= Fat Man =

" Fat Man " was the codename for the type of atomic bomb that was detonated over the Japanese city of Nagasaki by the United States on 9 August 1945 . It was the second of the only two nuclear weapons ever used in warfare , the first being Little Boy , and its detonation marked the third @-@ ever man @-@ made nuclear explosion in history . It was built by scientists and engineers at Los Alamos Laboratory using plutonium from the Hanford Site and dropped from the Boeing B @-@ 29 Superfortress Bockscar . For the Fat Man mission , Bockscar was piloted by Major Charles W. Sweeney .

The name Fat Man refers generically to the early design of the bomb , because it had a wide , round shape . It was also known as the Mark III . Fat Man was an implosion @-@ type nuclear weapon with a solid plutonium core . The first of that type to be detonated was the Gadget , in the Trinity nuclear test , less than a month earlier on 16 July at the Alamogordo Bombing and Gunnery Range in New Mexico .

Two more Fat Man bombs were detonated during the Operation Crossroads nuclear tests at Bikini Atoll in 1946 . Some 120 Fat Man units were produced between 1947 and 1949 , when it was superseded by the Mark 4 nuclear bomb . The Fat Man was retired in 1950 .

= = Early decisions = =

In 1942 , prior to the Army taking over wartime atomic research , Robert Oppenheimer held conferences in Chicago in June and Berkeley , California , in July , at which various engineers and physicists discussed nuclear bomb design issues . A gun @-@ type design was chosen , in which two sub @-@ critical masses would be brought together by firing a " bullet " into a " target " . Richard C. Tolman suggested an implosion @-@ type nuclear weapon , but the idea attracted scant consideration .

The feasibility of a plutonium bomb was questioned in 1942 . James Conant heard on 14 November from Wallace Akers , the director of the British " Tube Alloys " project , that James Chadwick had " concluded that plutonium might not be a practical fissionable material for weapons because of impurities . " Conant consulted Ernest Lawrence and Arthur Compton , who acknowledged that their scientists at Berkeley and Chicago respectively knew about the problem , but could offer no ready solution . Conant informed the director of the Manhattan Project , Brigadier General Leslie R. Groves , Jr . , who in turn assembled a special committee consisting of Lawrence , Compton , Oppenheimer , and McMillan to examine the issue . The committee concluded that any problems could be overcome simply by requiring higher purity .

Oppenheimer , reviewing his options in early 1943 , gave priority to the gun @-@ type weapon , but as a hedge against the threat of pre @-@ detonation , he created the E @-@ 5 Group at the Los Alamos Laboratory under Seth Neddermeyer to investigate implosion . Implosion @-@ type bombs were determined to be significantly more efficient in terms of explosive yield per unit mass of fissile material in the bomb , because compressed fissile materials react more rapidly and therefore more completely . Nonetheless , it was decided that the plutonium gun would receive the bulk of the research effort , since it was the project with the least amount of uncertainty involved . It was assumed that the uranium gun @-@ type bomb could be easily adapted from it .

= = Naming = =

The gun @-@ type and implosion @-@ type designs were codenamed " Thin Man " and " Fat Man " respectively . These code names were created by Robert Serber , a former student of Oppenheimer 's who worked on the Manhattan Project . He chose them based on their design shapes ; the Thin Man would be a very long device , and the name came from the Dashiell Hammett detective novel The Thin Man and series of movies by the same name ; the Fat Man would be round and fat and was named after Sydney Greenstreet 's character in The Maltese Falcon . Little Boy would come last , as a variation of Thin Man .

= = Development = =

Neddermeyer discarded Serber and Tolman 's initial concept of implosion as assembling a series of pieces in favor of one in which a hollow sphere was imploded by an explosive shell . He was assisted in this work by Hugh Bradner , Charles Critchfield , and John Streib . L. T. E. Thompson was brought in as a consultant , and discussed the problem with Neddermeyer in June 1943 . Thompson was skeptical that an implosion could be made sufficiently symmetric . Oppenheimer arranged for Neddermeyer and Edwin McMillan to visit the National Defense Research Committee 's Explosives Research Laboratory near the laboratories of the Bureau of Mines in Bruceton , Pennsylvania (a Pittsburgh suburb) , where they spoke to George Kistiakowsky and his team . But Neddermeyer 's efforts in July and August at imploding tubes to produce cylinders tended to produce objects that resembled rocks . Neddermeyer was the only person who believed that implosion was practical , and only his enthusiasm kept the project alive .

Oppenheimer brought John von Neumann to Los Alamos in September 1943 to take a fresh look at implosion . After reviewing Neddermeyer 's studies , and discussing the matter with Edward Teller , von Neumann suggested the use of high explosives in shaped charges to implode a sphere , which he showed could not only result in a faster assembly of fissile material than was possible with the gun method , but which could greatly reduce the amount of material required , because of the resulting higher density . The idea that , under such pressures , the plutonium metal itself would be compressed came from Teller , whose knowledge of how dense metals behaved under heavy pressure was influenced by his pre @-@ war theoretical studies of the Earth 's core with George Gamow . The prospect of more @-@ efficient nuclear weapons impressed Oppenheimer , Teller , and Hans Bethe , but they decided that an expert on explosives would be required . Kistiakowsky 's name was immediately suggested , and Kistiakowsky was brought into the project as a consultant in October 1943 .

The implosion project remained a backup until April 1944 , when experiments by Emilio G. Segrè and his P @-@ 5 Group at Los Alamos on the newly reactor @-@ produced plutonium from the X @-@ 10 Graphite Reactor at Oak Ridge and the B Reactor at the Hanford site showed that it contained impurities in the form of the isotope plutonium @-@ 240 . This has a far higher spontaneous fission rate and radioactivity than plutonium @-@ 239 . The cyclotron @-@ produced isotopes , on which the original measurements had been made , held much lower traces of plutonium @-@ 240 . Its inclusion in reactor @-@ bred plutonium appeared unavoidable . This meant that the spontaneous fission rate of the reactor plutonium was so high that it would be highly likely that it would predetonate and blow itself apart during the initial formation of a critical mass . The distance required to accelerate the plutonium to speeds where predetonation would be less likely would need a gun barrel too long for any existing or planned bomber . The only way to use plutonium in a workable bomb was therefore implosion .

The impracticability of a gun @-@ type bomb using plutonium was agreed at a meeting in Los Alamos on 17 July 1944 . All gun @-@ type work in the Manhattan Project was directed at the Little Boy , enriched @-@ uranium gun design , and the Los Alamos Laboratory was reorganized , with almost all of the research oriented around the problems of implosion for the Fat Man bomb . The idea of using shaped charges as three @-@ dimensional explosive lenses came from James L. Tuck , and was developed by von Neumann . To overcome the difficulty of synchronizing multiple detonations , Luis Alvarez and Lawrence Johnston invented exploding @-@ bridgewire detonators to replace the less precise primacord detonation system . Robert Christy is credited with doing the calculations that showed how a solid subcritical sphere of plutonium could be compressed to a critical state , greatly simplifying the task , since earlier efforts had attempted the more @-@ difficult compression of a hollow spherical shell . After Christy 's report , the solid @-@ plutonium core weapon was referred to as the " Christy Gadget " .

The task of the metallurgists was to determine how to cast plutonium into a sphere . The difficulties became apparent when attempts to measure the density of plutonium gave inconsistent results . At first contamination was believed to be the cause , but it was soon determined that there were

multiple allotropes of plutonium . The brittle ? phase that exists at room temperature changes to the plastic ? phase at higher temperatures . Attention then shifted to the even more malleable ? phase that normally exists in the 300 ? 450 ° C (570 ? 840 ° F) range . It was found that this was stable at room temperature when alloyed with aluminum , but aluminum emits neutrons when bombarded with alpha particles , which would exacerbate the pre @-@ ignition problem . The metallurgists then hit upon a plutonium ? gallium alloy , which stabilized the ? phase and could be hot pressed into the desired spherical shape . As plutonium was found to corrode readily , the sphere was coated with nickel .

The size of the bomb was constrained by the available aircraft . The only Allied aircraft capable of carrying the Fat Man were the British Avro Lancaster and the American Boeing B @-@ 29 Superfortress . For logistic and nationalistic reasons , the B @-@ 29 was preferred , but this constrained the bomb to a maximum length of 132 inches (3 @,@ 400 mm) , width of 60 inches (1 @,@ 500 mm) and weight of 20 @,@ 000 pounds (9 @,@ 100 kg) . Removing the bomb rails allowed a maximum width of 66 inches (1 @,@ 700 mm) . Drop tests began in March 1944 , and resulted in modifications to the Silverplate aircraft due to the weight of the bomb . High @-@ speed photographs revealed that the tail fins folded under the pressure , resulting in an erratic descent . Various combinations of stabilizer boxes and fins were tested on the Fat Man shape to eliminate its persistent wobble until an arrangement dubbed a " California Parachute " , a cubical open @-@ rear tail box outer surface with eight radial fins inside of it , four angled at 45 ° and four orthogonally to the line of fall holding the outer square @-@ fin box to the bomb 's rear end , was approved . In drop tests in early weeks , the Fat Man missed its target by an average of 1 @,@ 857 feet (566 m) , but this was halved by June as the bombardiers became more proficient with it .

The early Y @-@ 1222 model Fat Man was assembled with some 1 @,@ 500 bolts . This was superseded by the Y @-@ 1291 design in December 1944 . This redesign work was substantial , and only the Y @-@ 1222 tail design was retained . Later versions included the Y @-@ 1560 , which had 72 detonators ; the Y @-@ 1561 , which had 32 ; and the Y @-@ 1562 , which had 132 . There were also the Y @-@ 1563 and Y @-@ 1564 , which were practice bombs with no detonators at all . The final wartime Y @-@ 1561 design was assembled with just 90 bolts .

Because of its complicated firing mechanism and the need for previously untested synchronization of explosives and precision design , it was thought that a full test of the concept was needed before the scientists and military representatives could be confident it would perform correctly under combat conditions . On 16 July 1945 , a Y @-@ 1561 model Fat Man , known as the Gadget for security reasons , was detonated in a test explosion at a remote site in New Mexico , known as the " Trinity " test . It gave a yield of about 20 kilotonnes (84 TJ) . Some minor changes were made to the design as a result of the Trinity test . Philip Morrison recalled that " There were some changes of importance ... The fundamental thing was , of course , very much the same . "

= = Bomb interior = =

The bomb was 128 inches (3 @,@ 300 mm) long and 60 inches (1 @,@ 500 mm) in diameter . It weighed 10 @,@ 300 pounds (4 @,@ 700 kg) .

= = Assembly = =

To allow insertion of the 3 @.@ 62 @-@ inch (92 mm) diameter plutonium pit , containing the 0 @.@ 8 @-@ inch (20 mm) diameter " Urchin " modulated neutron initiator , as late as possible in the device 's assembly , the spherical 8 @.@ 75 @-@ inch (222 mm) diameter depleted uranium tamper surrounded by a 0 @.@ 125 @-@ inch (3 @.@ 2 mm) thick shell of boron impregnated plastic had a 5 @-@ inch (130 mm) diameter cylindrical hole running through it , like the hole in a cored apple . The missing tamper cylinder , containing the pit , could be slipped in through a hole in the surrounding 18 @.@ 5 @-@ inch (470 mm) diameter aluminium pusher . The pit was warm to touch , emitting 2 @.@ 4 W / kg @-@ Pu , about 15 W for the 6 @.@ 19 kilograms (13 @.@ 6 lb) core .

The plutonium was compressed to twice its normal density before the " Urchin " added free neutrons to initiate a fission chain reaction .

The result was the fission of about 1 kilogram (2 @.@ 2 lb) of the 6 @.@ 19 kilograms (13 @.@ 6 lb) of plutonium in the pit , i.e. of about 17 % of the fissile material present . 1 gram (0 @.@ 035 oz) of matter in the bomb is converted into the active energy of heat and radiation , releasing the energy equivalent to the detonation of 21 kilotons of TNT or 88 terajoules .

= = Bombing of Nagasaki = =

The first plutonium core , along with its polonium @-@ beryllium Urchin initiator , was transported in the custody of Project Alberta courier Raemer Schreiber in a magnesium @-@ field carrying @-@ case designed for the purpose by Philip Morrison . Magnesium was chosen because it does not act as a tamper . The core departed from Kirtland Army Air Field on a C @-@ 54 transport aircraft of the 509th Composite Group 's 320th Troop Carrier Squadron on 26 July , and arrived at North Field on Tinian on 28 July . Three Fat Man high @-@ explosive pre @-@ assemblies , designated F31 , F32 , and F33 , were picked up at Kirtland on 28 July by three B @-@ 29s ; two , Luke the Spook and Laggin ' Dragon , from the 509th Composite Group 's 393d Bombardment Squadron plus one from the 216th AAF Base Unit , and transported to North Field , arriving on 2 August . Upon arrival , F31 was partly disassembled in order to check all its components . F33 was expended near Tinian during a final rehearsal on 8 August , and F31 was the bomb dropped on Nagasaki . F32 presumably would have been used for a third attack or its rehearsal .

In August 1945 , the Fat Man was assembled on Tinian by Project Alberta personnel . When the physics package was fully assembled and wired , it was placed inside its ellipsoidal aerodynamic bombshell and wheeled out , where it was signed by nearly 60 people , including Rear Admiral William R. Purnell , Brigadier General Thomas F. Farrell and Captain William S. Parsons . It was then wheeled to the bomb bay of the B @-@ 29 Superfortress named Bockscar after its normally assigned command pilot , Captain Frederick C. Bock , who flew The Great Artiste with his crew on the mission . Bockscar was flown by Major Charles W. Sweeney and his crew , with Commander Frederick L. Ashworth from Project Alberta as the weaponeer in charge of the bomb .

Bockscar lifted off at 03 : 47 on the morning of 9 August 1945 , with Kokura as the primary target and Nagasaki the secondary target . The weapon was already armed , but with the green electrical safety plugs still engaged . Ashworth changed them to red after ten minutes so that Sweeney could climb to 17 @,@ 000 feet (5 @,@ 200 m) in order to get above storm clouds . During pre @-@ flight inspection of Bockscar , the flight engineer notified Sweeney that an inoperative fuel transfer pump made it impossible to use 640 US gallons (2 @,@ 400 l) of fuel carried in a reserve tank . This fuel would still have to be carried all the way to Japan and back , consuming still more fuel . Replacing the pump would take hours ; moving the Fat Man to another aircraft might take just as long and was dangerous as well , as the bomb was live . 509th Composite Group Commander Colonel Paul Tibbets and Sweeney therefore elected to have Bockscar continue the mission .

The original target for the bomb was the city of Kokura , but it was found to be obscured by clouds and drifting smoke from fires started by a major firebombing raid by 224 B @-@ 29s on nearby Yawata the previous day . This covered 70 % of the area over Kokura , obscuring the aiming point . Three bomb runs were made over the next 50 minutes , burning fuel and repeatedly exposing the aircraft to the heavy defenses of Yawata , but the bombardier was unable to drop visually . By the time of the third bomb run , Japanese anti @-@ aircraft fire was getting close , and Second Lieutenant Jacob Beser , who was monitoring Japanese communications , reported activity on the Japanese fighter direction radio bands .

Sweeney then proceeded to the alternative target , Nagasaki . It too was obscured by cloud , and Ashworth ordered Sweeney to make a radar approach . At the last minute , the bombardier , Captain Kermit K. Beahan , found a hole in the clouds . The Fat Man was dropped and , following a 43 @-@ second duration free fall , it exploded at 11 : 02 local time , at an altitude of about 1 @,@ 650 feet (500 m) . Because of poor visibility due to cloud cover , the bomb missed its intended detonation point by almost two miles , and damage was somewhat less extensive than that in

Hiroshima .

An estimated 35 @,@ 000 ? 40 @,@ 000 people were killed outright by the bombing at Nagasaki . A total of 60 @,@ 000 ? 80 @,@ 000 fatalities resulted , including from long @-@ term health effects , the strongest of which was leukemia , with an attributable risk of 46 % for bomb victims . Others died later from related blast and burn injuries , and hundreds more from radiation illnesses from exposure to the bomb 's initial radiation . Most of the direct deaths and injuries sustained from the bombing were munitions or industrial workers . Mitsubishi 's industrial production in the city were also severed by the attack ; the dockyard would have produced at 80 percent of its full capacity within three to four months , the steel works would have required a year to get back to substantial production , the electric works would have resumed some production within two months and been back at capacity within six months , and the restoration of the arms plant to 60 to 70 percent of former capacity would have required 15 months . The Mitsubishi @-@ Urakami Ordnance Works , the factory that manufactured the type 91 torpedoes released in the attack on Pearl Harbor , was destroyed in the blast .

= = Post @-@ war development = =

After the war , two Y @-@ 1561 Fat Man bombs were used in the Operation " Crossroads " nuclear tests at Bikini Atoll in the Pacific . The first , known as Gilda after Rita Hayworth 's character in the 1946 movie of the same name , was dropped by the B @-@ 29 Dave 's Dream . The bomb missed its aim point by 710 yards (650 m) . The second bomb , nicknamed Helen of Bikini , was placed , without its tail fin assembly , in a steel caisson made from a submarine 's conning tower , and detonated 90 feet (27 m) beneath the landing craft LSM @-@ 60 . The two weapons yielded about 23 kilotonnes (96 TJ) each .

The Los Alamos Laboratory and the Army Air Forces had already commenced work on improving the design . The North American B @-@ 45 Tornado , Convair XB @-@ 46 , Martin XB @-@ 48 , and Boeing B @-@ 47 Stratojet bombers , then on the drawing boards , had bomb bays sized to carry the Grand Slam , which was much longer but not as wide as the Fat Man . The only bombers that could carry the Fat Man were the B @-@ 29 and the Convair B @-@ 36 . In November 1945 , the Army Air Forces asked Los Alamos for 200 Fat Man bombs . At the time there were only two sets of plutonium cores and high @-@ explosive assemblies . The Army Air Forces wanted improvements to the design to make it easier to manufacture , assemble , handle , transport , and stockpile . The wartime Project W @-@ 47 was continued , and drop tests resumed in January 1946 .

The Mark III Mod 0 Fat Man was ordered to be put into production in mid @-@ 1946 . High explosives were manufactured by the Salt Wells Pilot Plant , which had been established by the Manhattan Project as part of Project Camel . A new plant was established at the Iowa Army Ordnance Plant . Mechanical components were made or procured by the Rock Island Arsenal . Electrical and mechanical components for about 50 bombs were stockpiled at Kirtland Army Air Field by August 1946 , but only nine plutonium cores were available . Production of the Mod 0 ended in December 1948 , by which time there were still only 53 cores available . It was replaced by improved versions , known as Mods 1 and 2 , which contained a number of minor changes , the most important of which was that they did not charge the X @-@ Unit firing system 's capacitors until released from the aircraft . The Mod 0s were withdrawn from service between March and July 1949 , and by October they had all been rebuilt as Mods 1 and 2 . Some 120 Mark III Fat Man units were added to the stockpile between 1947 and 1949 , when it was superseded by the Mark 4 nuclear bomb . The Mark III Fat Man was retired in 1950 .

Due to the limitations of the Mark III Fat Man , a nuclear strike would have been a formidable undertaking in the 1940s . The lead @-@ acid batteries that powered the fuzing system remained charged for only 36 hours , after which they needed to be recharged . To do this meant disassembling the bomb , and recharging took 72 hours . The batteries had to be removed in any case after nine days or they corroded . The plutonium core could not be left in for much longer , because its heat damaged the high explosives . Replacing the core also required the bomb to be

completely disassembled and reassembled . This required about 40 to 50 men and took between 56 and 72 hours , depending on the skill of the bomb assembly team , and in June 1948 the Armed Forces Special Weapons Project had only three teams . The only aircraft capable of carrying the bomb were Silverplate B @-@ 29s , and the only group equipped with them was the 509th Bombardment Group at Walker Air Force Base in Roswell , New Mexico . They would first have to fly to Sandia Base to collect the bombs , and then to an overseas base from which a strike could be mounted .

As much of the Manhattan Project data leaked by the spies Klaus Fuchs , Theodore Hall , and David Greenglass to the Soviet Union concerned Fat Man , the Soviet Union 's first nuclear weapon , designated " Joe @-@ 1 " by the United States , was based closely on Fat Man 's design . " Joe 1 " was detonated on 29 August 1949 as part of Operation " First Lightning " .