World, The; *The World Book* 2010 'M' section Chicago

Manhattan Project

It was created in 1942 by the United States governments to produce the first atom bomb. The official agency that produced the bomb was the Corps of Engineers' Manhattan Engineer District led by Major General Leslie R. Groves. The American physicist J, Robert Oppenheimer directed the design and building of the bomb. Industrial and research activities took place at such sites as Los Alamos, New Mexico; Oak Ridge, Tennessee; and Hanford, Washington. The idea for the project began in 1939, shortly before WWII began. United States scientists feared Germany might be the first country to develop an atomic bomb. They alerted President Franklin D. Roosevelt to this possibility. Manhattan Project scientists successfully exploded the first atomic bomb on July 16, 1945, near Alamogardo, New Mexico.

Pearl harbor in December 7 1941

Enrico Fermi in 1941 bombards neutrons into stable atoms producing radioactive elements. At the time he had thought that he had produced new elements. In reality however, it was shown that what he had actually done was split the atom. Later discovered by Otto Frisch and Lise Meitner found that once uranium is bombarded with neutrons, producing lighter elements of barium and krypton. Soon after in January 1939, Fermi attended a theoretical physics conference where he suggested that once fission neutrons may also be emitted. This meant that once an element was split, a chain reaction could be produced, neutrons from original element can react with element producing more neutrons etc, and with each reaction, more and more energy can be released. At the time many scientist doubted this saying that it was impossible, a Hungarian physicist Leo Szilard applied the patent for the atomic bomb. This was in 1934, He migrated to the US in 1938 since he was Jewish, in 1938 when he discovered about fission, he was eager to convince the US about the potentials of fission reaction. However since Szilard was a very little known physicist, so he asked Albert Einstein to write a letter to FDR. The letter also stated to the US that the scientist had started to believe that the Germans had started stockpiling uranium from Czech mines, which it had taken over. Letters continued to write letters in 1940, on the 6th of December 1941, he was eventually being able to convince the president to dedicate funding to the project, the day after, Pearl Harbor was attacked, the plan quickly rose in importance. At the start of the atomic race, Fermi and Szilard had been assigned to build the first nuclear reactor, They had to achieve a controlled chain reaction – they had to split an atom without creating an explosion. They tested at the University of Chicago in a relatively basic reactor. The risk was great, failure meant half of Chicago would explode. The experiment was a success and the scientist were able to achieve critical mass, meaning that the uranium had reached a point where it could self sustain the reaction. The success was quickly sent to Washington DC

TOP SECRET: MANHATTAN PROJECT

August 1942, the Manhattan Engineer District was formed to oversee the construction of the nuclear bomb. That is also where the origins of the Manhattan Project name come from. In September, General Leslie, R Groves was put in charge. Groves and many others believed the Germans were also working on a bomb. There was the idea of whoever first succeeded would win the conflict.

What was not known was that that the Nazi officials were never aware of the potential of such a bomb.

Groves appointed Oppenheimer as Scientific director of the Project. Oppenheimer suggested after recalling an area from a school camp, that there was an area in New Mexico prime for the experimentation. The government bought the land and Los Alamos, New Mexico was the site of the main lab and where the bomb was designed and constructed.

Oak Ridge, Tennessee was also used, where a reactor was built to produce and refine large quantities of uranium. 3 reactors were also built in Hanford Washington. These were used to produce Plutonium. Each site was its own city, with houses for workers, bus systems, grocery stores and everything else need by the workers. This was done to ensure little of the project got into the public.

A location was had but now, another challenge was faced: producing enough U235. The highly rare isotope of uranium only makes up around 1% of uranium ore while the other 99% is uranium 238. However 238 is not capable of fission since it cannot sustain a chain reaction. Oppenheimer was faced with 2 issues, separating the isotopes and also obtaining enough.

One method suggested was a cyclotron. The cyclotron consisted of a magnet. The isotopes were spun at high speed and the lighter 235 isotope would stay closer to the magnet, and then collected while the 238 atom would spin further away and not be captured. It was a tedious process; the magnets had to be constantly cleaned from dirt. This delayed progress. Delays which the project did not have. After spending millions of $s, the Berkeley team produced a miserly 1 gram or so of 235.

The second method, was gas diffusion, white used a membrane as a diffusion barrier to separate the two isotopes. The equipment was built at Oak Ridge. The lighter 235 isotope would pass through more quickly through the membrane and the 238 remained behind.

Meanwhile, a team in UoC Berkeley was studying the effects of Plutonium which also had an unstable, fissionable isotope 239. Plutonium was only discovered one year earlier.

What was also more interesting was that Seaborg discovered that U238 was able to gain more neutrons to become the fissionable P239. The fuels were found, now the issue was the design.

DESIGN

Since there were 2 potential fuels, 2 potential designs were developed. The U235 bomb was nicknamed Little Boy, the P bomb Fat Man, interestingly named after Winston Churchill. Little Boy worked by shooting an amount of U235 towards another amount of 235 so it created a critical mass capable of reaction. Fat Man worked upon implosion of P239. The isotope was surrounded by conventional explosive, imploding, causing nuclear reaction.

By July 1945, around 2500 scientist inhabited Los Alamos, FBI were stationed to make sure no one left or entered. Despite the seriousness of the project, the scientists were generally light hearted. Physicist Victor Weisskopf stated, ‘It was so amazing because everybody was there. WE all sort of lived in an excited state. Melvin Brooks said, “WE knew what the objective was. WE knew what it was going to be used for. There was never a question.”

Arthur Wahl a chemist stated, “We did not sit around discussing the ethics of the bomb. We wanted to make it. I think it was the right thing. Knowing what I know now, I’d do the same thing. Many scientists were formerly Europeans who escaped the Nazis and were intent on helping the allies.

http://science.howstuffworks.com/nuclear-power1.htm

Nuclear Fission

Uranium is a common element on Earth and has existed since the planet formed. While there are several varieties of uranium, uranium-235 (U-235) is the one most important to the production of both nuclear power and nuclear bombs.

U-235 decays naturally by alpha radiation: It throws off an alpha particle, or two neutrons and two protons bound together. It's also one of the few elements that can undergo induced fission. Fire a free neutron into a U-235 nucleus and the nucleus will absorb the neutron, become unstable and split immediately. See How Nuclear Radiation Works for complete details.

The decay of a single U-235 atom releases approximately 200 MeV (million electron volts). That may not seem like much, but there are lots of uranium atoms in a pound (0.45 kilograms) of uranium. So many, in fact, that a pound of highly enriched uranium as used to power a nuclear submarine is equal to about a million gallons of gasoline.

The splitting of an atom releases an incredible amount of heat and gamma radiation, or radiation made of high-energy photons. The two atoms that result from the fission later release beta radiation (superfast electrons) and gamma radiation of their own, too.

But for all of this to work, scientists have to first enrich a sample of uranium so that it contains 2 to 3 percent more U-235. Three-percent enrichment is sufficient for nuclear power plants, but weapons-grade uranium is composed of at least 90 percent U-235.

http://en.wikipedia.org/wiki/Manhattan_Project

The Manhattan Project was a research and development program by the United States with the United Kingdom and Canada that produced the first atomic bomb during World War II. From 1942 to 1946, the project was under the direction of Major General Leslie Groves of the US Army Corps of Engineers.

About 50 kilograms of uranium enriched to 89% uranium-235 was delivered to Los Alamos by July 1945. This was used to create a gun-type fission weapon. It worked by mechanically assembling a critical mass from two subcritical masses of uranium-235: a "bullet" and a "target". When they collided, a polonium-beryllium modulated neutron initiator would produce a burst of neutrons, which would initiate a chain reaction in the uranium-235.

The development effort on the gun-type device was carried out at Los Alamos by Parsons' O Division. Lieutenant Commander A. Francis Birch's group completed the design, which became Little Boy, in February 1945. There was no enriched uranium available for a test. Little Boy used up all the 89% enriched uranium-235, along with some 50% enriched, averaging out to about 85% enriched. The gun-type method was considered so certain to work that no test was considered necessary, although an extensive laboratory testing program was undertaken to make sure the fundamental assumptions were correct.

Weapon design

In 1943, development efforts were directed to a gun-type fission weapon with plutonium called Thin Man. Initial research on the properties of plutonium was done using cyclotron-generated plutonium-239, which was extremely pure, but could only be created in very small amounts. Los Alamos received the first sample of plutonium from the Clinton X-10 reactor in April 1944 and within days Emilio Segrè discovered a problem: the reactor-bred plutonium had a higher concentration of plutonium-240, resulting in up to five times the spontaneous fission rate of cyclotron plutonium. Seaborg had correctly predicted in March 1943 that some of the plutonium-239 would absorb a neutron and become plutonium-240.

This made reactor plutonium unsuitable for use in a gun-type weapon. The plutonium-240 would start the chain reaction too quickly, causing a predetonation that would release enough energy to disperse the critical mass with a minimal amount of plutonium reacted (a fizzle). A faster gun was suggested but found to be impractical. The possibility of separating the isotopes was considered and rejected, as plutonium-240 is even harder to separate from plutonium-239 than uranium-235 from uranium-238.

Work on an alternative method of bomb design, known as implosion, had begun earlier at the instigation of the physicist Seth Neddermeyer. Implosion used explosives to crush a subcritical sphere of fissile material into a smaller and denser form. When the fissile atoms are packed closer together, the rate of neutron capture increases, and the mass becomes a critical mass In September 1943, John von Neumann, who had experience with shaped charges used in armor-piercing shells, argued that not only would implosion reduce the danger of predetonation and fizzle, but would make more efficient use of the fissionable material. He proposed using a spherical configuration instead of the cylindrical one that Neddermeyer was working on.

By July 1944, Oppenheimer had concluded plutonium could not be used in a gun design, and opted for implosion. The accelerated effort on an implosion design, codenamed Fat Man, began in August 1944 when Oppenheimer implemented a sweeping reorganization of the Los Alamos laboratory to focus on implosion. The final design resembled a soccer ball, with 20 hexagonal and 12 pentagonal lenses, each weighing about 80 pounds (36 kg).

The ultimate 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 α phase that exists at room temperature changes to the plastic β phase at higher temperatures. Attention then shifted to the even more malleable δ phase that normally exists in the 300 °C to 450 °C 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 δ 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 work proved dangerous. By the end of the war, half the experienced chemists and metallurgists had to be removed from work with plutonium when unacceptably high levels of the element appeared in their urine. A minor fire at Los Alamos in January 1945 led to a fear that a fire in the plutonium laboratory might contaminate the whole town, and Groves authorized the construction of a new facility for plutonium chemistry and metallurgy, which became known as the DP-site. The hemispheres for the first plutonium pit (or core) were produced and delivered on 2 July 1945. Three more hemispheres followed on 23 July and were delivered three days later.

In June 1944, the Manhattan Project employed some 129,000 workers, of whom 84,500 were construction workers, 40,500 were plant operators and 1,800 were military personnel. As construction activity fell off, the workforce declined to 100,000 a year later, but the number of military personnel increased to 5,600. Procuring the required numbers of workers, especially highly skilled workers, in competition with other vital wartime programs proved very difficult. In 1943, Groves obtained a special temporary priority for labor from the War Manpower Commission. In March 1944, both the War Production Board and the War Manpower Commission gave the project their highest priority.

Trinity was the code name of the first detonation of a nuclear device. This test was conducted by the United States Army on July 16, 1945, in the Jornada del Muerto desert about 35 miles (56 km) southeast of Socorro, New Mexico, at the new White Sands Proving Ground, which incorporated the Alamogordo Bombing and Gunnery Range. (The site is now the White Sands Missile Range.). The date of the test is usually considered to be the beginning of the Atomic Age.

Trinity was a test of an implosion-design plutonium device. The weapon's informal nickname was "The Gadget". Using the same conceptual design, the Fat Man device was detonated over Nagasaki, Japan, on August 9, 1945. The Trinity detonation produced the explosive power of about 20 kilotons of TNT.

At 4:45 a.m., a crucial weather report came in favorably, and, at 5:10 a.m., the twenty-minute countdown began. Most top-level scientists and military officers were observing from a base camp 16 km southwest of the test tower. Many other observers were around 32 km away, and some others were scattered at different distances, some in more informal situations (physicist Richard Feynman claimed to be the only person to see the explosion without the dark glasses provided, relying on a truck windshield to screen out harmful ultraviolet wavelengths). The final countdown was read by physicist Samuel K. Allison.

At 05:29:45 local time (Mountain War Time), the device exploded with an energy equivalent to around 20 kilotons of TNT (90 TJ). It left a crater of radioactive glass in the desert 10 feet (3 m) deep and 1,100 feet (330 m) wide. At the time of detonation, the surrounding mountains were illuminated "brighter than daytime" for one to two seconds, and the heat was reported as "being as hot as an oven" at the base camp. The observed colors of the illumination ranged from purple to green and eventually to white. The roar of the shock wave took 40 seconds to reach the observers. The shock wave was felt over 100 miles (160 km) away, and the mushroom cloud reached 7.5 miles (12 km) in height. Test director Kenneth Bainbridge commented to Los Alamos director J. Robert Oppenheimer, "Now we are all sons of bitches." Oppenheimer later stated that, while watching the test, he was reminded of a line from the Bhagavad Gita, a Hindu scripture:

> Now I am become Death, the destroyer of worlds

> http://www.encyclopedia.com/topic/Manhattan_Project.aspx

The Manhattan Project was an epic, secret, wartime effort to design and build the world's first nuclear weapon. Commanding the efforts of the world's greatest physicists and mathematicians during World War II, the $20 billion project resulted in the production of the first uranium and plutonium bombs. The American quest for nuclear explosives was driven by the fear that Hitler's Germany would invent them first and thereby gain a decisive military advantage. The monumental project took less than four years, and encompassed construction of vast facilities in Oak Ridge, Tennessee, and Hanford, Washington, that were used for the purpose of obtaining sufficient quantities of the isotopes uranium-235 and plutonium-239, necessary to produce the fission chain reaction, which released the bombs' destructive energy. After a successful test in Alamogordo, New Mexico, the United States exploded a nuclear bomb on the Japanese city of Hiroshima on August 6, 1945. Three days later another bomb was dropped on the Japanese city of Nagasaki, and spurred the Japanese surrender that ended World War II.

In the 1930s and early 1940s, fundamental discoveries regarding the neutron and atomic physics allowed for the possibility of induced nuclear chain reactions. Danish physicist Neils Bohr's (1885–1962) compound nucleus theory, for example, laid the foundation for the theoretical exploration of fission, the process whereby the central part of an atom, the nucleus, absorbs a neutron, then breaks into two equal fragments. In certain elements, such as plutonium-239, the fragments release other neutrons which quickly break up more atoms, creating a chain reaction that releases large amounts of heat and radiation.

Hungarian physicist Leo Szilard (1898–1964) conceived the idea of the nuclear chain reaction in 1933, and immediately became concerned that, if practical, nuclear energy could be used to make weapons of war. Szilard, who fled Nazi persecution first in his native Hungary, then again in Germany, conveyed his concerns to his friend and contemporary, noted physicist Albert Einstein (1879–1955). In 1939, the two scientists drafted a letter (addressed from Einstein) warning United States President Franklin D. Roosevelt of the plausibility of nuclear weapons, and of German experimentation with uranium and fission. In December, 1941, after the Japanese attack at Pearl Harbor and the United States' entry into the war, Roosevelt ordered a secret United States project to investigate the potential development of atomic weapons. The Army Corps of Engineers took over and in 1942 consolidated various atomic research projects into the intentionally misnamed Manhattan Engineering District (now commonly known as the Manhattan Project), which was placed under the command of Army Brigadier General Leslie Richard Groves.

Groves recruited American physicist Robert Oppenheimer (1904–1967) to be the scientific director for the Manhattan Project. Security concerns required the development of a central laboratory for physics weapon research in Los Alamos, New Mexico. Oppenheimer's leadership attracted many top young scientists, including American physicist Richard Feynman (1918–1988), who joined the Manhattan Project while still a graduate student. Feynman and his mentor Hans Bethe (1906–) calculated the critical mass fissionable material necessary to begin a chain reaction.

Fuel for the nuclear reaction was a primary concern. At the outset, the only materials seemingly satisfactory for sustaining an explosive chain reaction were either U-235 (derived from U-238) or P-239 (an isotope of the yet unsynthesized element plutonium). Additional requirements included an abundant supply of heavy water (e.g., deuterium and tritium). At Oak Ridge, the process of gaseous diffusion was used to extract the U-235 isotope from uranium ore. At Hanford, production of P-239 was eventually made possible by leaving plutonium-238 in a nuclear reactor for an extended period of time.

In 1942, Italian physicist Enrico Fermi (1901–1954) supervised the first controlled sustained chain reaction at the University of Chicago. Underneath the university football stadium, in modified squash courts, Fermi and his team assembled a lattice of 57 layers of uranium metal and uranium oxide embedded in graphite blocks to create the first reactor pile.

The Manhattan Project eventually produced four bombs. Little Boy, the code name for the uranium bomb, utilized explosives to crash pieces of uranium together to begin an explosive chain reaction. Fat Man, the code name for the plutonium bomb, was more difficult to design. It required a neutron-emitting source to initiate a chain reaction within a series of concentric nested spheres. The outermost shell was an explosive lens system surrounding a pusher/neutron absorber shell designed to reduce the effect of Taylor waves, the rapid drop in pressure that occurs behind a detonation front and could interfere with an implosion. The next nested sphere was a uranium tamper/reflector shell containing a plutonium pit and beryllium neutron initiator. The spheres were designed to implode, causing the plutonium to fuse, reach critical mass, then start the reaction

The simple design of the uranium bomb left scientists confident of its success, but the complicated implosion trigger required by the plutonium bomb raised engineering concerns about reliability. On July 16, 1945, a plutonium test bomb code named Gadget was detonated in a remote area near Alamogordo, New Mexico. Observed by scientists wearing only welder's glasses and suntan lotion for protection, the test blast (code named Trinity) was more powerful than originally thought, roughly equivalent to 20,000 tons of TNT, and caused total destruction up to one mile from the blast center.

Protecting the secrecy of the Manhattan Project was one of the most complex intelligence and security operations during the war. At the Los Alamos facility, all residents were confined to the project area and surrounding town. Though several leading scientists knew the nature and scope of the entire project, most lab facilities were compartmentalized with various teams working on different project elements. Those who worked in the lab were forbidden to discuss any aspect of the project with friends or relatives. Military security personnel guarded the grounds and monitored communications between research teams. Official communications outside of Los Alamos, especially to the other Manhattan Project sites, were coded and enciphered. Mail was permitted, but heavily censored. Since the actual location of the Los Alamos facility was secret, all residents used the clandestine address "Box 1663, Santa Fe, New Mexico," for correspondence.

Communities were created around other project sites as well. The government created the towns of Oak Ridge and Hanford, relocating thousands of area residents before beginning construction. The towns, thus secured for facility personnel and their families, placed severe restrictions on civilian activities. In some areas, private telephones and radios were prohibited. Residents were encouraged to use simple pseudonyms outside of the lab. Children did not use their full names in school in Oak Ridge, Tennessee.

Managing several different facilities, spaced nearly two thousand miles apart, raised some significant security challenges. Communication was limited, and incoming and outgoing traffic from facility areas was closely monitored. Security of key documents was a constant concern. The isolated locations of the sites helped to insulate them from enemy espionage. However, the separate locations were also a key security strategy. Breaking the Manhattan Project into various smaller operations prevented jeopardizing the entire project in the event of a nuclear accident. The compartmentalization of such projects remains a common practice.

On August 6, 1945, an American B-29 "Flying Fortress," the *Enola Gay,* dropped the uranium bomb over Hiroshima. Sixty thousand people were killed instantly, and another 200,000 subsequently died as a result of burn and radiation injuries. Three days later, a plutonium bomb was dropped over Nagasaki. Although it missed its actual target by over a mile, the more powerful plutonium bomb killed or injured more than 65,000 people and destroyed half of the city. Ironically, ground zero, the point under the bomb explosion, turned out to be the Mitsubishi Arms Manufacturing Plant, at one time the major military target in Nagasaki. The fourth bomb remained unused.

Many Manhattan Project scientists eventually became advocates of the peaceful use of nuclear power and advocates for nuclear weapons control.

http://en.wikipedia.org/wiki/Atomic_bombings_of_Hiroshima_and_Nagasaki

Hiroshima during World War II

At the time of its bombing, Hiroshima was a city of both industrial and military significance. A number of military camps were located nearby, including the headquarters of Field Marshal Shunroku Hata's 2nd General Army Headquarters, which commanded the defense of all of southern Japan. His command consisted of some 400,000 men, most of whom were on Kyushu where an Allied invasion was correctly expected. Also present in Hiroshima was the headquarters of the Fifty-Ninth Army, and most of the 224th Division, a recently formed mobile unit. The city's air defenses comprised five batteries of 7-and-8-centimetre (2.8 and 3.1 in) anti-aircraft guns.

Hiroshima was a minor supply and logistics base for the Japanese military. The city was a communications center, a storage point, and an assembly area for troops. It was one of several Japanese cities left deliberately untouched by American bombing, allowing a pristine environment to measure the damage caused by the atomic bomb.

The center of the city contained several reinforced concrete buildings and lighter structures. Outside the center, the area was congested by a dense collection of small wooden workshops set among Japanese houses. A few larger industrial plants lay near the outskirts of the city. The houses were constructed of wood with tile roofs, and many of the industrial buildings were also built around wood frames. The city as a whole was highly susceptible to fire damage.

The population of Hiroshima had reached a peak of over 381,000 earlier in the war, but prior to the atomic bombing the population had steadily decreased because of a systematic evacuation ordered by the Japanese government. At the time of the attack, the population was approximately 340,000–350,000.

The bombing

Hiroshima was the primary target of the first nuclear bombing mission on 6 August, with Kokura and Nagasaki as alternative targets. The 393d Bombardment Squadron B-29 *Enola Gay*, piloted by Tibbets, took off from North Field airbase on Tinian, about six hours flight time from Japan. The *Enola Gay* (named after Tibbets' mother) was accompanied by two other B-29s. *The Great Artiste*, commanded by Major Charles W. Sweeney, carried instrumentation, and a then-nameless aircraft later called *Necessary Evil*, commanded by Captain George Marquardt, served as the photography aircraft.

Special Mission 13, Primary target Hiroshima, 6 August 1945			
Aircraft	Pilot	Call Sign	Mission role
Straight Flush	Major Claude R. Eatherly	Dimples 85	Weather reconnaissance (Hiroshima)
Jabit III	Major John A. Wilson	Dimples 71	Weather reconnaissance (Kokura)
Full House	Major Ralph R. Taylor	Dimples 83	Weather reconnaissance (Nagasaki)
Enola Gay	Colonel Paul W. Tibbets	Dimples 82	Weapon Delivery
The Great Artiste	Major Charles W. Sweeney	Dimples 89	Blast measurement instrumentation
Necessary Evil	Captain. George W. Marquardt	Dimples 91	Strike observation and photography
Top Secret	Captain Charles F. McKnight	Dimples 72	Strike spare—did not complete mission

After leaving Tinian the aircraft made their way separately to Iwo Jima where they rendezvoused at 2,440 meters (8,010 ft) and set course for Japan. The aircraft arrived over the target in clear visibility at 9,855 meters (32,333 ft). Parsons, who was in command of the mission, armed the bomb during the flight to minimize the risks during takeoff. His assistant, Second Lieutenant Morris Jeppson, removed the safety devices 30 minutes before reaching the target area.

About an hour before the bombing, Japanese early warning radar detected the approach of some American aircraft headed for the southern part of Japan. An alert was given and radio broadcasting stopped in many cities, among them Hiroshima. At nearly 08:00, the radar operator in Hiroshima determined that the number of planes coming in was very small—probably not more than three—

and the air raid alert was lifted. To conserve fuel and aircraft, the Japanese had decided not to intercept small formations. Hiroshima's anti-aircraft batteries were put on alert, but held their fire; because anti-aircraft guns caused significant collateral damage and casualties on the ground, the anti-aircraft gunners of all belligerents in the war were typically ordered to avoid firing on small numbers of enemy aircraft, especially if they were stationed in or near large population centers.

The normal radio broadcast warning was given to the people that it might be advisable to go to air-raid shelters if B-29s were actually sighted. However a reconnaissance mission was assumed because at 07:31 the first B-29 to fly over Hiroshima at 32,000 feet (9,800 m) had been the weather observation aircraft *Straight Flush* that sent a Morse code message to the *Enola Gay* indicating that the weather was good over the primary target. Because it then turned out to sea, the 'all clear' was sounded in the city. At 08:09 Colonel Tibbets started his bomb run and handed control over to his bombardier.

The release at 08:15 (Hiroshima time) went as planned, and the gravity bomb known as "Little Boy", a gun-type fission weapon with about 64 kilograms (140 lb) of uranium-235, took 43 seconds to fall from the aircraft flying at 31,060 feet (9,470 m) to the predetermined detonation height about 1,968 feet (600 m) above the city. The *Enola Gay* traveled 11.5 miles (18.5 km) before it felt the shock waves from the blast.

Due to crosswind, it missed the aiming point, the Aioi Bridge, by approximately 800 feet (240 m) and detonated directly over Shima Surgical Clinic. It created a blast equivalent to 16 kilotons of TNT (67 TJ). (The U-235 weapon was considered very inefficient, with only 1.7% of its material fissioning. The radius of total destruction was about one mile (1.6 km), with resulting fires across 4.4 square miles (11 km^2). Americans estimated that 4.7 square miles (12 km^2) of the city were destroyed. Japanese officials determined that 69% of Hiroshima's buildings were destroyed and another 6–7% damaged.

Some 70,000–80,000 people, or some 30% of the population of Hiroshima were killed by the blast and resultant firestorm, and another 70,000 injured. Over 90% of the doctors and 93% of the nurses in Hiroshima were killed or injured—most had been in the downtown area which received the greatest damage.

After the Hiroshima bombing, Truman issued a statement announcing the use of the new weapon. He stated, "We may be grateful to Providence" that the German atomic bomb project had failed, and that the United States and its allies had "spent two billion dollars on the greatest scientific gamble in history—and won." Truman then warned Japan:

If they do not now accept our terms, they may expect a rain of ruin from the air, the like of which has never been seen on this earth. Behind this air attack will follow sea and land forces in such numbers and power as they have not yet seen and with the fighting skill of which they are already well aware.

Leaflets urging quick surrender were dropped over Japan by the 509th Composite Group on the bombing mission

The Japanese government still did not react to the Potsdam Declaration. Emperor Hirohito, the government, and the war council were considering four conditions for surrender: the preservation of the *kokutai* (Imperial institution and national polity), assumption by the Imperial Headquarters of responsibility for disarmament and demobilization, no occupation of the Japanese Home Islands, Korea, or Formosa, and delegation of the punishment of war criminals to the Japanese government.

The Soviet Foreign Minister Vyacheslav Molotov had informed Tokyo of the Soviet Union's unilateral abrogation of the Soviet–Japanese Neutrality Pact on 5 April. At two minutes past midnight on 9 August, Tokyo time, Soviet infantry, armor, and air forces had launched the Manchurian Strategic Offensive Operation. Four hours later, word reached Tokyo that the Soviet Union had declared war on Japan. The senior leadership of the Japanese Army began preparations to impose martial law on the nation, with the support of Minister of War Korechika Anami, in order to stop anyone attempting to make peace.

Nagasaki during World War II

The city of Nagasaki had been one of the largest sea ports in southern Japan and was of great wartime importance because of its wide-ranging industrial activity, including the production of ordnance, ships, military equipment, and other war materials.

In contrast to many modern aspects of Hiroshima, almost all of the buildings were of old-fashioned Japanese construction, consisting of wood or wood-frame buildings with wood walls (with or without plaster) and tile roofs. Many of the smaller industries and business establishments were also situated in buildings of wood or other materials not designed to withstand explosions. Nagasaki had been permitted to grow for many years without conforming to any definite city zoning plan; residences were erected adjacent to factory buildings and to each other almost as closely as possible throughout the entire industrial valley.

Nagasaki had never been subjected to large-scale bombing prior to the explosion of a nuclear weapon there. On August 1, 1945, however, a number of conventional high-explosive bombs were dropped on the city. A few hit in the shipyards and dock areas in the southwest portion of the city, several hit the Mitsubishi Steel and Arms Works, and six bombs landed at the Nagasaki Medical School and Hospital, with three direct hits on buildings there. While the damage from these bombs was relatively small, it created considerable concern in Nagasaki and many people—principally school children—were evacuated to rural areas for safety, thus reducing the population in the city at the time of the nuclear attack. By early August the city was defended by four batteries of 7 centimeters (2.8 in) anti-aircraft guns and two searchlight batteries.

To the north of Nagasaki there was a camp holding British Commonwealth prisoners of war, some of whom were working in the coal mines and only found out about the bombing when they came to the surface.

The bombing

Responsibility for the timing of the second bombing was delegated to Tibbets. Scheduled for 11 August against Kokura, the raid was moved earlier by two days to avoid a five day period of bad weather forecast to begin on 10 August. Three bomb pre-assemblies had been transported to Tinian, labeled F-31, F-32, and F-33 on their exteriors. On 8 August, a dress rehearsal was conducted off Tinian by Sweeney using *Bockscar* as the drop airplane. Assembly F-33 was expended testing the components and F-31 was designated for the August 9 mission.

Special Mission 16, Secondary target Nagasaki, 9 August 1945			
Aircraft	Pilot	Call Sign	Mission role
Enola Gay	Captain George W. Marquardt	Dimples 82	Weather reconnaissance (Kokura)
Laggin' Dragon	Captain Charles F. McKnight	Dimples 95	Weather reconnaissance (Nagasaki)
Bockscar	Major Charles W. Sweeney	Dimples 77	Weapon Delivery
The Great Artiste	Captain Frederick C. Bock	Dimples 89	Blast measurement instrumentation
Big Stink	Major James I. Hopkins, Jr.	Dimples 90	Strike observation and photography
Full House	Major Ralph R. Taylor	Dimples 83	Strike spare—did not complete mission

On the morning of 9 August 1945, the B-29 Superfortress *Bockscar*, flown by Sweeney's crew, carried Fat Man, with Kokura as the primary target and Nagasaki the secondary target. The mission plan for the second attack was nearly identical to that of the Hiroshima mission, with two B-29s flying an hour ahead as weather scouts and two additional B-29s in Sweeney's flight for instrumentation and photographic support of the mission. Sweeney took off with his weapon already armed but with the electrical safety plugs still engaged.

This time Penney and Cheshire were allowed to accompany the mission, flying as observers on the third plane, *Big Stink*, which was flown by the group's Operations Officer, Major James I. Hopkins, Jr. Observers aboard the weather planes reported both targets clear. When Sweeney's aircraft arrived at the assembly point for his flight off the coast of Japan, *Big Stink* failed to make the rendezvous. *Bockscar* and the instrumentation plane circled for 40 minutes without locating Hopkins. Already 30 minutes behind schedule, Sweeney decided to fly on without Hopkins.

By the time they reached Kokura a half hour later, a 70% cloud cover had obscured the city, inhibiting the visual attack required by orders. After three runs over the city, and with fuel running low because a transfer pump on a reserve tank had failed before take-off, they headed for their secondary target, Nagasaki. Fuel consumption calculations made en route indicated that *Bockscar* had insufficient fuel to reach Iwo Jima and would be forced to divert to Okinawa. After initially deciding that if Nagasaki were obscured on their arrival the crew would carry the bomb to Okinawa and dispose of it in the ocean if necessary, the weaponeer, Navy Commander Frederick Ashworth, decided that a radar approach would be used if the target was obscured.

At about 07:50 Japanese time, an air raid alert was sounded in Nagasaki, but the "all clear" signal was given at 08:30. When only two B-29 Superfortresses were sighted at 10:53, the Japanese apparently assumed that the planes were only on reconnaissance and no further alarm was given

A few minutes later at 11:00, *The Great Artiste*, the support B-29 flown by Captain Frederick C. Bock, dropped instruments attached to three parachutes. These instruments also contained an unsigned letter to Professor Ryokichi Sagane, a nuclear physicist at the University of Tokyo who studied with three of the scientists responsible for the atomic bomb at the University of California, Berkeley, urging him to tell the public about the danger involved with these weapons of mass destruction. The messages were found by military authorities but not turned over to Sagane until a month later. In 1949, one of the authors of the letter, Luis Alvarez, met with Sagane and signed the document.

At 11:01, a last minute break in the clouds over Nagasaki allowed *Bockscar*'s bombardier, Captain Kermit Beahan, to visually sight the target as ordered. The Fat Man weapon, containing a core of about 6.4 kilograms (14 lb) of plutonium, was dropped over the city's industrial valley. It exploded 43 seconds later at 469 metres (1,539 ft) above the ground halfway between the Mitsubishi Steel and

Arms Works in the south and the Mitsubishi-Urakami Ordnance Works (Torpedo Works) in the north. This was nearly 3 kilometres (1.9 mi) northwest of the planned hypocenter; the blast was confined to the Urakami Valley and a major portion of the city was protected by the intervening hills. The resulting explosion had a blast yield equivalent to 21 kilotons of TNT (88 TJ). The explosion generated heat estimated at 3,900 °C (7,050 °F) and winds that were estimated at 1,005 km/h (624 mph).

Casualty estimates for immediate deaths range from 40,000 to 75,000. Total deaths by the end of 1945 may have reached 80,000. At least eight known POWs died from the bombing and as many as 13 POWs may have died, including a British Commonwealth citizen, and seven Dutch POWs. One American POW, Joe Kieyoomia, was in Nagasaki at the time of the bombing but survived, reportedly having been shielded from the effects of the bomb by the concrete walls of his cell. The radius of total destruction was about 1 mile (1.6 km), followed by fires across the northern portion of the city to 2 miles (3.2 km) south of the bomb. 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. There is also a peace monument and Bell of Nagasaki in the Kokura.