

A dramatic background image of a nuclear explosion. A large, bright, white and yellow mushroom cloud rises from a dark, smoky base. The sky is filled with horizontal bands of orange and red, suggesting intense heat and fire. The overall scene is one of immense power and destruction.

There are two basic types of nuclear weapon:

- **fission bombs**

- Atomic bombs, atom bombs, or A-bombs.

- **fusion bomb**

- hydrogen bombs, H-bombs, thermonuclear bombs, and fusion bombs.

Fission bombs (overview)

- Fissile materials (Uranium-235, Plutonium-239, and Uranium-233)
- Gun method and Implosion method
- Little boy and fat man
- Maximum yield is only 500 kt
- Low efficiency at about maximum 25%



Fission Materials:

◇ enriched uranium: uranium-235

- U-235 is the only fissile isotope found in any quantity in nature.

(* **fissile** material is one that is capable of sustaining a chain reaction of nuclear fission.)

- U-238 (99.29%) with only fissile isotope U-235 (0.71%) found in nature.
- Thermal diffusion, gaseous diffusion, gas centrifuge, zippe centrifuge, aerodynamic process, electromagnetic isotope separation, laser processes, chemical methods, and plasma separation



Diffusion method - The large Tricastin enrichment plant in France (beyond cooling towers). The four nuclear reactors in the foreground provide over 3000 MWe power for it.

(taken from Uranium Information Centre

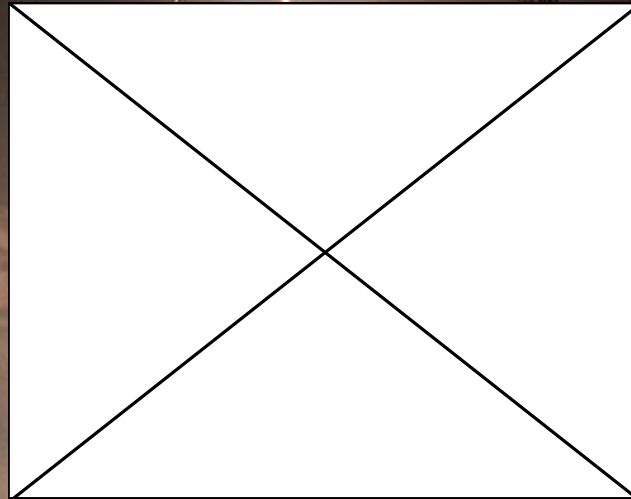
<<http://www.uic.com.au/>>, article 33, March 2006)



Gas centrifuge cascade (taken from Department of Energy digital photo archive.)

Fission Materials (cont.)

- **Weapon(s)-grade** contains 85% or more of ^{235}U
- Though for a crude, inefficient weapon 20% is sufficient (called **weapon(s)-usable**);
- U-235 is one of the very few atoms that can undergo **induced fission**.



- The fission of one atom of U-235 generates $200 \text{ MeV} = 3.2 \times 10^{-11} \text{ J}$
- The ^{238}U remaining after enrichment is known as depleted uranium (DU)

Fission Material (cont.)

◇ Plutonium

- The most important isotope of plutonium is ^{239}Pu (half-life 24,110 years)
- key fissile component in modern nuclear weapons.
- It can be made from natural uranium.
- Mainly used due to its ease of **fissioning and availability**.
- The critical mass for an unreflected sphere of plutonium is **16 kg**.
- When use of a neutron reflecting tamper the pit of plutonium in a fission bomb is reduced to 10 kg, which is a sphere with a diameter of 10 cm.
- Complete detonation of plutonium will produce an explosion of 20 kilotons of (TNT) per kilogram.



Picture of Plutonium-239 with diameter of 10cm. (Photo taken from Wikipedia)

◇ Uranium-233

- U-233 is an artificially produced isotope, bred from [thorium-232](#) in a nuclear reactor.

The fissile properties of U-233 are generally somewhere between those of U-235 and Pu-239.

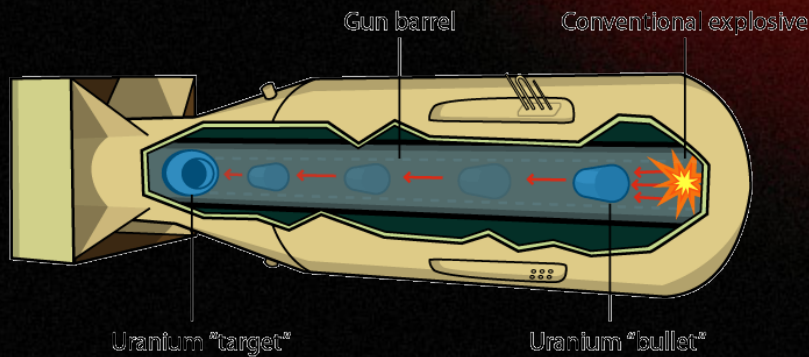
Fission Bomb Types:

Gun method:

- Shooting one piece of fissile material as a projectile against a second part as a target

The "Little Boy"

- 10 feet (3 m) in length, 28 inches (71 cm) wide and weighed 8,900 lb (4000 kg).
- Dropped on Hiroshima, on August 6, 1945.



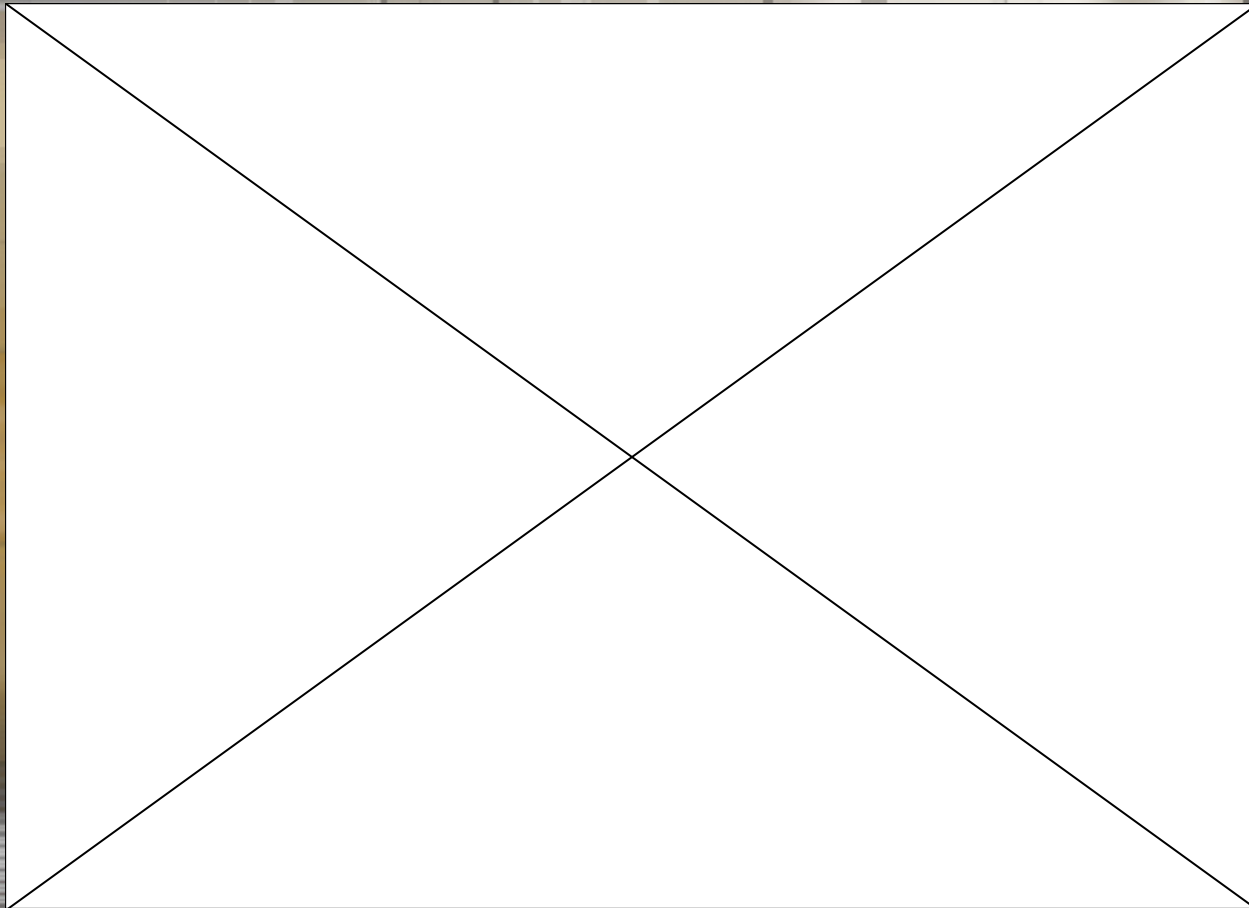
The "gun" assembly method. (picture taken from Wikipedia)



First photograph of the Little Boy bomb casing to ever be released by the U.S. government (it was declassified in 1960) (photo taken from Wikipedia)

Gun method continued...

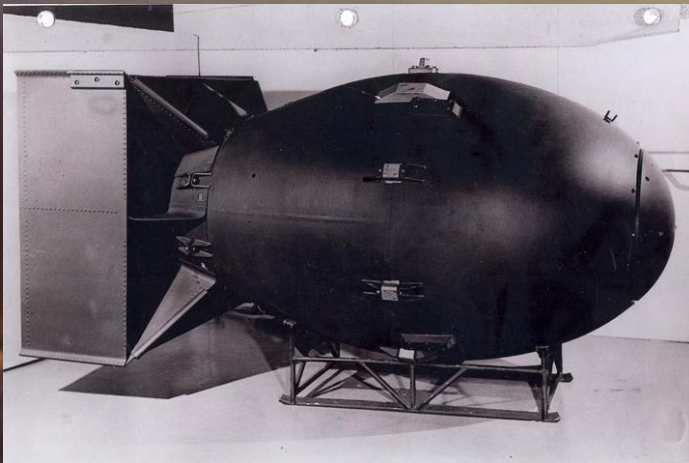
- Dropped at altitude of 580 m
- Yield estimate of "Little Boy" was about 15 kilotons of TNT
- Approximately 70,000 people were killed as a direct result of the blast.
- 60 kg of 80% grade U-235 was used (hence 48 kg)



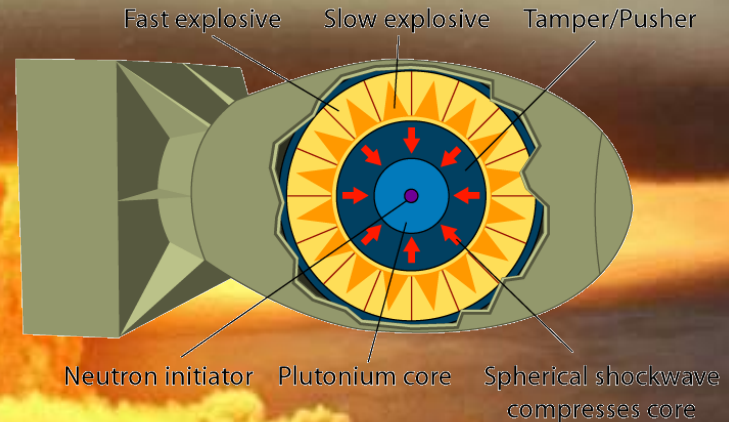
(Flash taken from howstuffworks.com)

Implosion method:

- Uses conventional explosives surrounding the material to rapidly compress the mass to a supercritical state.
- The “Fat man”
 - 7 feet 8 inches (2.34 m) long, five feet (1.52 m) in diameter, and weighed 10,200 pounds (4,630 kg)
 - detonated over Nagasaki at an altitude of about 1,800 feet
 - Uses plutonium



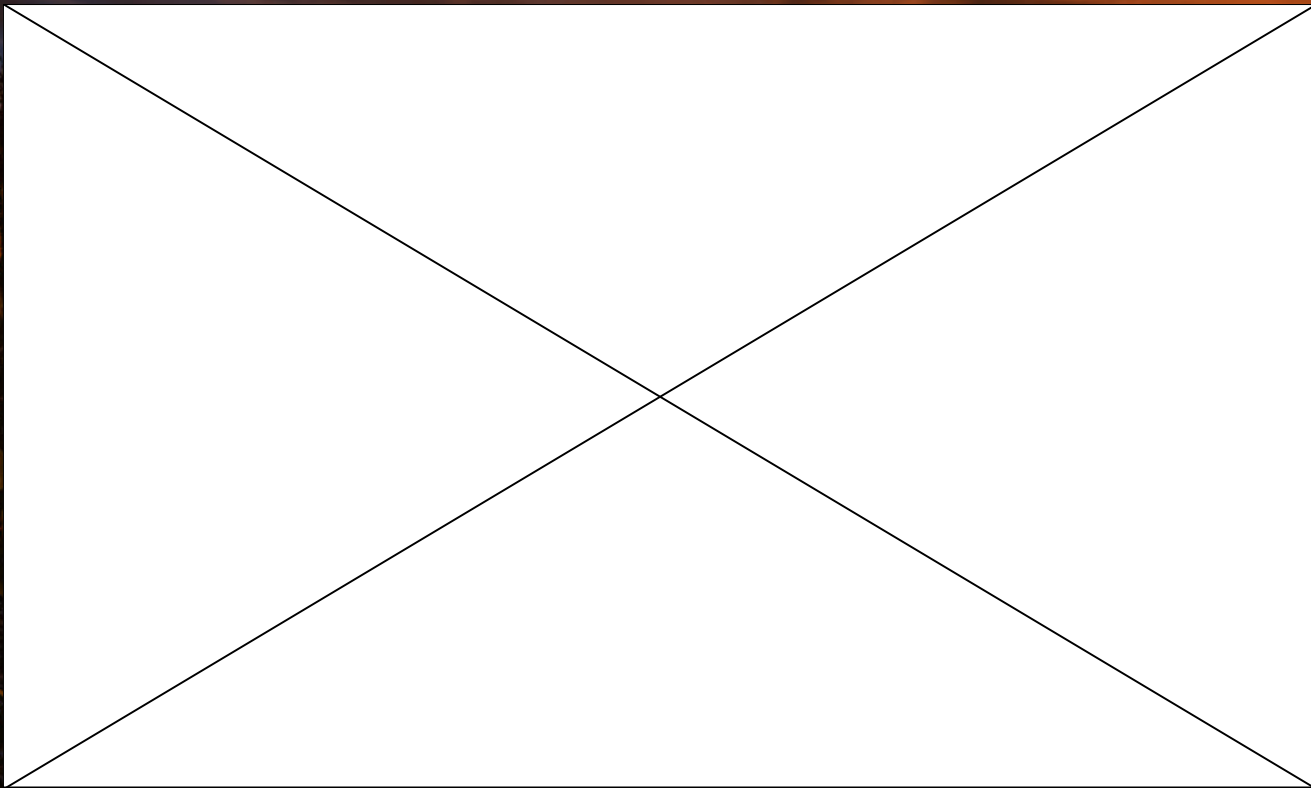
(photo taken from Defense Threat Reduction Agency)
<http://www.dtra.mil/press_resources/photo_library/CS/CS-2.cfm>



(Picture taken from Wikipedia)

Fat man continued...

- An estimated 40,000 people were killed instantly at Nagasaki, and about 25,000 were injured.
- yield of about 21 kilotons of TNT and with only 10% more mass than the “little boy”



(Flash taken from howstuffworks.com)

Main problems with fission weapon:

- Efficiency

- The efficiency of a fission weapon is the fraction of the fissile material that actually fissions.
- The maximum efficiency is calculated to be 25%.
- For Little Boy only 1.4%.
- For Fat Man it was 14%.

- Maximum Power

- “Little Boy” is about 15 kilotons of TNT
- “Fat Man” is only 21 kilotons of TNT
- Maximum at 500 kilotons of TNT

Fusion Bomb (Overview):

- Produces a large amount of its energy through nuclear fusion reactions.
- More energy per reaction than fission
- Thousand times more powerful than fission bombs.
- Very efficient fuel by weight (because of light weight of element used as fusion fuel and large energy release)
- Teller–Ulam design.
- “Ivy Mike”

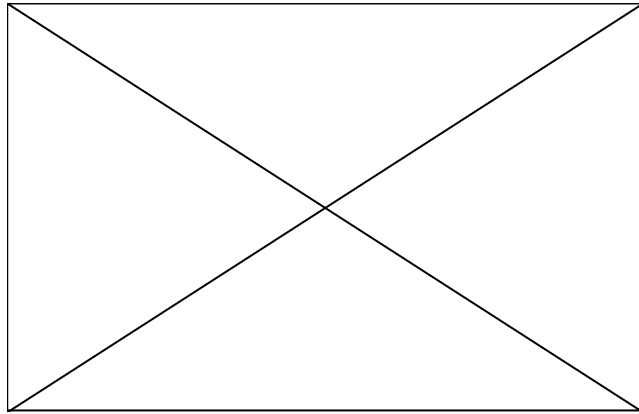


Fusion Bomb History:

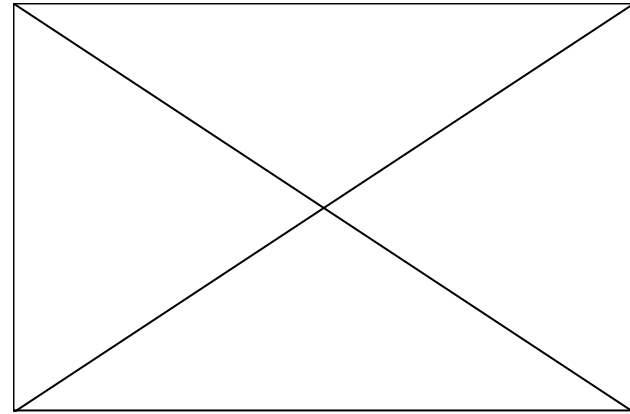
- The Teller-Ulam design is a nuclear weapon design that is more colloquially referred to as "the secret of the hydrogen bomb".
- It is named after two of its chief contributors, Hungarian physicist Edward Teller and Polish mathematician Stanislaw Ulam.
- Design was developed in 1951.
- Basic principle of the Teller-Ulam configuration is based upon the idea that different parts of a thermonuclear weapon can be chained together in "stages" which allow for the full detonation of each (staged thermonuclear weapon).

The Way Fusion Reacts:

- Combination of two light atoms, usually isotopes of hydrogen, to form a more stable heavy atom and release excess energy.



Sample using deuterium
(taken from how stuff works)



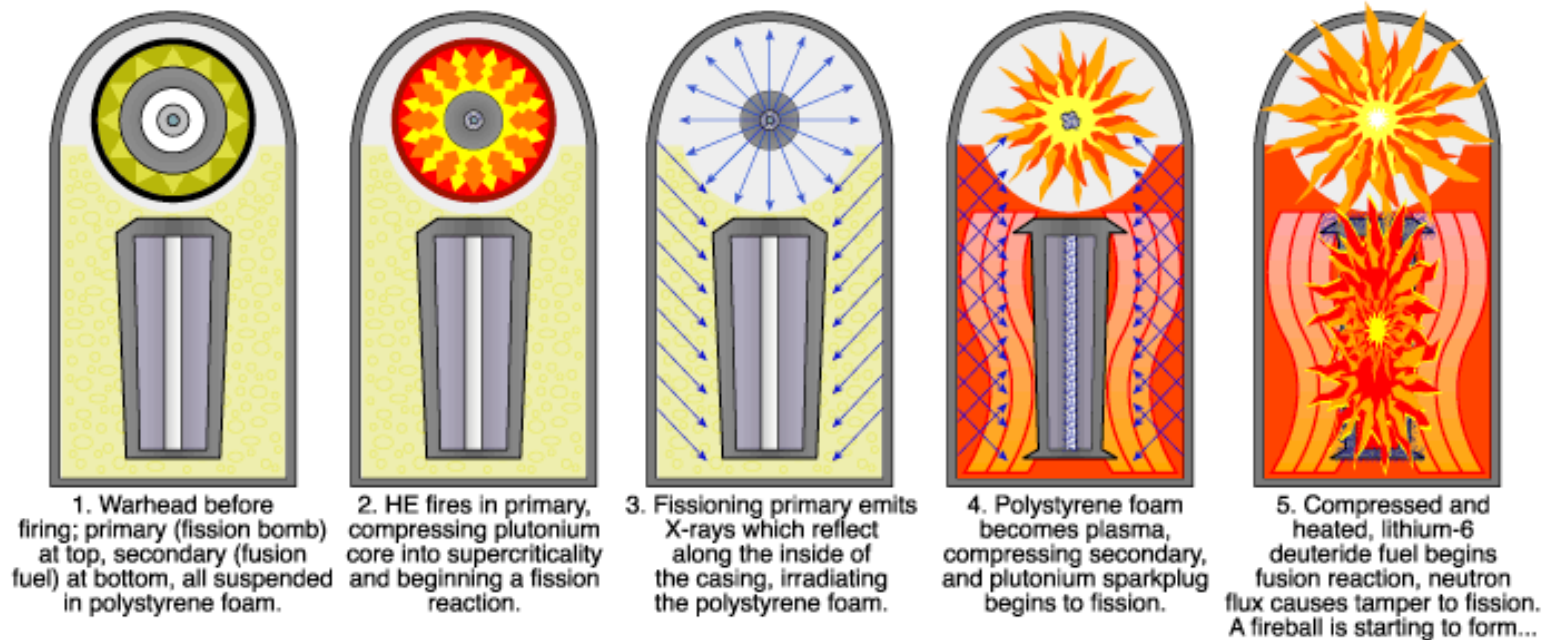
Sample using tritium
(taken from how stuff works)

Fusion can also used for boosting:

- By placing mixture of deuterium and tritium inside the hollow core of an implosion style plutonium pit.
- Imploding fission first gives sufficient pressure for fusion reaction
- Then it releases a large number of energetic neutrons into the surrounding fissile materials.
- This increases the rate of burn of the fissile material, so more fissile materials are consumed before the pit disintegrates.
- Thus increase the pure fission bomb efficiency from 20% to 40 %.
- Allow less fissile material for a given yield.
- Avoid radiation interference (RI) by using less Plutonium.
- (Plutonium pits would be particularly susceptible to partial pre-detonation if exposed to the intense radiation of a nearby nuclear explosion. This means one nuclear explosion can make all other nuclear weapon in close by range to explode).

Staged Thermonuclear Weapons (Teller–Ulam design):

- Diagram explanation:

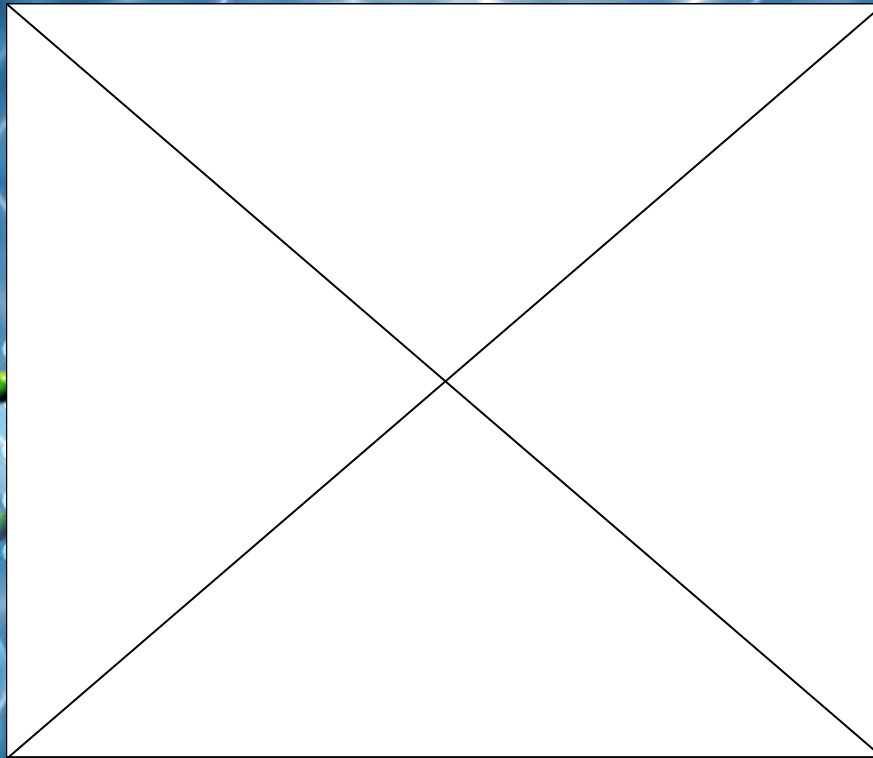


(diagram taken from Wikipedia)

Steps explanation:

1. Fission weapon (primary) is placed at one end of the warhead casing
2. When detonated, it first releases X-rays.
3. X-rays are travel into a space surrounding the secondary part (column of lithium deuterium fusion fuel encased by a natural uranium "tamper")
4. The plastic foam between the radiation casing and secondary part which is essentially just carbon and hydrogen becomes completely ionized and transparent as the x-rays penetrate.
5. Then the temper gets heated and ablates (causing an implosion).
6. Capsule is compressed to perhaps $1/30$ of its original diameter, reaches or exceeds 1000 times its original density.
7. Fissionable rod experience an extremely violent shock wave that will heat it to high temperatures cause to compress and doing so increases its density by a factor of about 4 and cause the rod to become super-critical.
8. As the rod undergoes fission, it releases neutrons into the surrounding deuterium and causes some deuterium to become tritium.
9. Then the high temperature ignites the deuterium and tritium fuel and cause fusion reaction.
10. As fusion reaction explodes, it releases neutron and cause the temper to fission.

Flash of a Fusion Bomb:

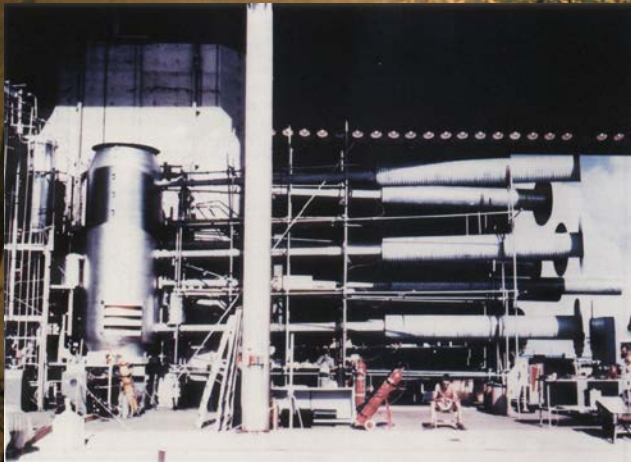


(flash taken from how stuff works)

- All of these events happened in about 600 billionths of a second (550 billionths of a second for the fission bomb implosion, 50 billionths of a second for the fusion events).

Fusion test bombs

- The first device based on this principle that was detonated by the United States is the “Ivy Mike” nuclear test on October, 1952. (0715 hours local time on November 1, 1952)
- It uses cryogenic liquid deuterium.
- It is measured 80 inches in diameter and 244 inches in height and weighed about 60 tons.

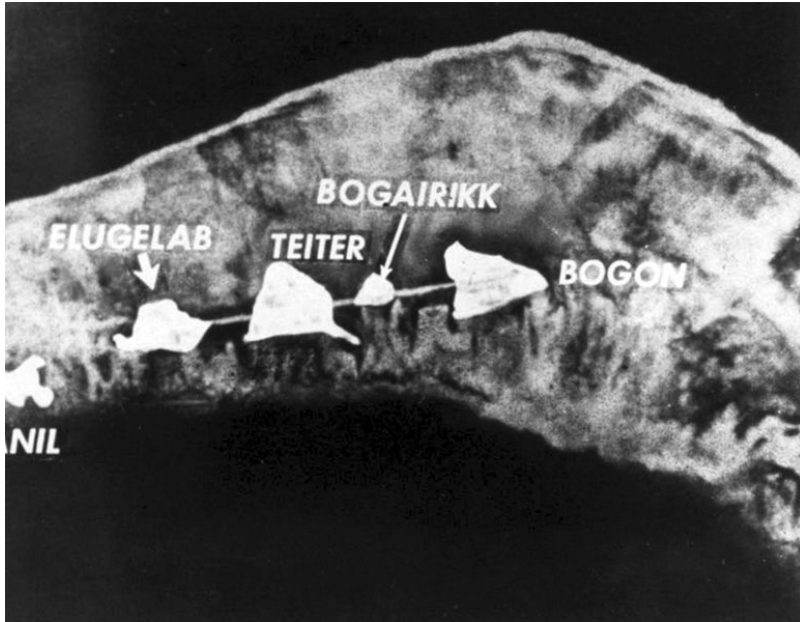


(picture taken from US Atomic Energy Commission)

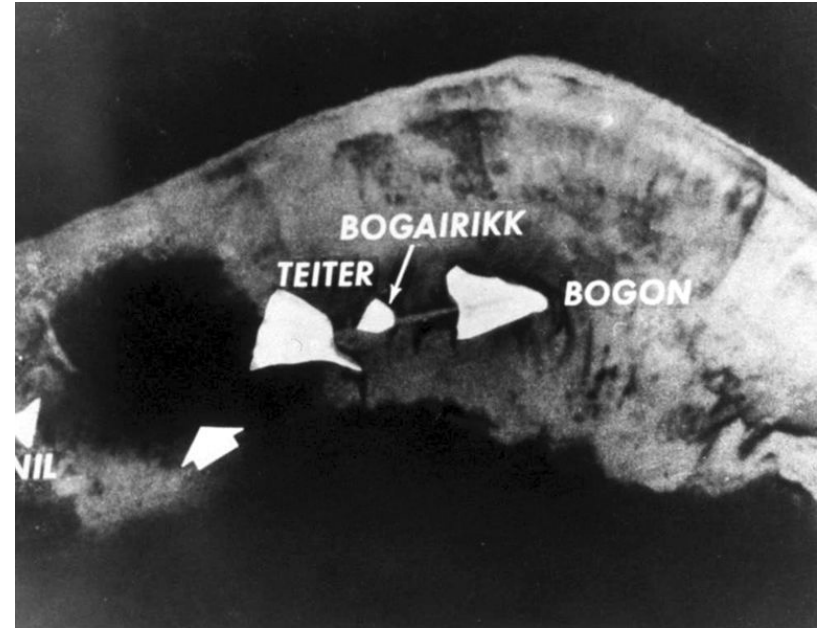


(picture taken from US Atomic Energy Commission)

- Produced a yield of 10.4 megatons (10.4 million tons of TNT)
(fission only had 50 thousand tons of TNT)
- The fireball was over 3 miles wide and reached an altitude of 120,000 feet



Before explosion



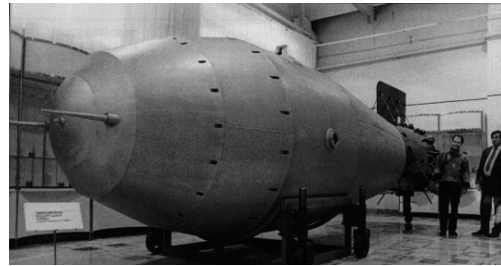
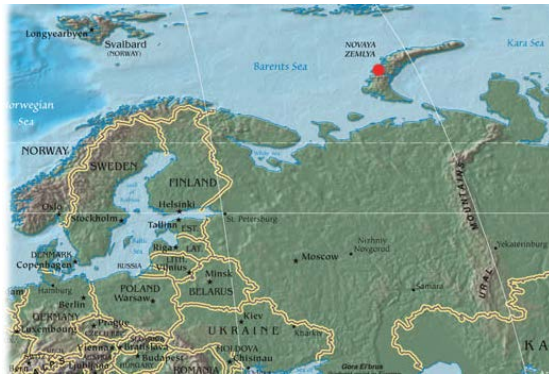
After explosion

(pictures taken from Wikipedia)

- The blast created a crater 6,240 feet in diameter and 164 feet deep
- stripped the test islands clean of vegetation
- the water around the blast site boiled for up to twelve hours afterwards

King of Bombs

- most powerful nuclear explosive ever detonated
- Developed by the Soviet Union
- ~50 megaton bomb
- tested on October 30, 1961 in Novaya Zemlya
- Detonate at a height of 4,000 m over the land surface.
- The explosion could be seen and felt in Finland
- Compare to the largest one tested by U.S. which was 15 megaton.



(above pictures taken from
<http://nuclearweaponarchive.org/>)