion*, Eiji Toyoda, (Kodansha International, NY, 1987), p. 71.
[380] Personal communication from Mort Camac to the author dated 8/11/04.
[381] *Operation Crossroads: The Atomic Tests at Bikini Atoll*, Jonathin Weisgall, (Naval Institute Press, Annapolis, MD, 1994), pp. 180, 185, 264-265; Personal communication to the author from Fred Ashworth

dated 2/1/95. "I clearly remember that there was a pin up of Rita Hayworth taped to the *Fat Man* bomb and the name Gilda painted on it. The majority now claims this had only to do with the CROSSROADS bomb."

[382] Personal communication to the author dated 4/17/95. The B-29 (Silverplate 42-65387) disintegrated in mid-air. Although the bulk of the plane crashed and burned about 62 miles southwest of Kirtland Field in New Mexico, the wreckage was scattered out as far as 16 miles from the main crash site. A number of possible causes were mentioned in the crash reports, but the actual cause will never be known. The last radio transmission was sent shortly after they cleared the Wendover bombing range at 1246 MST (Mountain Standard Time) following a 10,150-lb pumpkin drop and the crash occurred a few minutes later at about 1300 MST. Ten people were killed, including the Pilot Capt. Ralph J. Teetor.

[383] *Operation Crossroads: The Atomic Tests at Bikini Atoll*, pp. 221, 264-265.

[384] December 16, 1986 letter to Paul Filipkowski.

[385] *Operation Crossroads*, Defense Nuclear Agency, DNA 6032F, 1 May 1984, p. 1.

[386] "Nuclear Graveyard," John L. Eliot, June 1992, Vol. 181, No. 6, National Geographic Magazine.

[387] Thornton interviews 5/23/96 and 8/25/96; *The Swords of Armageddon*, VI-77. Actually, only five units were made. According to a 21 August 1945 memo from Birch to Lt. Col. Lockridge and a 10 September 1945 memo from Maj. Franklin Parker to Lt. D.R. Moody (?), *Little Boy* "units L12 and L13 (Batch 5) which were held at 627A, and also units L3, L4, L7, L8, L9, and L10 which have been delivered to Destination [Tinian]" were to be stored temporarily at W-47, and later at Sandia. Since units L1, L2, L5, and L6 were dropped in tests at Tinian and L-11 was used at Hiroshima, this would seem to indicate that there were at least eight (partial or complete) *Little Boy* weapons available in the inventory at the end of the war. Combined with the five produced at Sandia between 1945 and 1950, it would appear that a total of 13 LB units may have been in existence at that time, although some of these might also have been scrapped. As of this writing, five actual *Little Boy* units are on display at various museums. Three LB training units and one drop dummy were found at LANL in 1981. Since one of these training units was ultimately put on display for a time at the Bradbury Museum (replacing a unit that was shipped earlier to the Imperial War Museum in London), and one of the training units was used during the LB Replication project in 1984, it is likely the remaining training unit and drop dummy remain in storage at LANL. In 2004, the author was commissioned by the Historic Wendover Airfield Museum to create an exact replica of the L-11 unit for permanent display at the museum. Before being delivered to Wendover, this steel and fiberglass replica was transported to the 509th reunion in Wichita, Kansas where all of the surviving members signed it, including the three remaining crewmembers of the *Enola Gay* and the widows of Tom Ferebee, Jake Beser, Chaplain William Downey, and the nephew of Fred Olivi.

[388] Personal communication from Thomas Allison at the Smithsonian Institution National Air and Space Museum (NASM) to the author dated 8/24/94.

[389] There is sufficient archival color movie footage taken at Tinian on 8 August 1945 to establish the correct color of the F-31 *Fat Man*. However, *Little Boy* is another matter. The only surviving declassified color footage shows the L-11 combat unit as it was being rolled out of the Tinian assembly building on 5 August 1945. It appeared to have been either very dark blue or dark gunmetal, although the blue was most likely be attributable to a color shift created when the original footage was copied. Efforts by the author, numerous historians, LANL, SNL, and the surviving *Project Alberta* and *Enola Gay* crewmembers over the years to establish the actual color have proven inconclusive. However, new information came forward in 2010 and, based on two original nose plugs removed in 1945 from a LB test unit on Tinian and discovered in storage, a source at LANL states the color is closest to FS 24079, which would be an olive-drab primer.

[390] *The Men Who Bombed Hiroshima*, p. 83.

[391] "Los Alamos Science," No. 7, Winter/Spring 1983, p. 155.

[392] "*Little Boy* Neutron Spectrum Below 1 MEV," A.E. Evans, Los Alamos, Proceedings of the 17th Midyear Topical Symposium of the Health Physics Society, Pasco, WA, February 5-9, 1984, p. 8.30. The Comet Assembly Machine was named for its designer, Jano Haley. It proved so popular that a duplicate machine was constructed. It was called Planet. Both machines were used to test gun-type weapons and components along with any cylindrical critical assemblies. Other critical assembly machines were given such colorful names as Big Ten, Elsie, Flattop, Hydro, Jezebel, Kinglet, Lady Godiva, Little Eva, Sheba, Skua, and Topsy.

[393] *The Swords of Armageddon*, VI-110. Although the DOE admitted in RDD-7, p. 93 (1/1/2001) that only "2 gun-type non-nuclear components" (declassified in 1976) were stockpiled by Fiscal Year 1948, it is abundantly clear from the earlier 26 August 1947 Z-Division Progress Report (LAMS-607), p.48, that materials and components for least 76 and probably as many as 100 LB's were in the process of being

manufactured.

[394] *History of Project A*, Ramsey.

[395] List compiled by Richard Campbell.

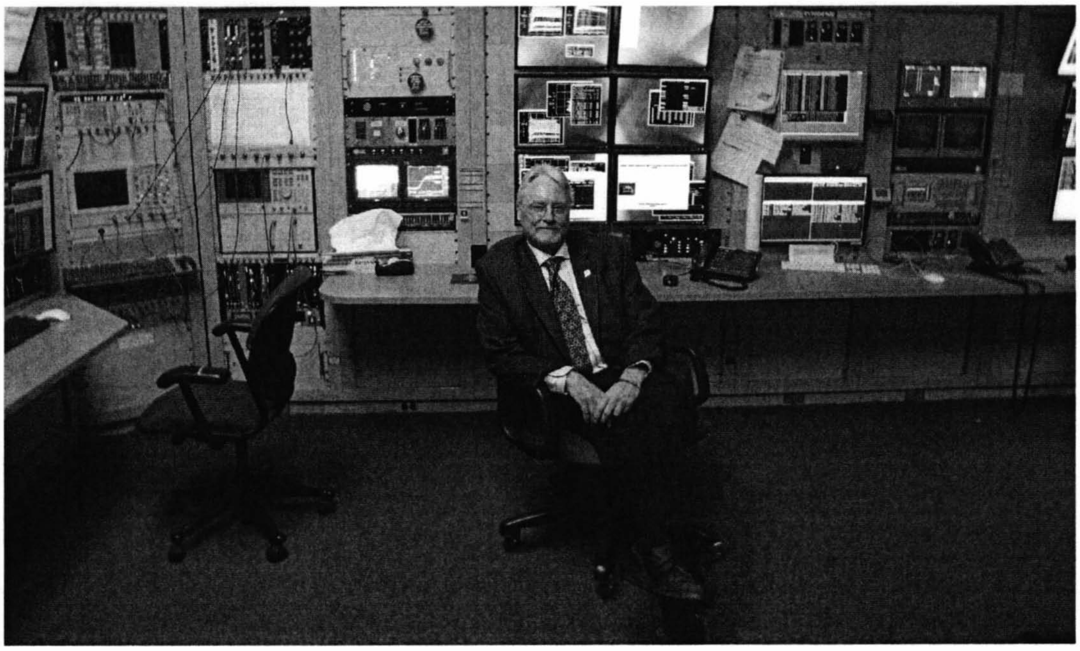
[396] *Ibid.*

[397] Crew lists for all three missions compiled by Robert Krauss. It is safe to say Krauss probably knows more about the 509th than anyone.

[398] Most of the valuable information used to compile this list was graciously provided to the author by Steve Bice who furnished a listing of some of the thousands of items sent to Tinian in the so-called "Bowery" shipments. Bice, whose father Richard A. Bice was one of the key people at Los Alamos during the Manhattan Project and later at Sandia, meticulously hand copied the listing from the declassified NARA Record Group 77, File 17 "Tinian File" originals, which at the time were in the NARA but later withdrawn. "Bowery" shipments were planned shipments by sea, "Bronx" were ad lib shipments by air, and "Red Ball" shipments were planned shipments by air. Sadly, Steve Bice died on 2/12/06.

About the Author

The author is a married father of three who was born after the end of WWII in 1946, the same year as the Crossroads tests. His Chemistry teacher in high school (he was also his assistant) worked at the University of Chicago Metallurgical Laboratory on the development of Plutonium during WWII as part of the Manhattan Project. The author was a Professional Corporate/Advertising Photographer for 30 years, including three years as Chief Photographer for the Trane Air Conditioning Company and spent ten years in charge of an Advertising Photography studio in Milwaukee. This allowed him to see first-hand the entire process of how things were made, from concept, to prototype, to finished product, then to the use of that product to make other things. This gave him a very unique perspective into exactly how these weapons were made. He has lectured around the world including places like Los Alamos, University of Chicago Enrico Fermi Institute, Fermilab, and on Tinian. In 2001 the surviving veterans of the 509th Composite Group (The Atomic Bombers) voted to make him a Permanent Honorary Members of their most prestigious of WWII aircrews. In 2008 he was the subject of a major Cover Story in The New Yorker magazine. He coined the term "Nuclear Archeology" to describe his efforts at retrieving this most important information at sites around the World. He received numerous state and national awards, including a Graphic Design USA DESI Award, and served on the editorial board of Industrial Photography magazine, the Board of Directors of the Chicago Chapter of the ASMP (American Society of Magazine Photographers), and as Vice President of the APM (Advertising Photographers of Milwaukee).



Seated at the controls of Fermilab's Tevatron in 2011.