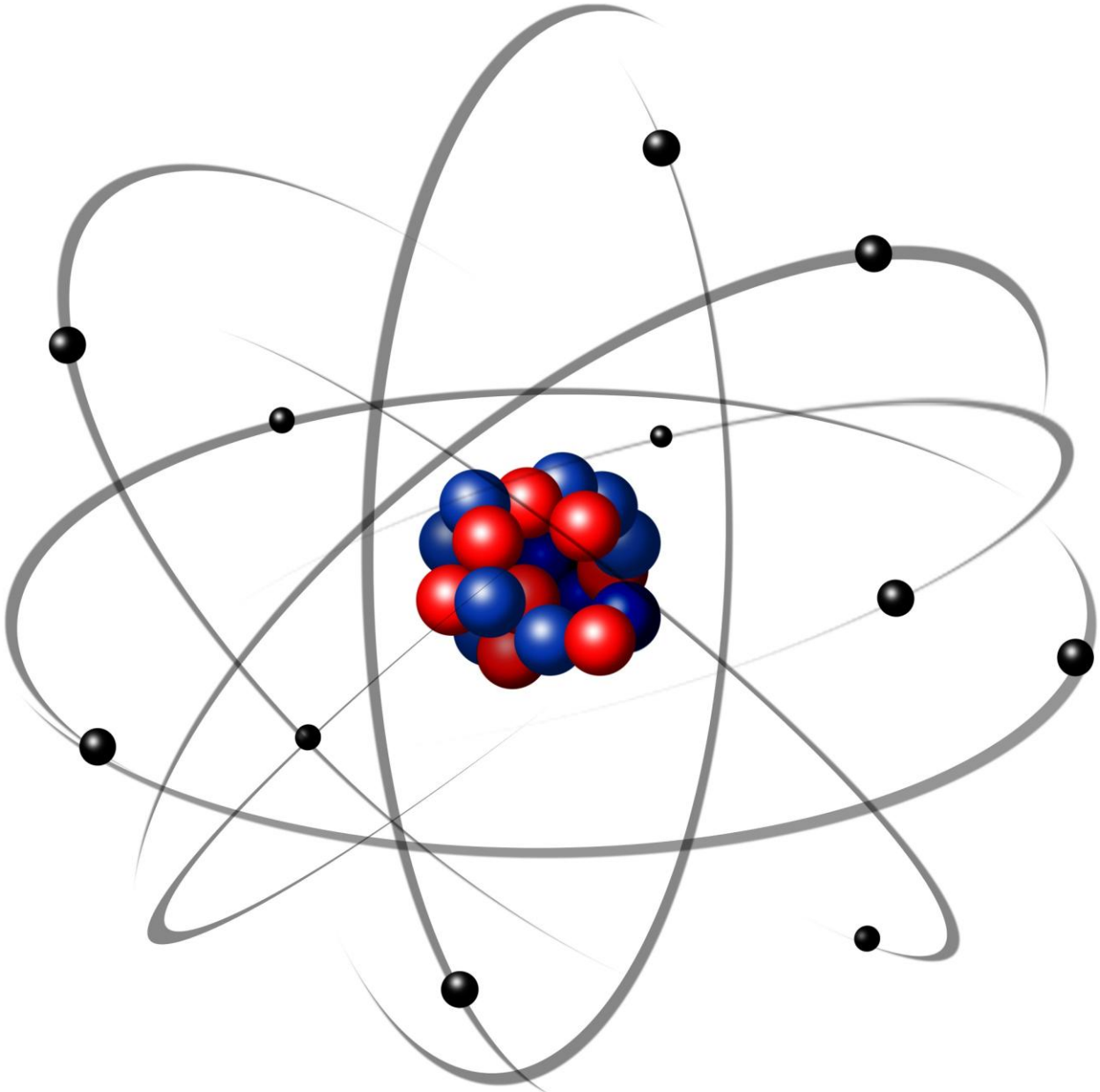
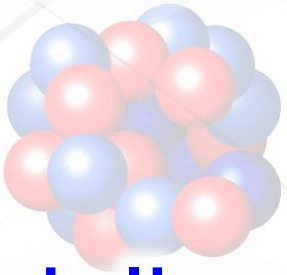


Brighter than a Thousand Suns

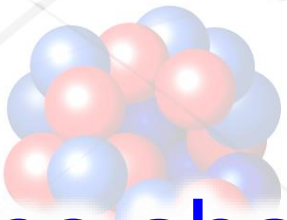
How curiosity about the natural world inadvertently led Science to stumble upon one of the most dangerous discoveries that has ever been made.

A Review of the Manhattan Project



Interdisciplinary Unit: A Scientific Perspective on the History of the Atomic Bomb

History ↔ Science



- How Science shapes History.
- How History determines the path of Science.

Nuclear Weapons

Online Presentation

- http://www.nygh.sg/bonding/history_of_atomic_bomb.pdf

Nuclear Weapons

Conceptual Lenses

• **Question:** How are *conflict* and *change* defined?

Nuclear Weapons

Conceptual Lenses

- **Answer:** Conflict

Conflict arises from differences in opinions and / or principles. Conflict can be emotional and / or physical. Conflict may exist within a single person, or between large groups of people.

- **Answer:** Change

Change is inevitable. Change occurs as things become different over time. Change can be positive (good) or negative (bad). Change can be planned or unexpected. Change can be linear or cyclic.

Nuclear Weapons

1. What events mark key moments in human history?

2. What drives scientific innovation? Would the Manhattan Project have taken place during peacetime?

3. How could people of conscience create weapons of mass destruction?

4. What is the purpose of Science?

5. What responsibilities does Science have to society?

6. Who determines what Science should do?

7. What are some positive outcomes from research into atomic weapons?

8. Is it acceptable to do Science for the sake of curiosity, without any care for the consequences?

Nuclear Weapons

The beginning…

…of events that changed the world.

Nuclear Weapons

Nuclear Weapons

- The discovery of *nuclear fission* by German Chemists Otto Hahn (Nobel Prize in Chemistry, 1944) and Fritz Strassmann in 1938 made development of an *atomic bomb* a theoretical possibility.

- Lise Meitner's (pictured) contribution to the work was not recognised by the Nobel Prize Committee, or in Otto Hahn's acceptance speech.

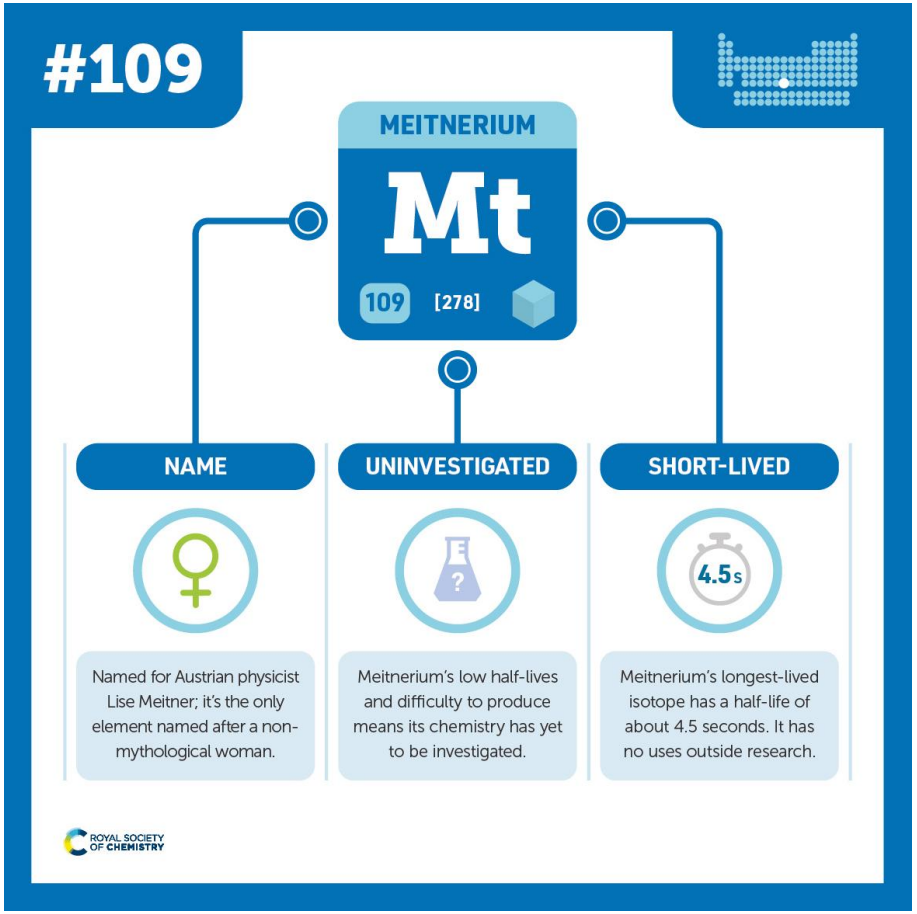
Nuclear Weapons

- **Question:** What *internal conflict* do you imagine Otto Hahn had to come to terms with after learning about America's use of nuclear weapons against Japan?

Nuclear Weapons

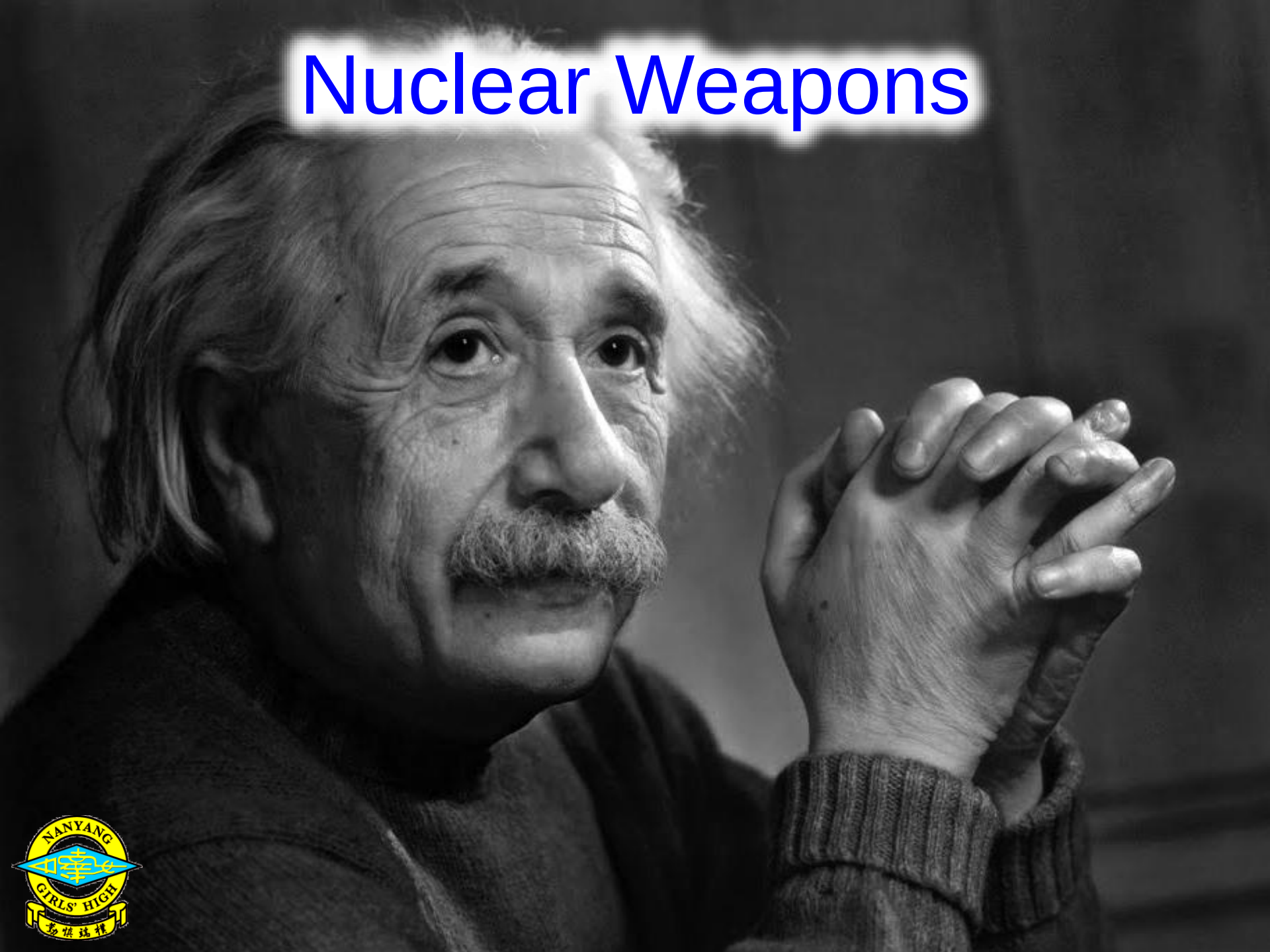
- **Answer:** Although he was not directly involved with the development of any nuclear weapons, Otto Hahn felt personally responsible for the deaths resulting from the atomic bombs that were dropped on Hiroshima and Nagasaki.

Nuclear Weapons



- Chemical element 109 – *Meitnerium* – is named in honour of Lise Meitner's outstanding contribution to Science.

Nuclear Weapons



Nuclear Weapons

- Scientists recognised the potential for nuclear fission to create enormous amounts of energy. This energy could be used peacefully, or could be used to create "*bombs with a destructiveness vastly greater than anything now known".

- In August 1939 a *letter, signed by *Albert Einstein* (Nobel Prize in Physics, 1921), was delivered to Franklin D. Roosevelt.

- **Question:** What do you think Albert Einstein urged the United States Government to do?

Nuclear Weapons

- **Answer:** Einstein urged Roosevelt to secure a source of uranium for the United States. He also urged for research into nuclear fission to be sped-up and scaled-up, with help from industry. It was essential the Allies should develop the first atomic bomb before their aggressors.

Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

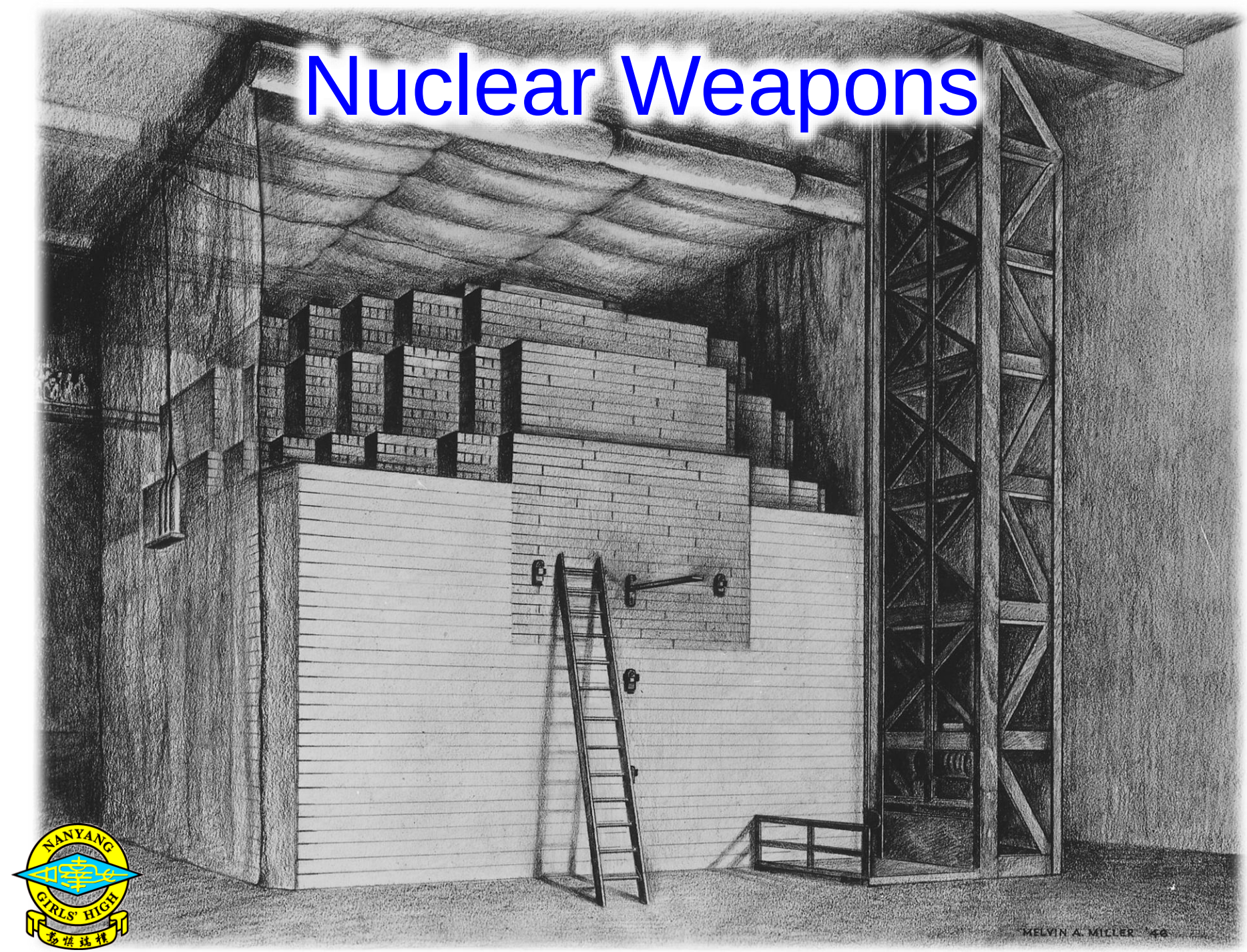
Nuclear Weapons

- *The Manhattan Project* was a collaboration between the United States of America, Canada and England to build the world's first atomic bomb. The project began in earnest in 1939.

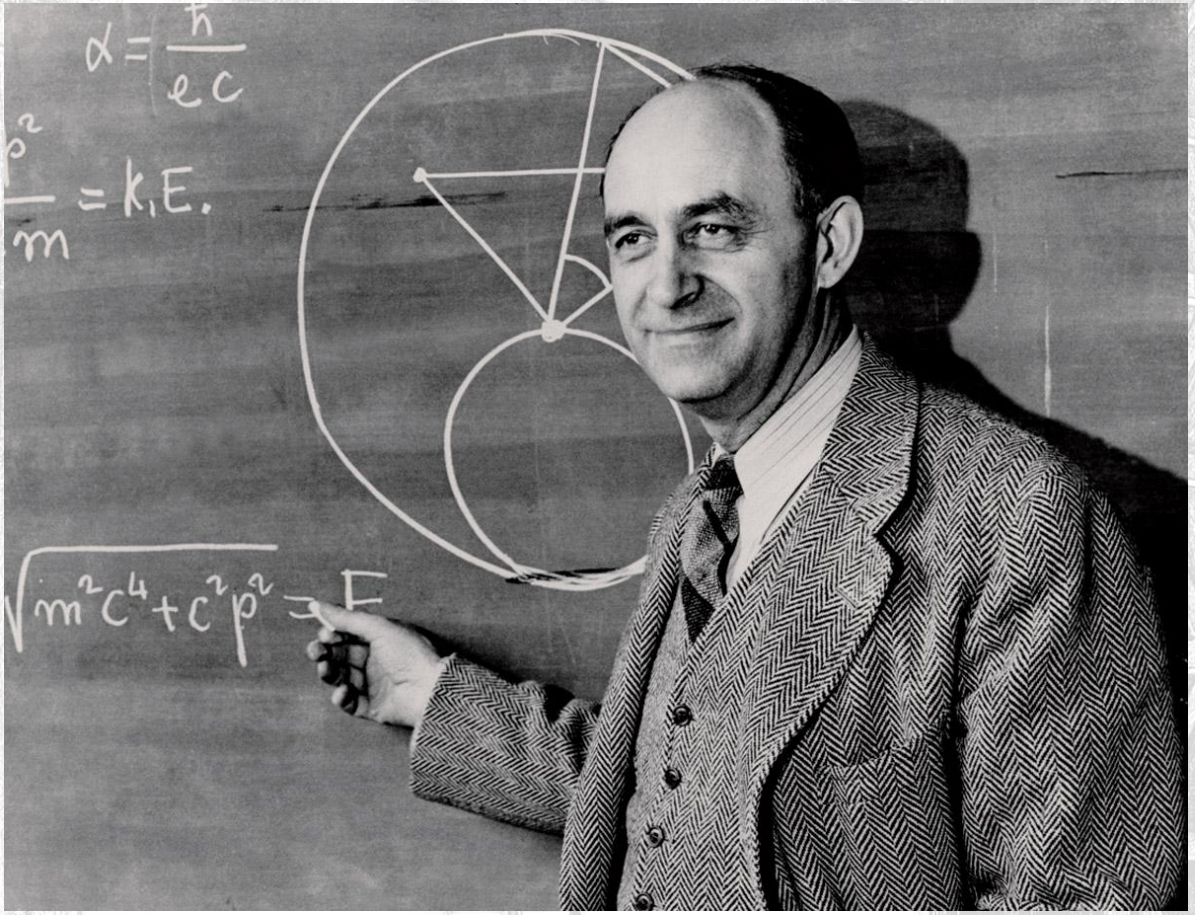
- *Robert Oppenheimer* led the team of Scientists working on the project, while Major General *Leslie Groves* was in-charge of the military.

- The Manhattan Project prioritised Enrico Fermi's (Nobel Prize in Physics, 1938) construction of a *nuclear fission reactor* to synthesise plutonium from uranium.

Nuclear Weapons



Nuclear Weapons



- Enrico Fermi (Nobel Prize in Physics, 1938).

Nuclear Weapons

- The first human-made self-sustaining nuclear chain-reaction was initiated on 2nd December 1942 at the University of Chicago, USA, in an experiment led by the Physicist Enrico Fermi.

- The reactor was built on a squash court under the stands at one of the university's sports fields.

- **Question:** What does the location of the reactor tell you about the Scientist's and United States Government's approach to the Manhattan Project?

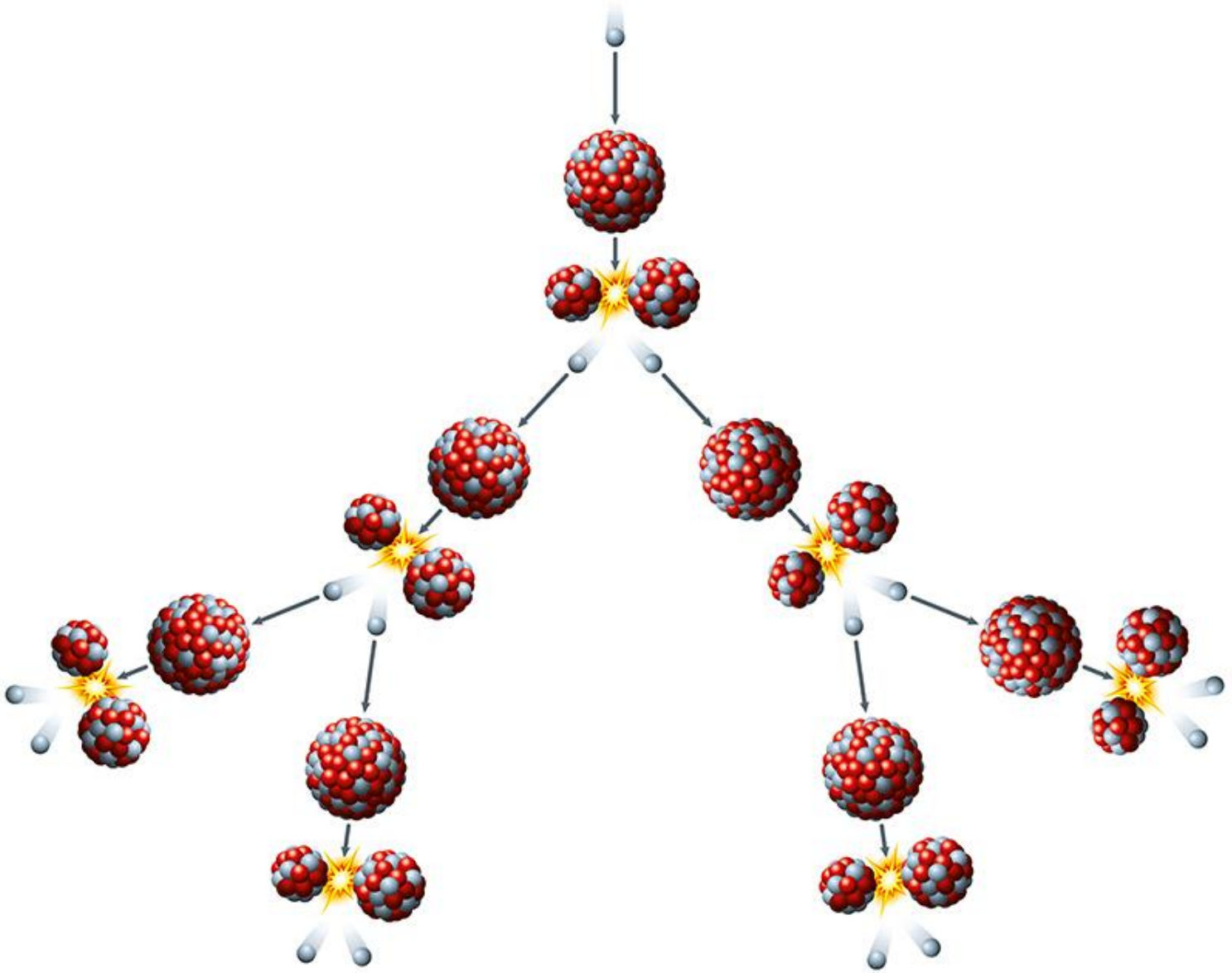
Nuclear Weapons

- **Answer:** To build an untested nuclear fission reactor, which has the potential to *melt down* (imagine the Chernobyl nuclear disaster) in a highly populated area shows the urgency with which the Allies were trying to develop the world's first atomic bomb.

Nuclear Weapons

- **Question:** How does such a relatively small mass of radioactive material produce such an enormous amount of energy?

Nuclear Weapons



Nuclear Weapons

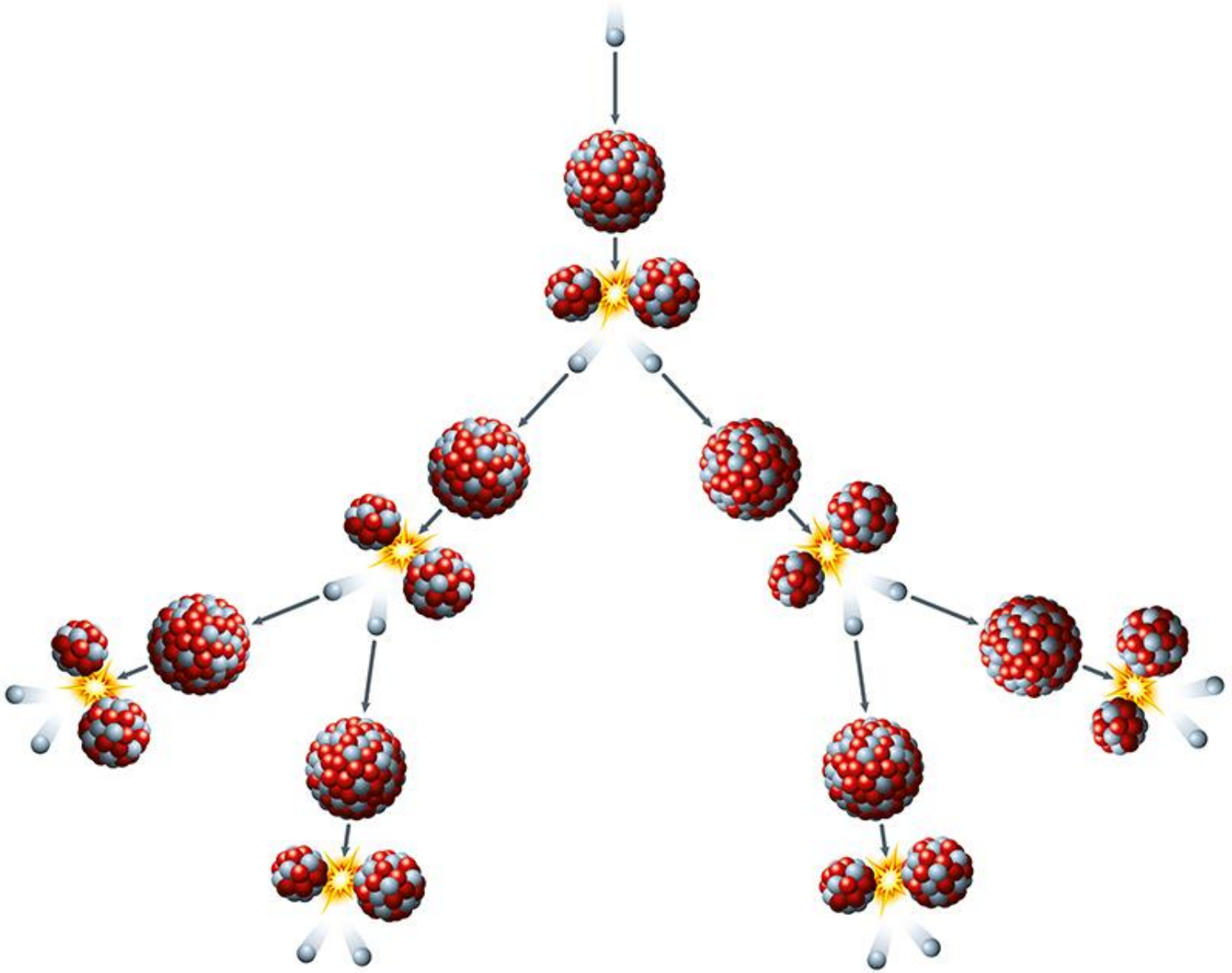
- **Answer:** What it is *not*:

It is *not* the result of a *chemical reaction*.
It is *not* the result of *nuclear fusion*.

- When the nucleus of a ^{235}U atom is struck by a neutron it undergoes *fission*, forming two stable nuclei, *more neutrons* and *energy*.

- If ^{235}U is of a sufficiently *high purity* (referred to as *weapons grade*) and exceeds a certain *critical mass*, then the *fission* of one ^{235}U nucleus will result in a *chain-reaction*, that releases an enormous amount of *energy*.

Nuclear Weapons



Nuclear Weapons

- Video: Simulation of a Nuclear Chain Reaction – 1 min. 51 sec.

Nuclear Weapons

- When the nucleus of a ^{235}U atom is struck by a neutron and undergoes fission, *0.1% of its mass is converted into energy*.

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2\,^{1}_{0}n$$

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3\,^{1}_{0}n$$

- The energy that is released can be calculated using Einstein's famous equation…

Nuclear Weapons

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- The energy that is released can be calculated using Einstein's famous equation… …$E = mc^2$

E = energy / joules

m = mass / kilograms

c = speed of light = 300 000 000 ms^{-1}

Nuclear Weapons

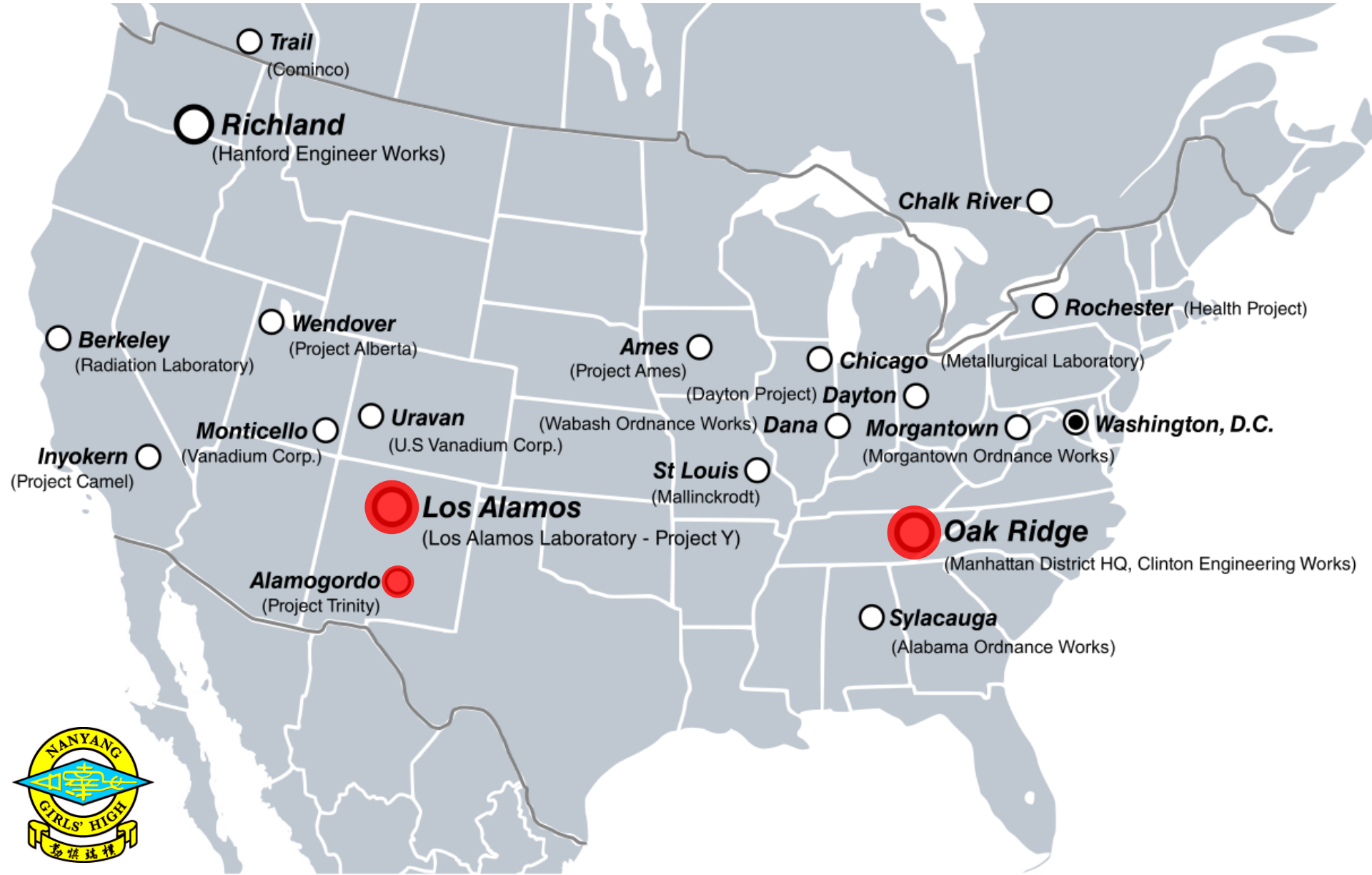
- Energy is released in the form of kinetic energy (motion of the particles) and electromagnetic radiation (gamma rays or γ-rays).

- According to Einstein's equation $E = mc^2$, one kilogram of ^{235}U, when converted into pure energy, will release…

…the same amount of energy as detonating 21 500 000 000 kg of conventional explosive…

…the same amount of energy as burning 2 630 000 000 *l* of petrol.

Nuclear Weapons



Nuclear Weapons

- **Question:** Why was the Manhattan Project spread over so many different locations?

Nuclear Weapons

- **Answer:** The Manhattan Project was *top secret*. The research and industrial manufacturing were spread widely over many different locations in order to make it impossible for anybody to piece together what was happening and how it was happening. Even workers at specific locations did not know exactly what they were working on, except that it was something to help with the war effort. This had some negative consequences on moral.

Nuclear Weapons

Nuclear Weapons

- The vast K-25 Plant, part of the Oak Ridge site of the Manhattan Project.
- Uranium is a mixture of ^{235}U (0.7%) and ^{238}U (99.3%), but only the ^{235}U isotope is *fissile*.
- The first atomic bomb required 56 kg (critical mass) of weapons grade (85% pure) ^{235}U.
- In order to purify the ^{235}U isotope, uranium was converted into gaseous uranium(VI) fluoride, UF_6.
- **Question:** How could you separate $^{235}UF_6(g)$ from $^{238}UF_6(g)$?

Hint: M_r $^{235}UF_6$ = 349 and M_r $^{238}UF_6$ = 352.

Nuclear Weapons

- **Answer:** One method used to separate the lighter ^{235}U isotope from the heavier ^{238}U isotope was *gaseous diffusion*.

- Uranium was converted into uranium(VI) fluoride. In the gaseous state, the *lighter molecules* of $^{235}UF_6$ *diffuse faster* than the heavier molecules of $^{238}UF_6$.

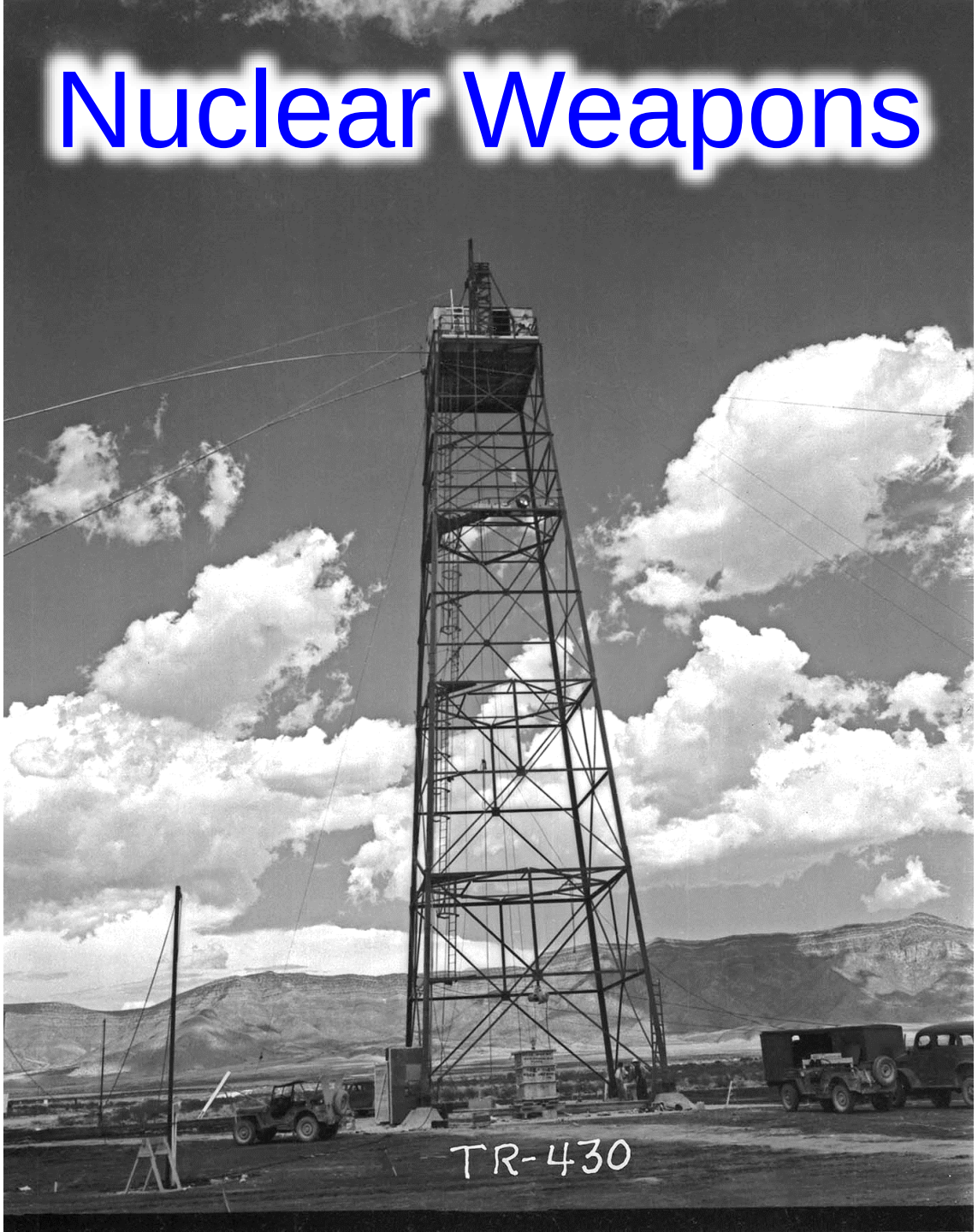
Nuclear Weapons

Nuclear Weapons

- The first atomic weapon that was made and detonated was known simply as *the gadget*.

- This photograph shows *the gadget* being prepared at the *Trinity test site* at Alamogordo in New Mexico.

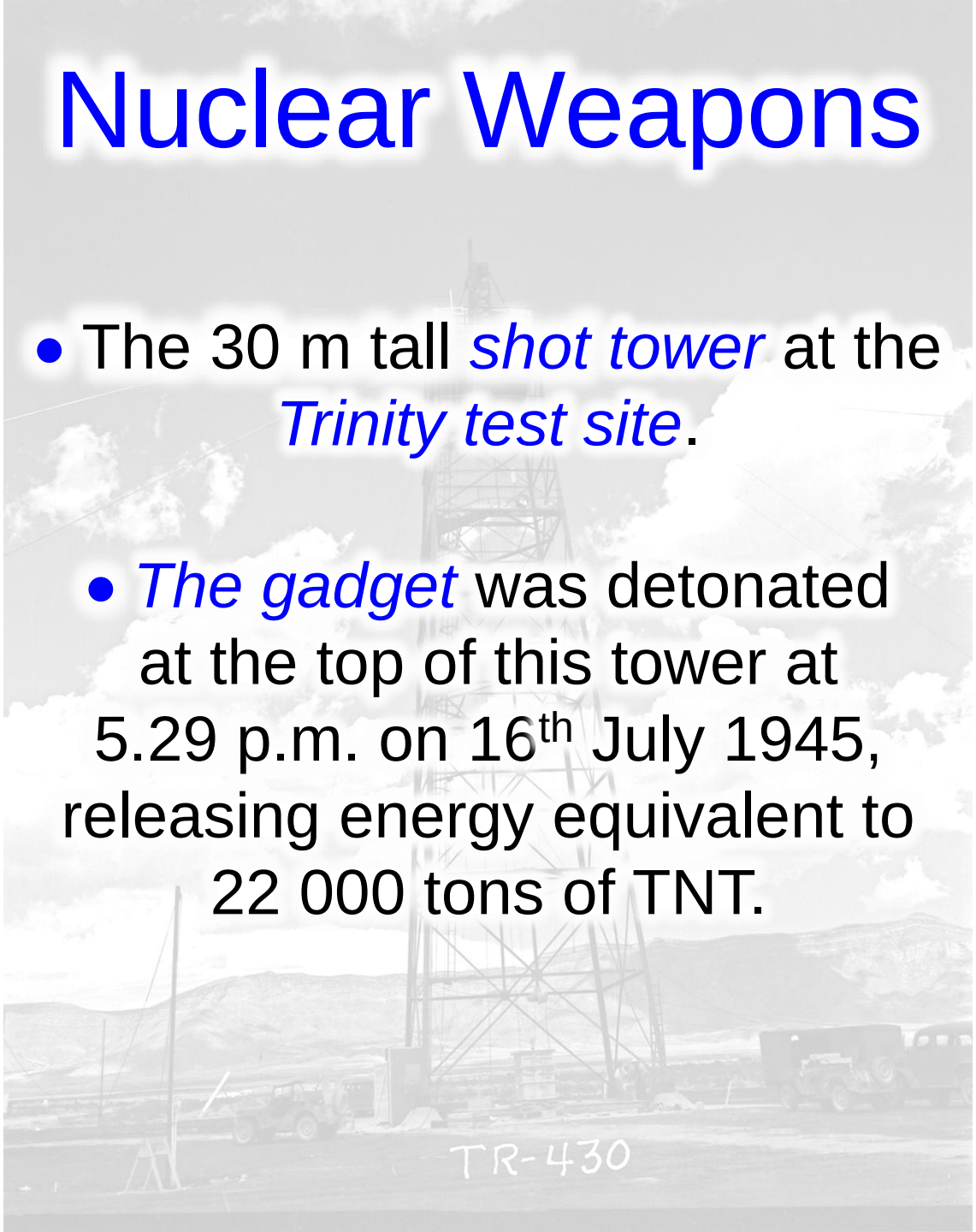
Nuclear Weapons



Nuclear Weapons

- The 30 m tall *shot tower* at the *Trinity test site*.

- *The gadget* was detonated at the top of this tower at 5.29 p.m. on 16th July 1945, releasing energy equivalent to 22 000 tons of TNT.



Nuclear Weapons

"I am become death, the destroyer of worlds."

- Bhagavad Gita – Hindu Scripture.

Nuclear Weapons

"We knew the world would not be the same."

- Robert Oppenheimer.

Nuclear Weapons

- The first test of a nuclear weapon was carried out on 16th July 1945. This photograph taken nine seconds after the *Trinity* detonation shows early formation of the familiar mushroom cloud.

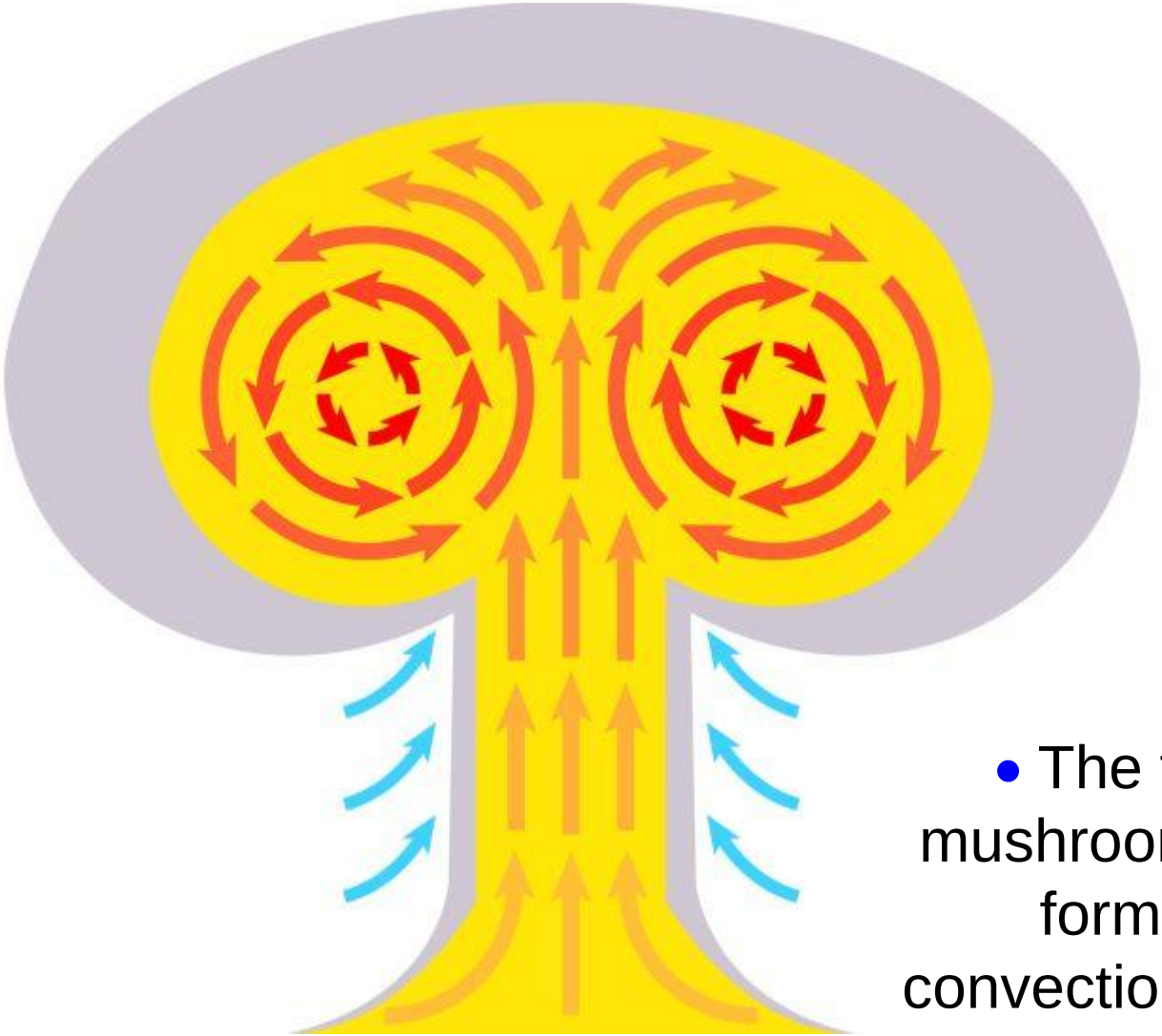
Nuclear Weapons

- Before the Trinity test, Physicists had to calculate whether or not energy released by detonating the world's first atomic bomb would *ignite the Earth's atmosphere*.

Nuclear Weapons

- Video: The Trinity test held on 16th July 1945 – 25 sec.
- Footage recorded approximately 9000 m away from the site of detonation.

Nuclear Weapons



- The familiar mushroom cloud is formed by convection currents.

Nuclear Weapons

- Robert Oppenheimer (left) and Major General Leslie Groves (right) at the Trinity test site.

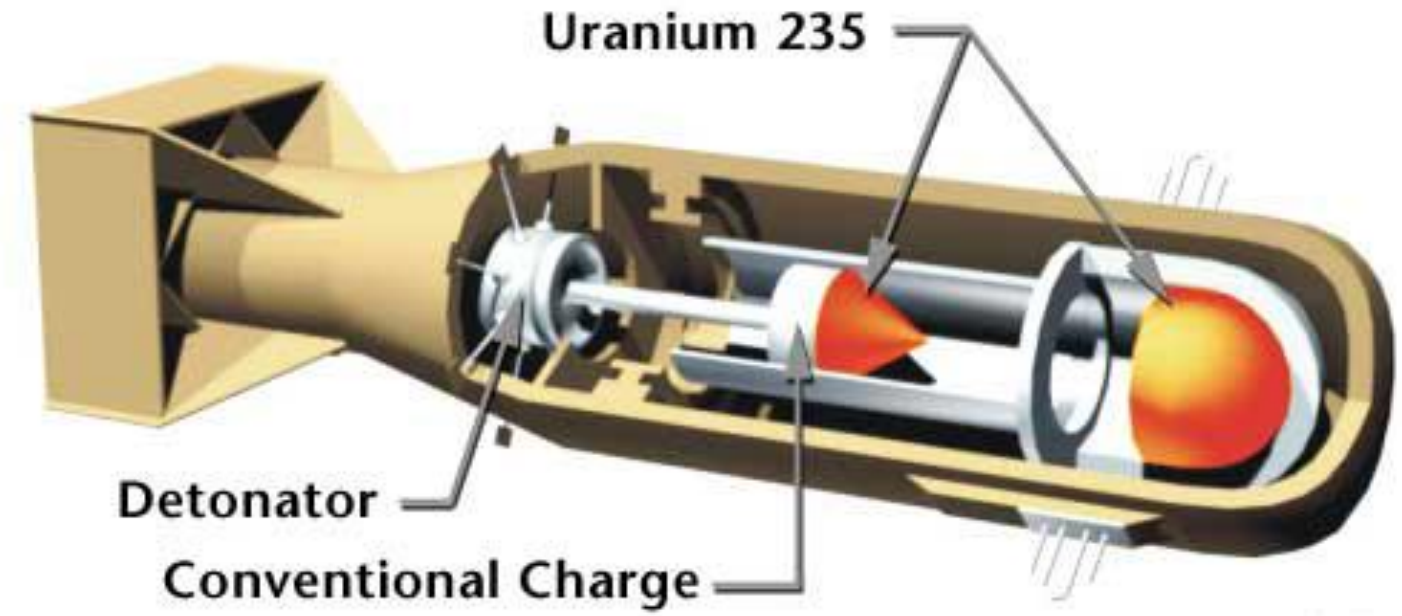
Nuclear Weapons

- **Question:** How do you pack something the size of a nuclear reactor into something the size of a bomb that can be carried by an aircraft?

Nuclear Weapons

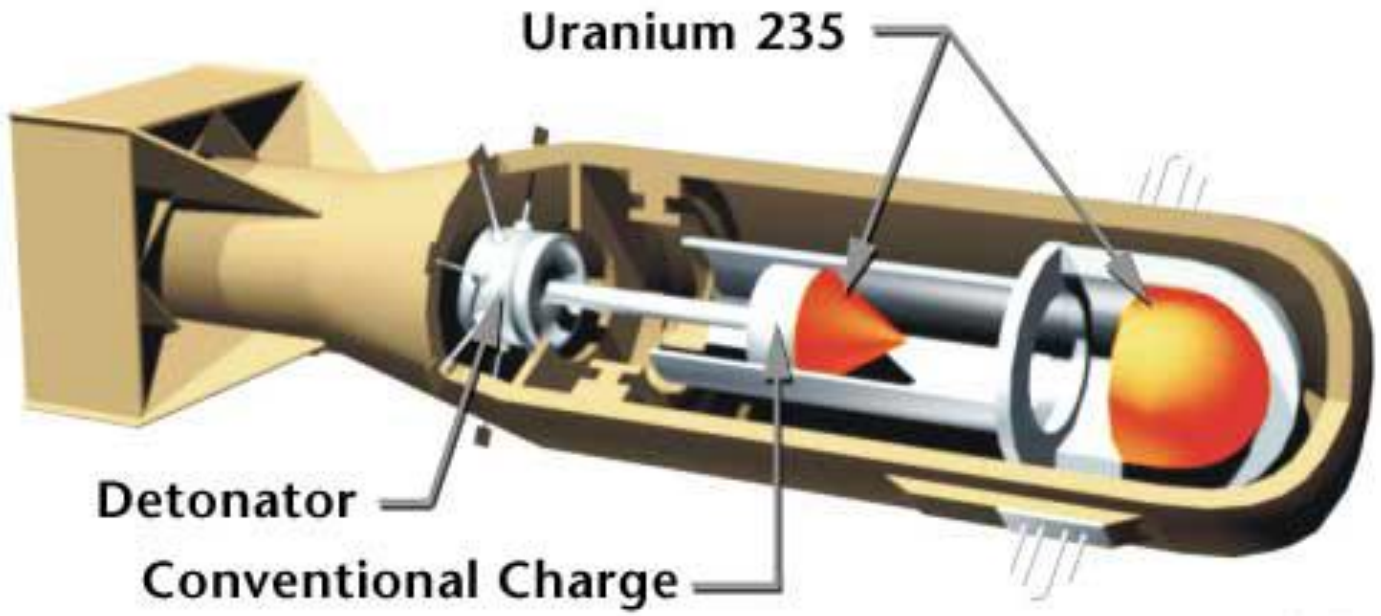
- **Answer:** "*Little Boy*" – the atomic bomb that was detonated over Hiroshima, Japan, on 6th August 1945. The explosion directly killed an estimated 70 000 people.

Nuclear Weapons



- "Little Boy" contained approximately 50 kg of enriched ^{235}U, which was detonated by a *gun-type* mechanism.

Nuclear Weapons



- One piece of ^{235}U was fired into a second piece of ^{235}U, with the two combined pieces exceeding the *critical mass* required for *sustained nuclear fission* to take place.

Nuclear Weapons

Nuclear Weapons

- Boeing B-29 Superfortress, *the Enola Gay*, photographed at an aviation museum in Virginia, USA.
- The pilot, Colonel Paul Tibbets, named the aircraft after his mother, Enola Gay Tibbets.
- The Enola Gay took off from the Northern Mariana Islands, a six hour flight time from Japan, accompanied by two other planes.
- Just in case the Enola Gay crashed on take-off, “Little Boy” was not armed for detonation until after the plane was in the air.

Nuclear Weapons

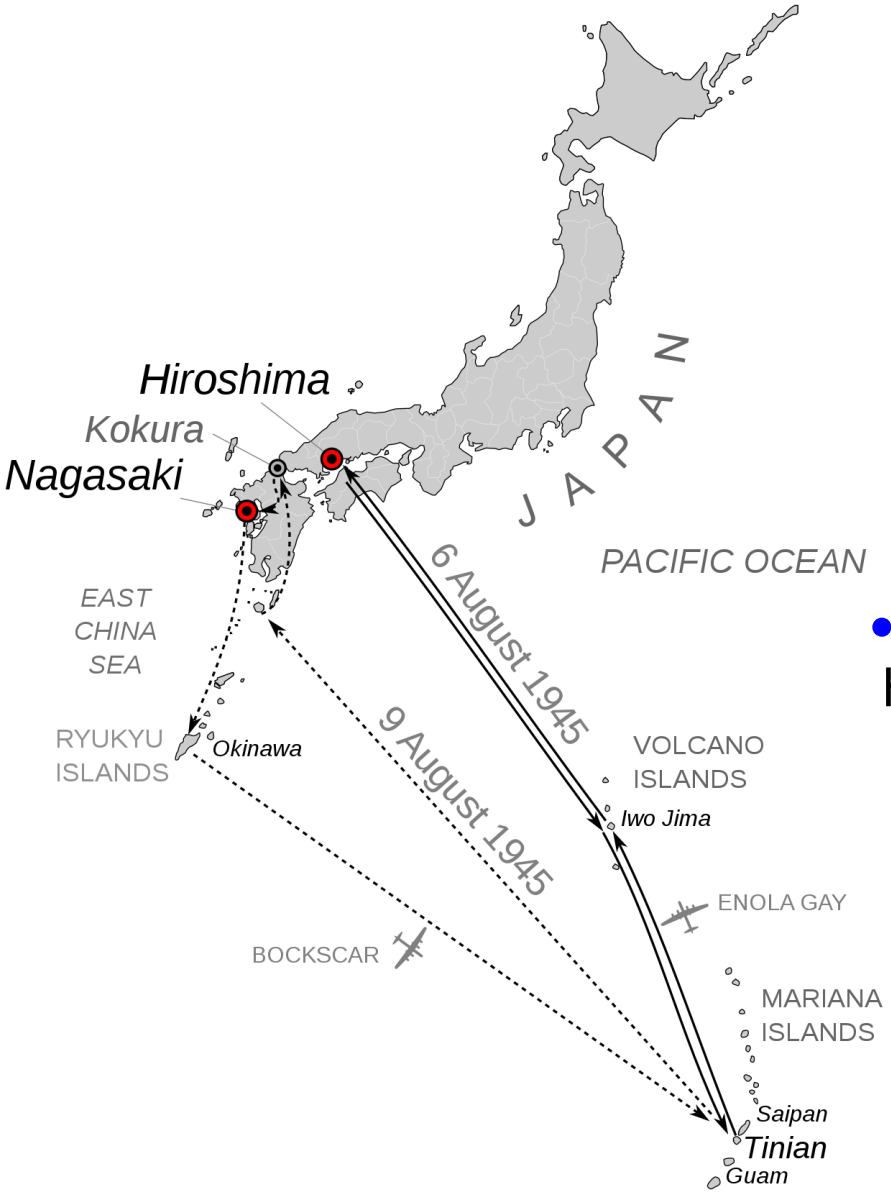
- **Question:** Why was the aircraft silver, and not painted in camouflage colours?

Nuclear Weapons

- **Answer:** The aircraft would have been close to the blast when the atomic bomb exploded. The aircraft's *silver coating would help to reflect the heat and radiation from the blast*, reducing any possible damage to the plane.

Nuclear Weapons

- Map of the routes flown by the B-29 bombers on 6th August 1945 (Hiroshima) and 9th August 1945 (Nagasaki).



- Three B-29s flew on each mission:
  - → Bomber.
  - → Instruments.
  - → Photography.
- The B-29s flew too high to be engaged by Japanese fighters and air defence.

Nuclear Weapons

Nuclear Weapons

- "Little Boy" exploded over Hiroshima at 8.15 a.m. on 6th August 1945.

- The bomb fell for 44.4 seconds before it exploded 600 metres above the ground.

- The bomb was designed to explode *above the ground*, rather than on the ground, to reduce the amount of radioactive dust or *fallout*.

- The detonation of this single nuclear weapon released the same amount of energy as ~15 000 tons of conventional explosive.

Nuclear Weapons

- **Question:** In what form(s) does the damage from an atomic bomb manifest itself?

Nuclear Weapons

- **Answer:** The damage from a atomic bomb comes in three distinct forms:

1. *Blast* – the blast is the result of rapidly expanding hot air that has been heated by radiation. This pressure wave or shock wave travels out in all directions faster than the speed of sound (343 ms^{-1}).

2. *Fire* – the initial effect of the explosion is a blinding light, accompanied by radiant heat from the fireball. The Hiroshima fireball was 370 m in diameter, with a surface temperature of 6 000°C.

3. *Radiation* – fallout is dust and ash contaminated with highly radioactive fission products. Radiation can burn, and can cause mutations to DNA, leading to cancer.

Nuclear Weapons

- Video: Hiroshima – Dropping the Bomb © BBC: 4 mins. 12 sec.

Nuclear Weapons

- The explosion at Hiroshima was recorded at 8.15 a.m. on a wrist watch that was found in the ruins.

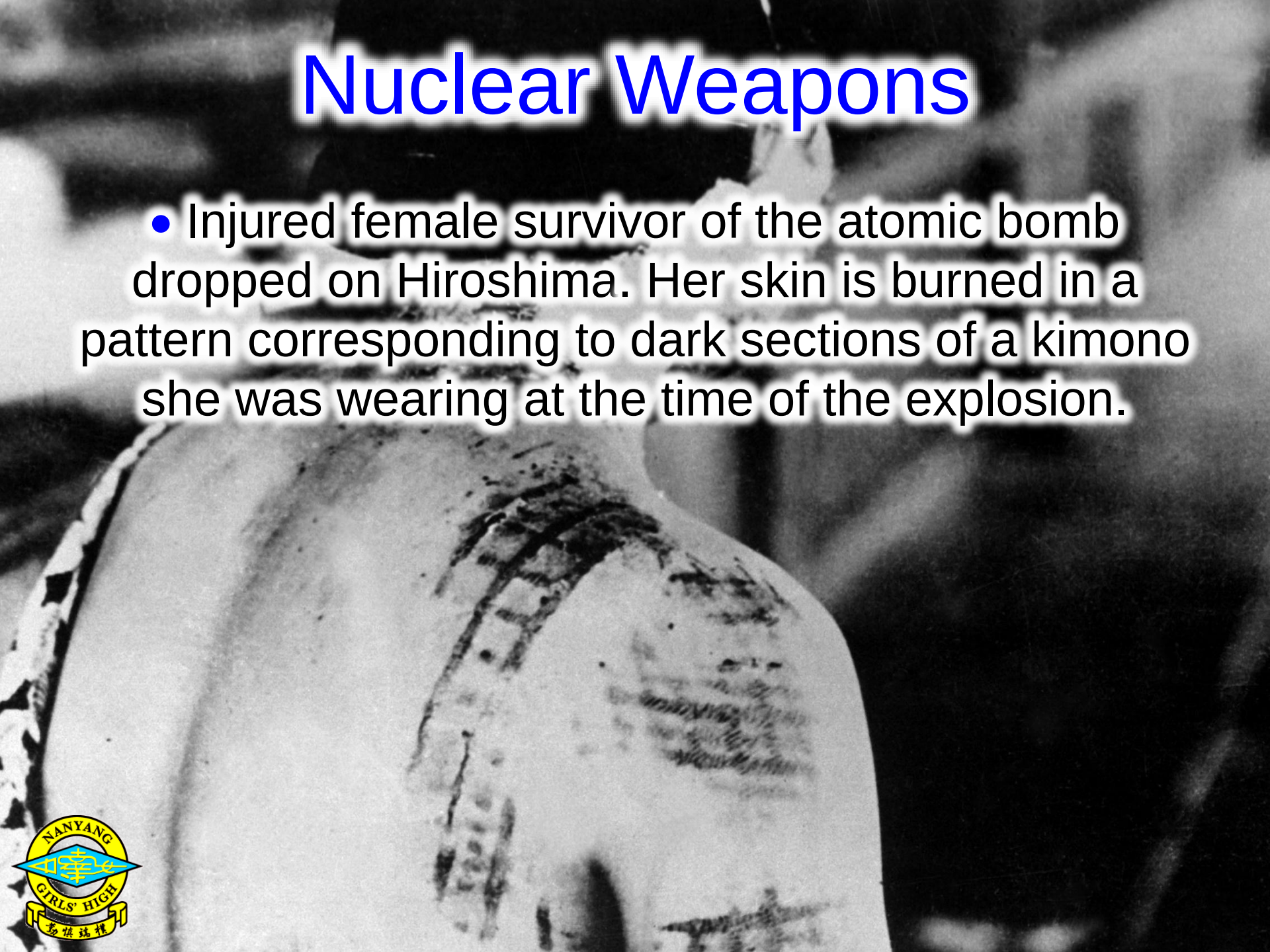
Nuclear Weapons

- Wrecked framework of the Museum of Science and Industry in Hiroshima, Japan.

Nuclear Weapons

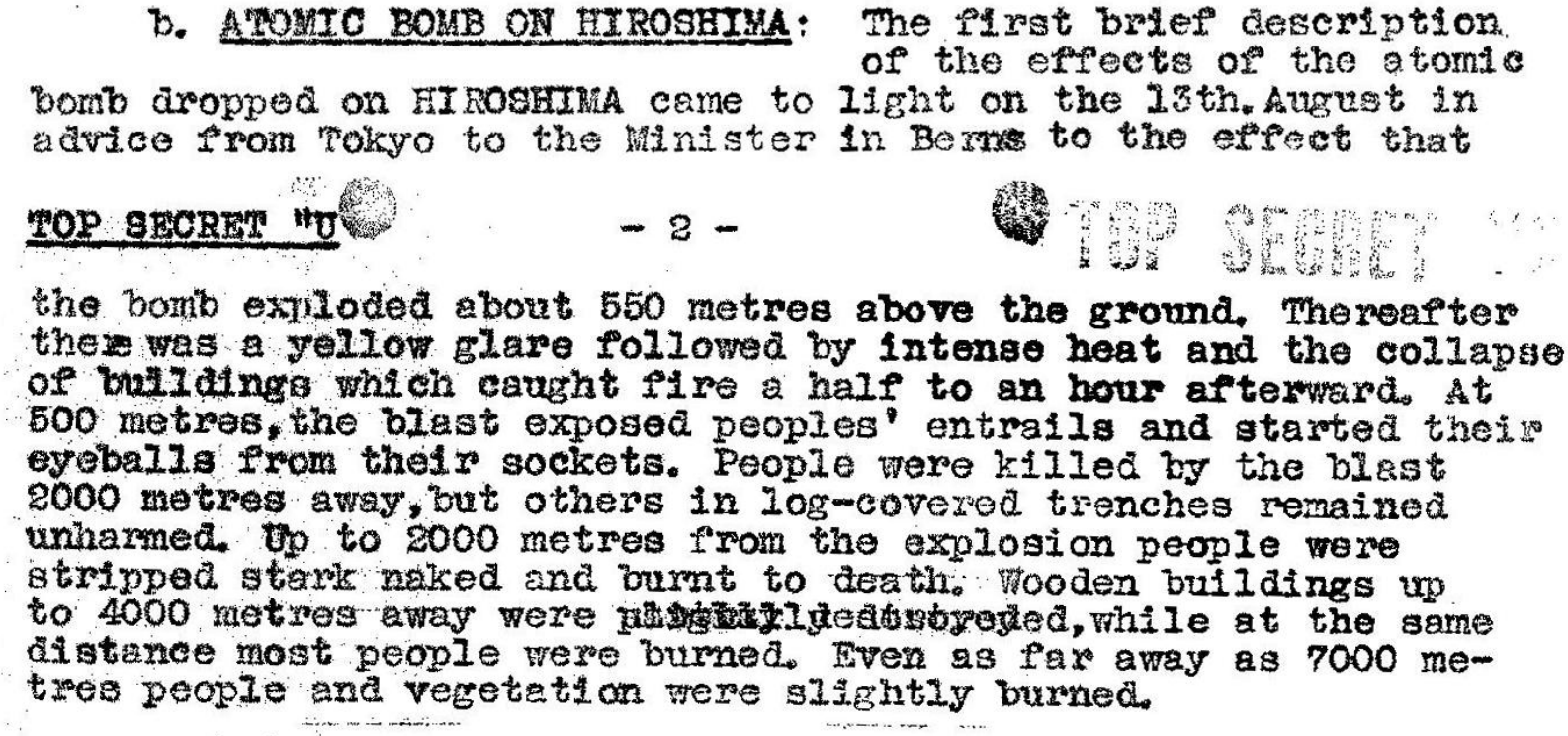
- In December 1996, the building was added to the UNESCO World Heritage List as a reminder to the entire world of the horrors of the atomic bomb, and as a symbol of global peace.

Nuclear Weapons



- Injured female survivor of the atomic bomb dropped on Hiroshima. Her skin is burned in a pattern corresponding to dark sections of a kimono she was wearing at the time of the explosion.

Nuclear Weapons



b. ATOMIC BOMB ON HIROSHIMA: The first brief description of the effects of the atomic bomb dropped on HIROSHIMA came to light on the 13th. August in advice from Tokyo to the Minister in Berne to the effect that

TOP SECRET "U

- 2 -

TOP SECRET

the bomb exploded about 550 metres above the ground. Thereafter there was a yellow glare followed by intense heat and the collapse of buildings which caught fire a half to an hour afterward. At 500 metres, the blast exposed peoples' entrails and started their eyeballs from their sockets. People were killed by the blast 2000 metres away, but others in log-covered trenches remained unharmed. Up to 2000 metres from the explosion people were stripped stark naked and burnt to death. Wooden buildings up to 4000 metres away were [illegible] destroyed, while at the same distance most people were burned. Even as far away as 7000 metres people and vegetation were slightly burned.

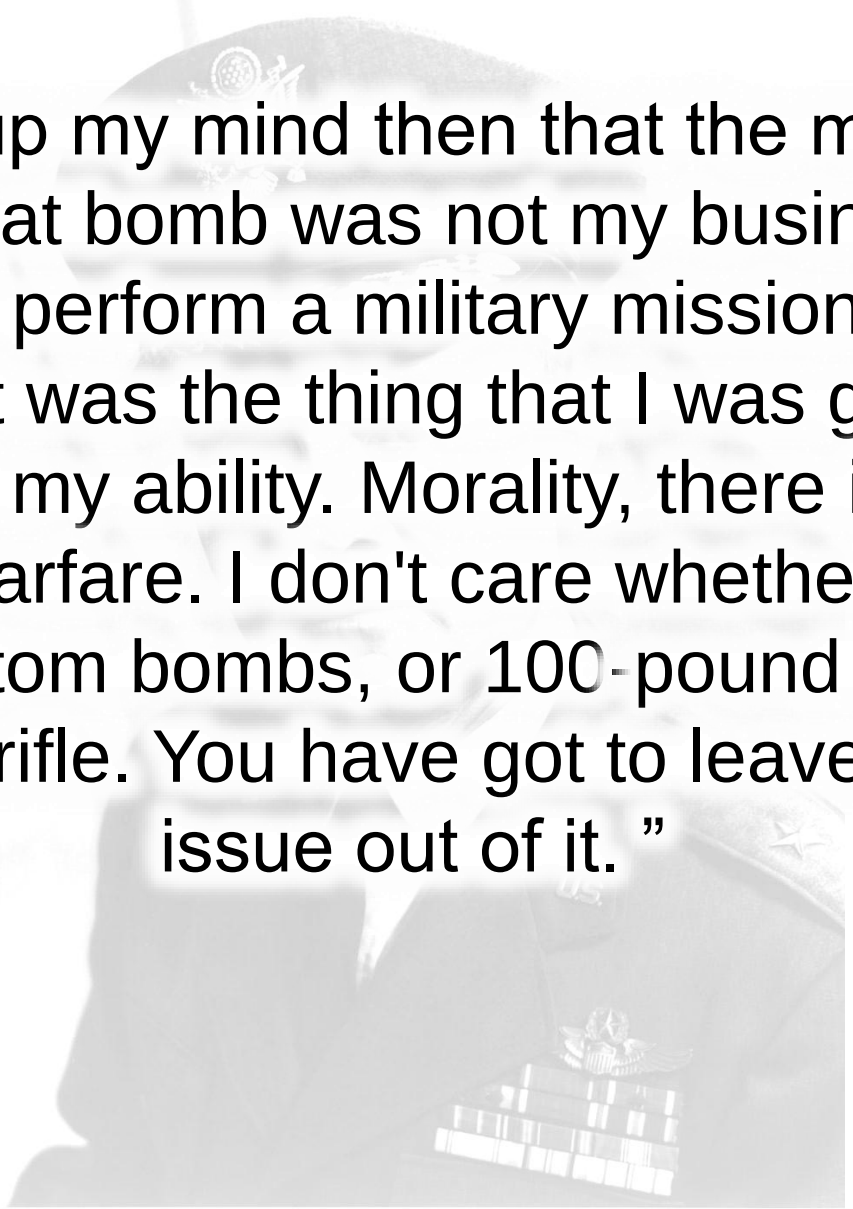
- Declassified top secret document that describes the effects of the atomic bomb dropped on Hiroshima.

Nuclear Weapons

- Brigadier General Paul W. Tibbets Jr. (1915 – 2007)

Nuclear Weapons

“ I made up my mind then that the morality of dropping that bomb was not my business. I was instructed to perform a military mission to drop the bomb. That was the thing that I was going to do the best of my ability. Morality, there is no such thing in warfare. I don't care whether you are dropping atom bombs, or 100-pound bombs, or shooting a rifle. You have got to leave the moral issue out of it. ”



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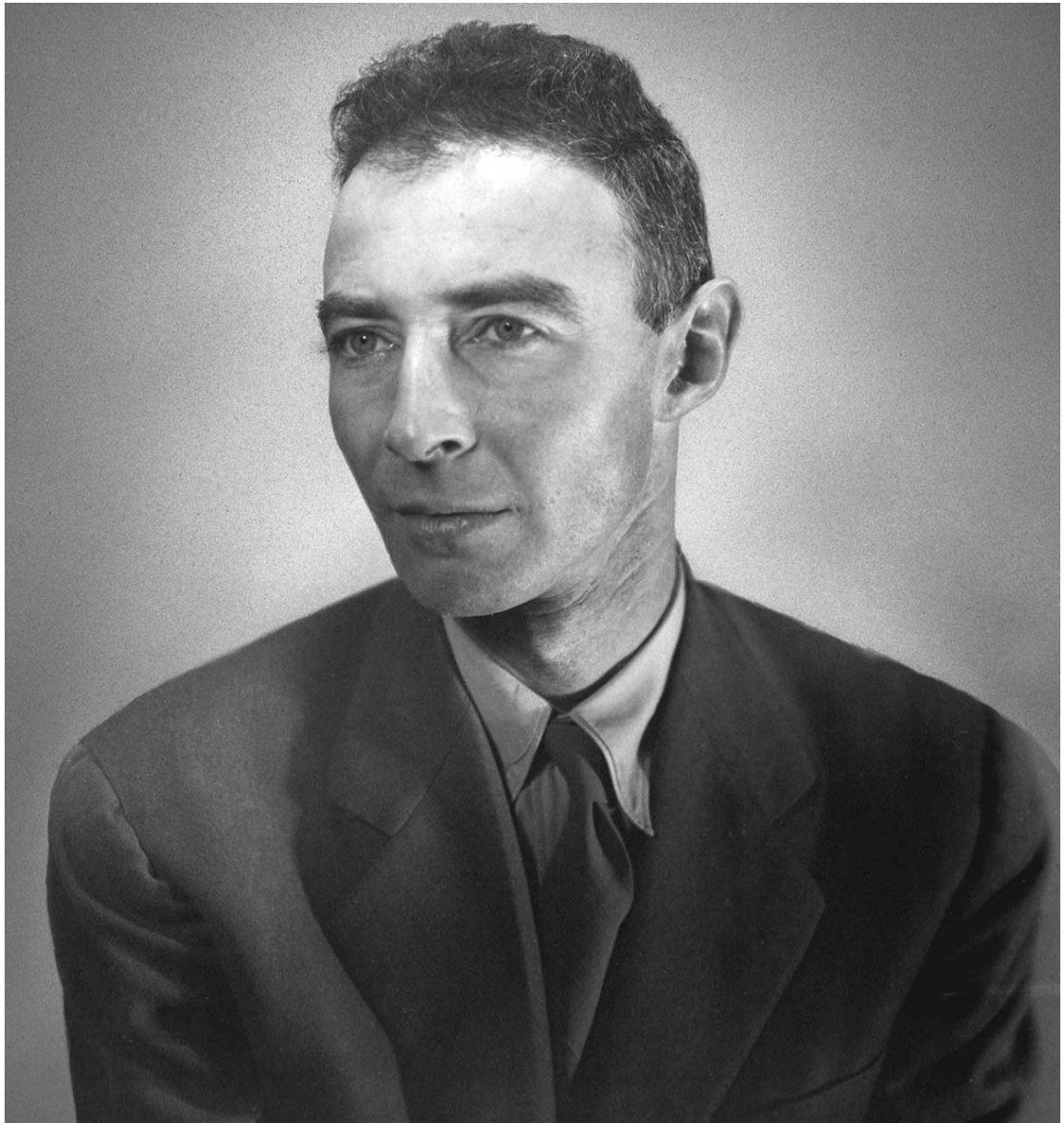
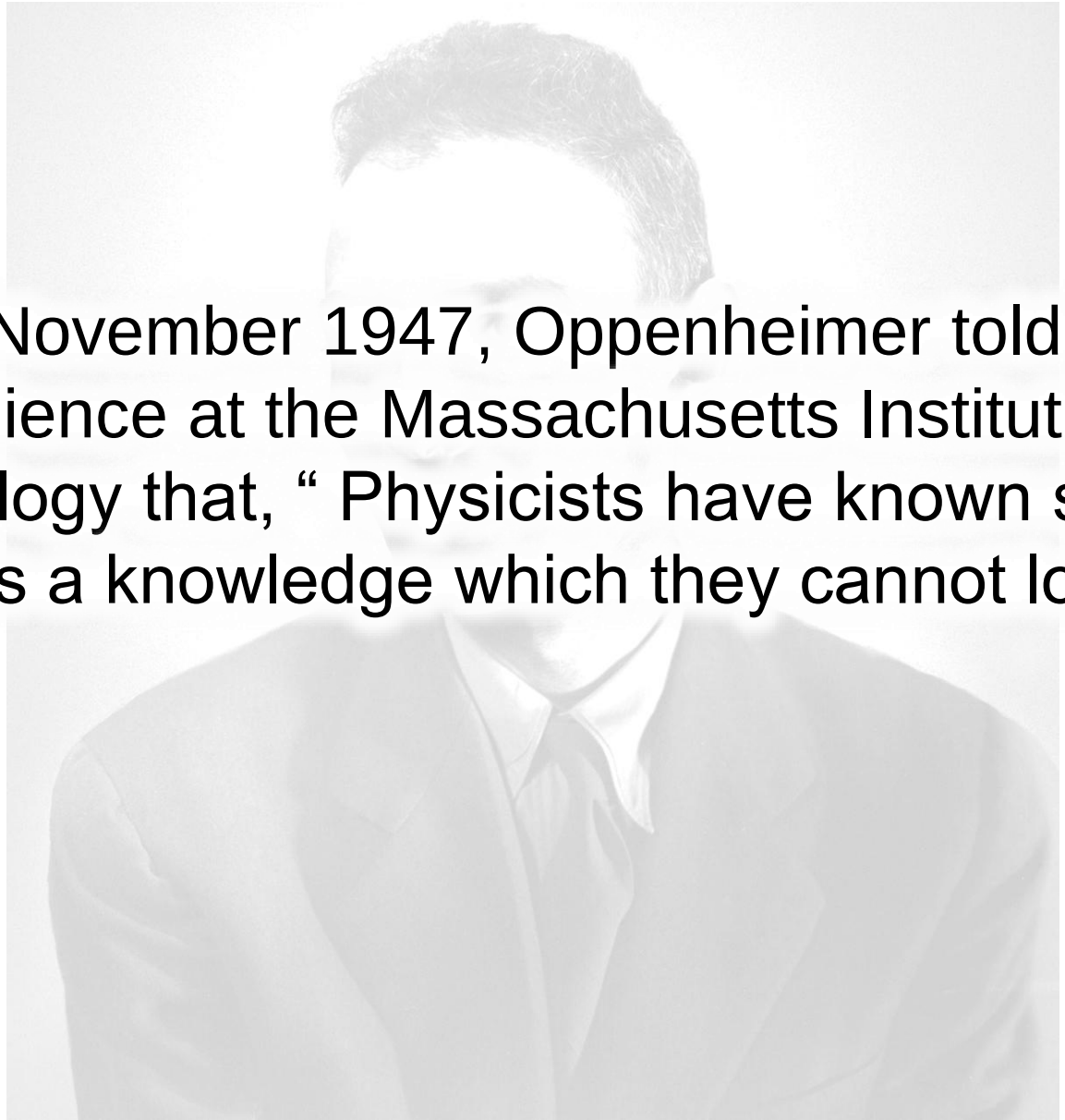
Nuclear Weapons



- Robert Oppenheimer (1904 – 1967)

Nuclear Weapons



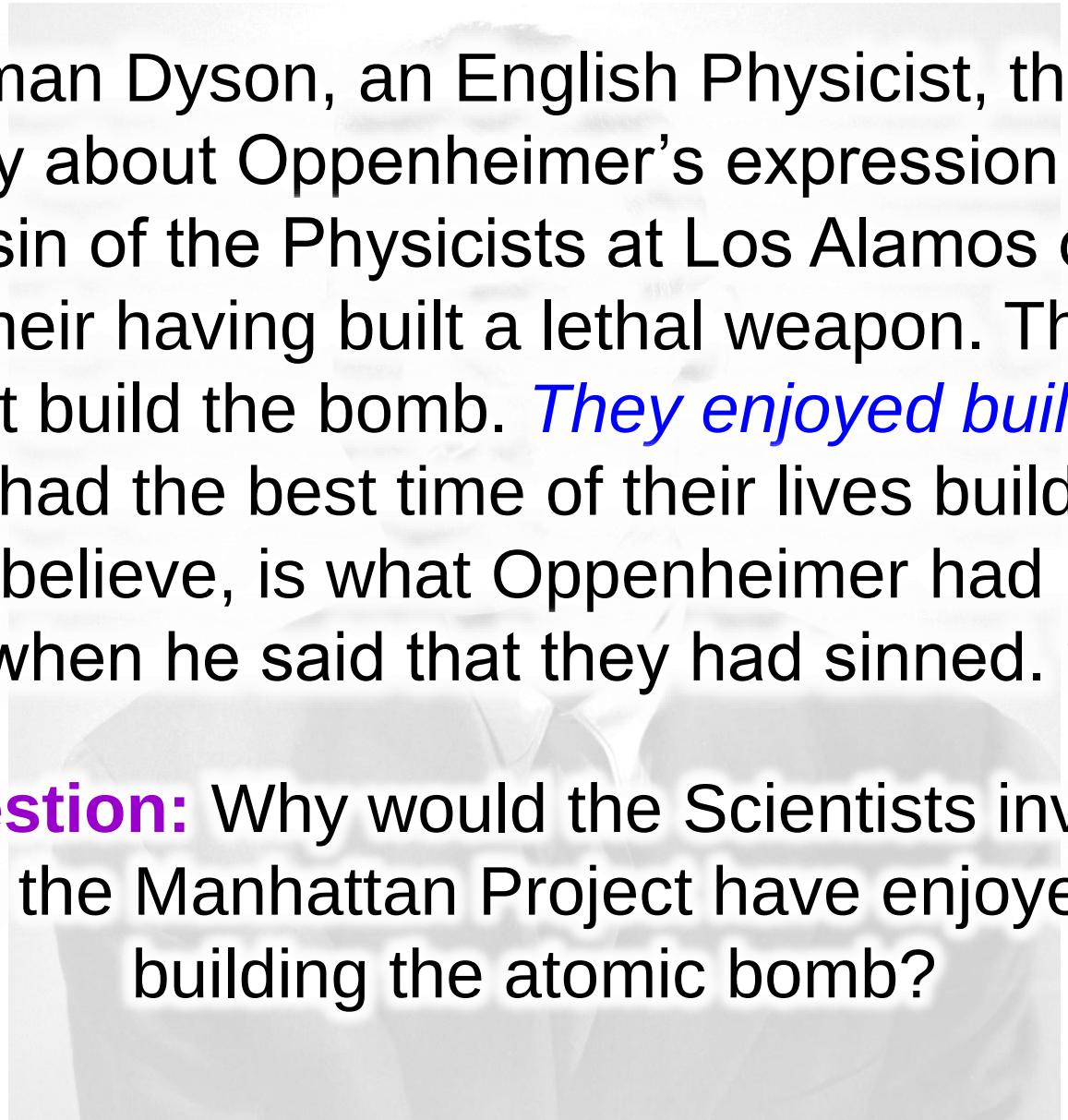
In November 1947, Oppenheimer told an audience at the Massachusetts Institute of Technology that, “ Physicists have known sin, and this is a knowledge which they cannot lose. ”

- Robert Oppenheimer (1904 – 1967)

Nuclear Weapons

Freeman Dyson, an English Physicist, thought carefully about Oppenheimer's expression of guilt. " The sin of the Physicists at Los Alamos did not lie in their having built a lethal weapon. They did not just build the bomb. *They enjoyed building it*. They had the best time of their lives building it. That, I believe, is what Oppenheimer had in mind when he said that they had sinned. "

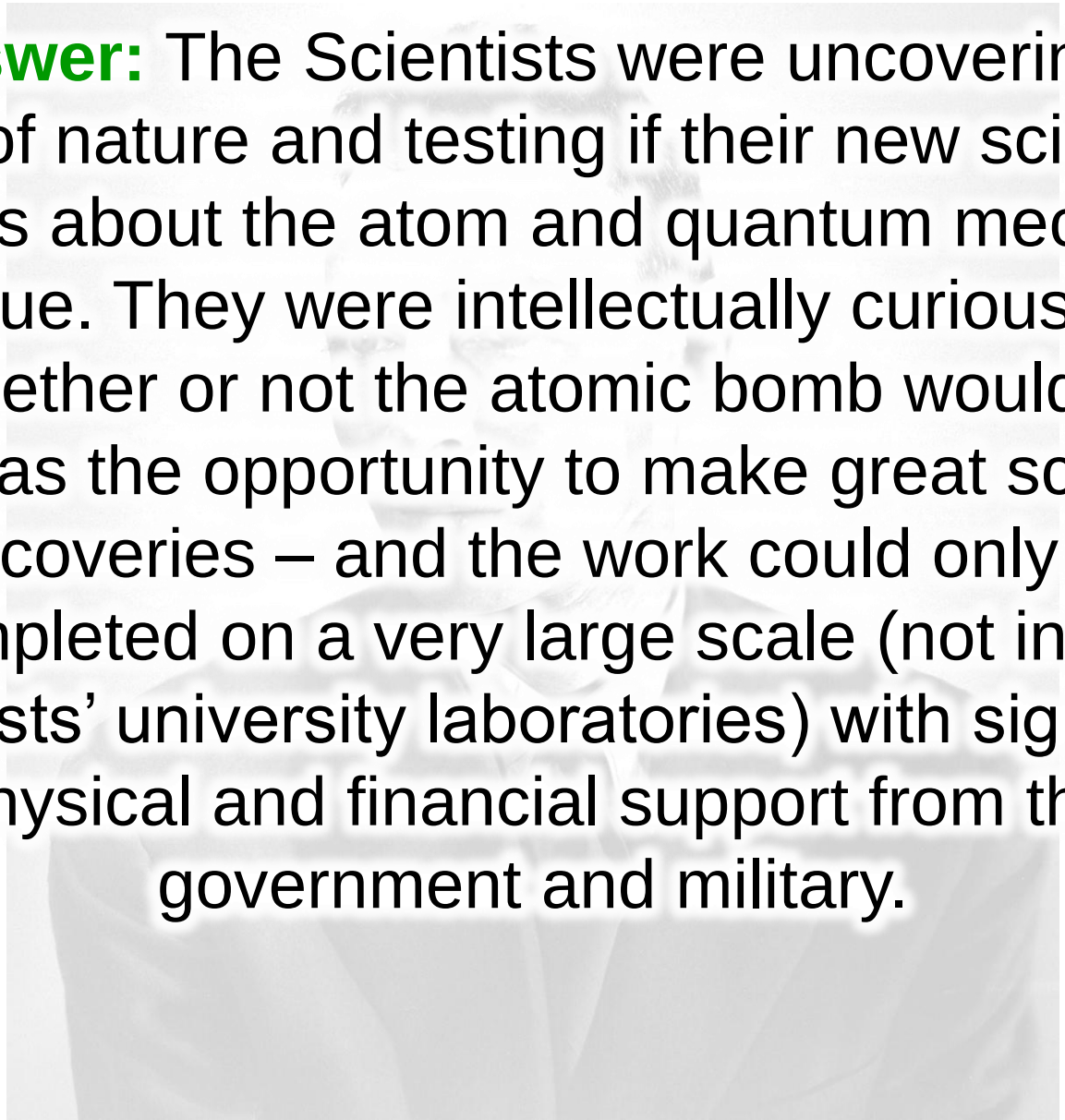
- **Question:** Why would the Scientists involved in the Manhattan Project have enjoyed building the atomic bomb?



- Robert Oppenheimer (1904 – 1967)

Nuclear Weapons

- **Answer:** The Scientists were uncovering the laws of nature and testing if their new scientific theories about the atom and quantum mechanics were true. They were intellectually curious to find out whether or not the atomic bomb would work. This was the opportunity to make great scientific discoveries – and the work could only be completed on a very large scale (not in the Scientists' university laboratories) with significant physical and financial support from the government and military.



- Robert Oppenheimer (1904 – 1967)

Nuclear Weapons

1. What events mark key moments in human history?

2. What drives scientific innovation? Would the Manhattan Project have taken place during peacetime?

3. How could people of conscience create weapons of mass destruction?

4. What is the purpose of Science?

5. What responsibilities does Science have to society?

6. Who determines what Science should do?

7. What are some positive outcomes from research into atomic weapons?

8. Is it acceptable to do Science for the sake of curiosity, without any care for the consequences?

Nuclear Weapons

Make Your Thinking Visible

- **Discussion:** What were the consequences of America's of bombing Hiroshima and Nagasaki using nuclear weapons?

- Short term.
- Long term.
- Environmental.
- Global.
- Political.

1. Facilitator **2.** Scribe **3.** Motivator
4. Time Keeper.

Nuclear Weapons

Make Your Thinking Visible

- **Discussion:** What other events have occurred in human history after which, "*We knew the world would not be the same*"?

1. Facilitator **2.** Scribe **3.** Motivator
4. Time Keeper.

Nuclear Weapons

Make Your Thinking Visible

- **Discussion:** "The research and development of nuclear weapons by America and her allies has been detrimental to humanity."

- Give two or three points in support.
- Give two or three points against.
- Your conclusion.

1. Facilitator **2.** Scribe **3.** Motivator
4. Time Keeper.

Nuclear Weapons

Make Your Thinking Visible

- **Individual:** Write a general statement (*generalisation*) to illustrate what you now understand about scientific progress and how it influences humanity.

- Try to use the conceptual lenses *conflict* and *change* in your statement.

Nuclear Weapons

Make Your Thinking Visible

- Key moments in human history are marked by significant technological or scientific events. For example, the iron age, nuclear age, space age, information age.

- Conflict drives scientific innovation, leading to significant advances in human knowledge that may benefit humanity. For example, the development of the atomic bomb during World War II and the Space Race during the Cold War.

Nuclear Weapons

- Robert Oppenheimer

- Accident at the Manhattan Project

- The Bomb Marker Inside Your Body

- BBC News Article: Robert Oppenheimer:
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Nuclear Weapons

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Nuclear Weapons

Presentation on:

Brighter than a Thousand Suns:
A Scientific Perspective on the History of the Atomic Bomb

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Nuclear Weapons

- Students will learn that the end of the World War II in the Asia-Pacific region was the result of dropping atomic bombs on Hiroshima and Nagasaki. Beyond learning about the atomic bomb being a significant turning point in the war, students will also learn how the bomb could be a terrible invention that brings great destruction, but in the long-run, it also brings great benefits to humankind.