Atomic Bomb Development
- Huge System Development -

原爆開発
―巨大システム開発―

2019.8.19-21

増井博―

Introduction

“Atomic bombs” were developed in just six years (1939-1945) despite the complexity and state-of-the-art science used.

As you know, the results of this project have caused tremendous damage to Japan.

The project name of the Atomic Bomb development was “Manhattan Project”.

I’d like to review from the view point of engineering.

Manhattan Project

Manhattan Project started from 1939 and
the atomic bombs were developed in 1945.

In just 6 years, some important discover and invention were achieved.

The project name comes from Manhattan
in New York where the headquarters was located.

The original project name was
「Laboratory for the Development of Substitute Materials」

Time line of Manhattan Project

1939 : Einstein Shirard's letter reaches Roosevelt.
1940年 :
1941 : Discovery of plutonium
1942 : Institute established in Los Alamos
1943 : Production of plutonium started
1944 : Successful development of implosion lens
1945 : Trinity experiment succeeded and
Atomic bombs dropped
in Hiroshima and Nagasaki.

Background

Nuclear development and nuclear physics were just beginning.

It was theoretically known that
it is possible to extract enormous
energy from nuclear fission（Special relativity）

However, no substance has been found that
generates neutrons by splitting and causes a chain reaction.

It was found out that uranium has that possibility.

Key scientist and engineer (1)

Robert Oppenheimer

Theoretical physicist
His work predicted many later finds, which include the neutron, meson and neutron star

Appointed as the head of the Manhattan Project scientists.

Initially, he was a “scientist” but gradually transformed into a “project leader”.

「The father of Atomic Bomb」

The surrounding evaluation is "Charisma"

https://upload.wikimedia.org/wikipedia/commons/0/03/JROppenheimer-LosAlamos.jpg

Key scientist and engineer (2)

Leo Szilard

A person who wrote a letter to
President Roosevelt with Einstein.

He realized early on the possibility of
“chain reaction by fission "
Originally he was a biologist and
showed that entropy is linked to
information obtained by observation.

https://upload.wikimedia.org/wikipedia/commons/1/1a/Leo_Szilard.jpg

Contributing to the development
of the world's first reactor built in Chicago

Key scientist and engineer (3)

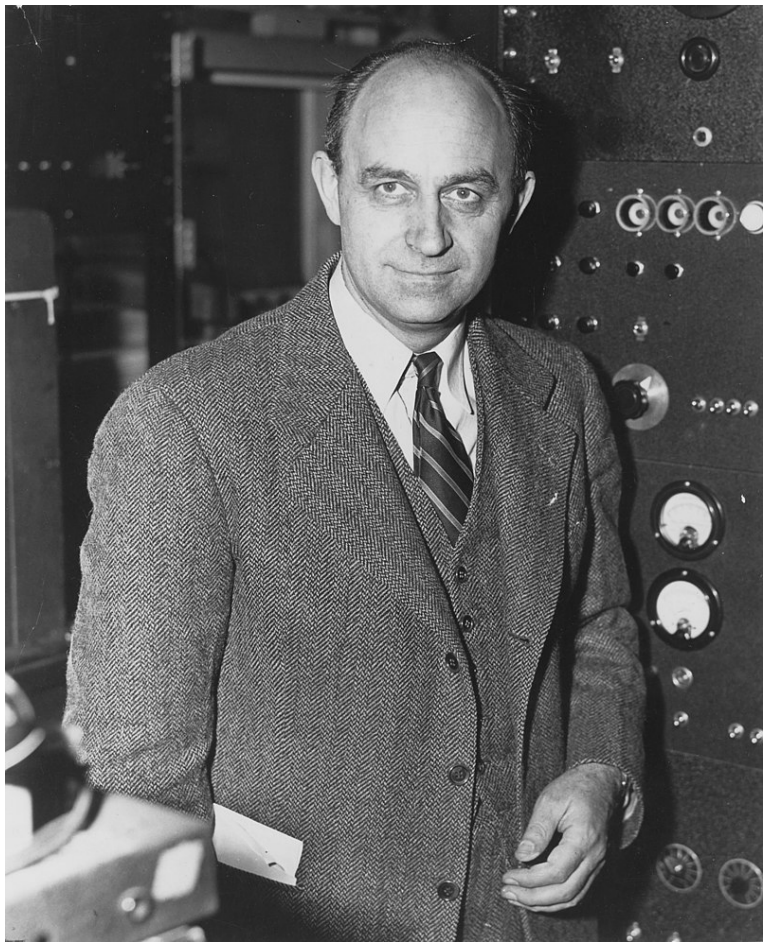
Enrico Fermi

The most important person
in the Manhattan Project
and the best performance
in both theory and experiment.

Building The world's first nuclear reactor
“Chicago Pile 1”
and based on that knowledge,
a nuclear reactor was built in
Hanford for plutonium production.

”Master of approximate”

There are many terms derived from his name.
Examples: Particles, statistics, balladox, etc.



https://upload.wikimedia.org/wikipedia/commons/thumb/d/d4/Enrico_Fermi_1943-49.jpg/800px-Enrico_Fermi_1943-49.jpg

Key scientist and engineer (4)

John von Neumann

Mathematician, Physicist,
Computer scientist
and polymath.

Implosion lens design
(provided that it is composed
of 32 faces)

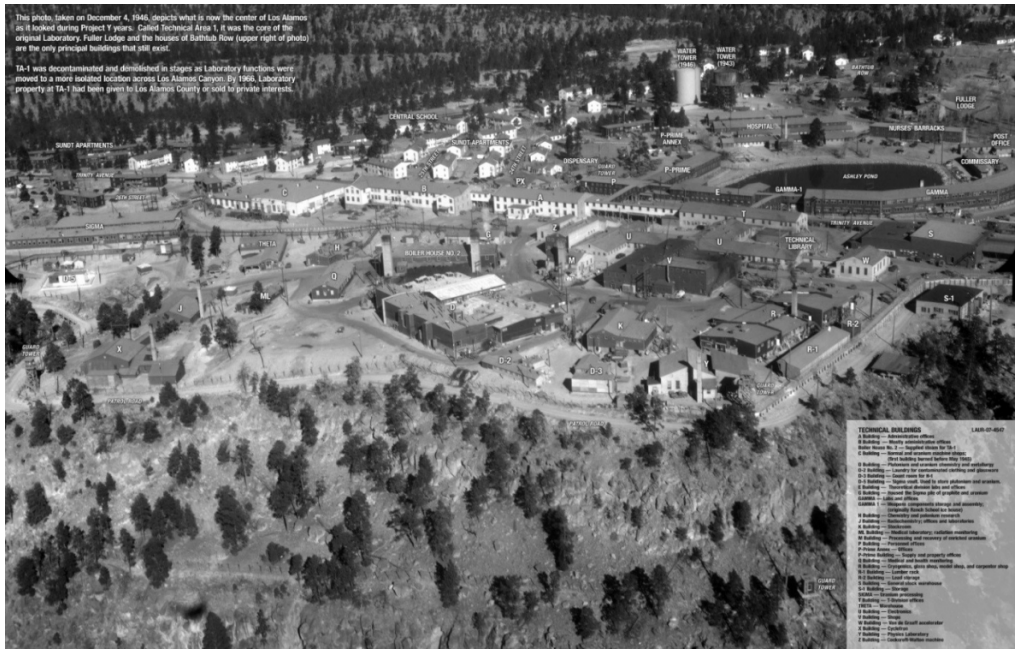
Significant contributions
to computer science
(Neumann computer)

https://upload.wikimedia.org/wikipedia/commons/5/5e/JohnvonNeumann-LosAlamos.gif

The person with the best brain in human history

Key sites

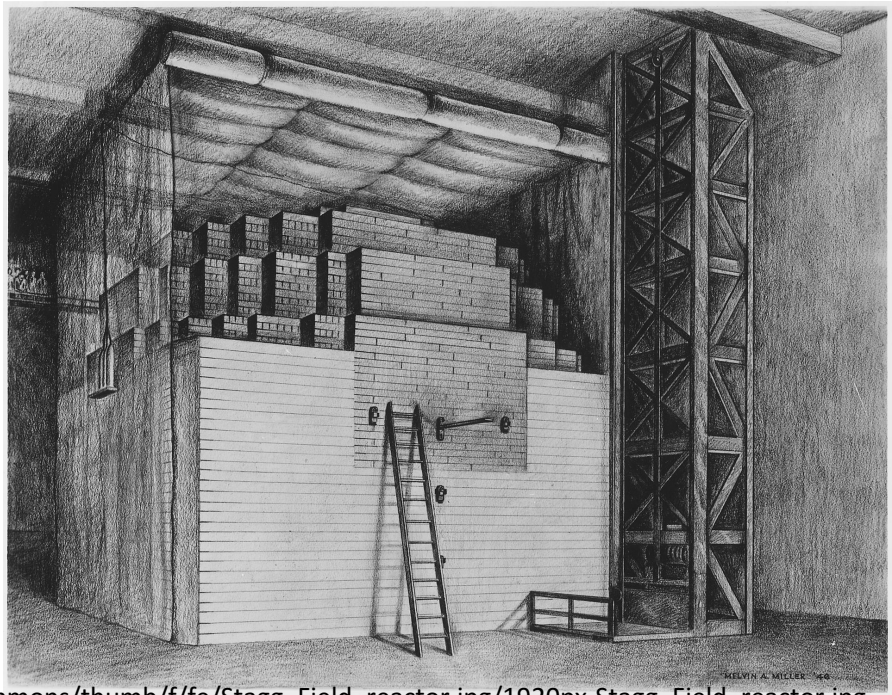
Los Alamos
It was called Site Y.
Center of Development and Neutron research



https://www.energy.gov/sites/prod/files/styles/borealis_default_hero_respondxl/public/LANL-Site-1946.jpg?itok=-8ez7xLe

Oak Ridge
Purification of uranium

Chicago
The world's first nuclear reactor (Chicago Pile 1),



https://upload.wikimedia.org/wikipedia/commons/thumb/f/fe/Stagg_Field_reactor.jpg/1920px-Stagg_Field_reactor.jpg

Hanford
Generation of plutonium

Cost

Hewlett, Richard G.; Anderson, Oscar E. (1962). *The New World, 1939–1946* (PDF). University Park: Pennsylvania State University Press. ISBN 0-520-07186-7. OCLC 637004643. Retrieved 26 March 2013.

Manhattan Project costs through 31 December 1945			
Site	Cost (1945 USD)	Cost (2018 USD)	% of total
Oak Ridge	$1.19 billion	$13.4 billion	62.90%
Hanford	$390 million	$4.4 billion	20.60%
Special operating materials	$103 million	$1.17 billion	5.50%
Los Alamos	$74.1 million	$835 million	3.90%
Research and development	$69.7 million	$786 million	3.70%
Government overhead	$37.3 million	$420 million	2.00%
Heavy water plants	$26.8 million	$302 million	1.40%
Total	$1.89 billion	$21.3 billion	

Annual budget of Japanese Space Development is $ 3 billion
(=3000億円)

Two types of Atomic Bomb

Two types of atomic bombs were developed
in a 6-year project

Uranium type

Use uranium 235 (natural uranium 238).
When a certain amount is collected,
it becomes a critical state and
a chain reaction occurs.
(One or more neutrons are generated in one reaction)
→Difficult to manufacture

Plutonium type

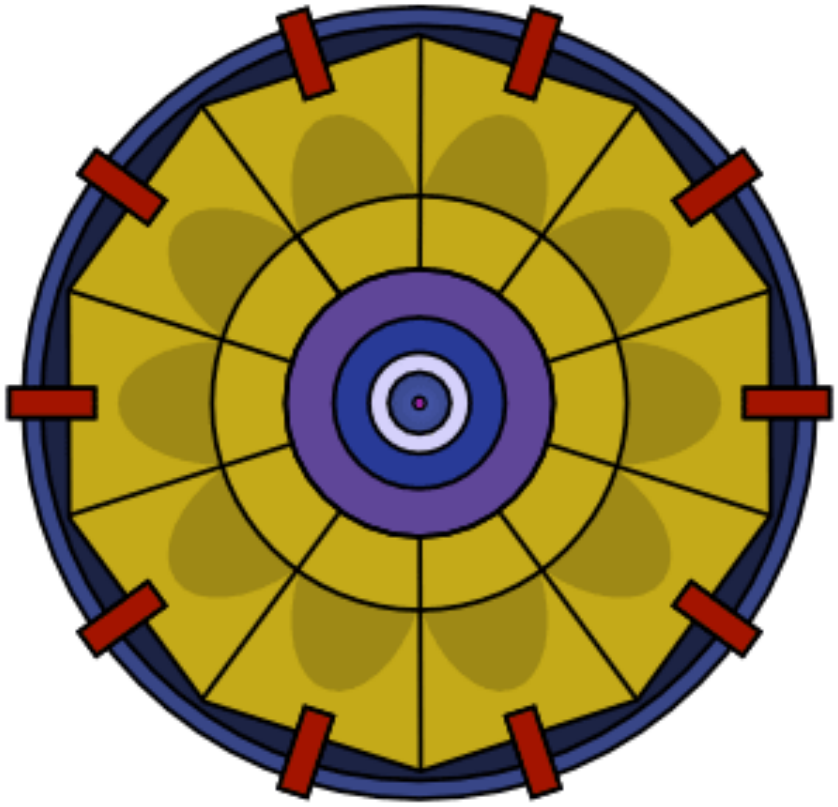
Compress plutonium with implosion lens,
achieve a critical value and causes a chain reaction.
→The current atomic bomb is this type

Explosion Lenz

In order to generate fission with plutonium, it is necessary to apply pressure uniformly to plutonium.

Although a shock wave is generated using gunpowder, if the plutonium is simply surrounded by a gunpowder and ignited, only the tip of the shock wave reaches the plutonium and pressure is not applied uniformly.

The solution is to use gunpowder with different burning rates. This makes the wave front of the shock wave reaching the plutonium uniform.



https://upload.wikimedia.org/wikipedia/commons/e/e0/Implosion_bomb_animated.gif

Exploding-bridgewire detonator

With the implosion lens, it was necessary to ignite 32 powders at the same time, but the technology at that time inevitably caused delays and variations.

Therefore, as an ignition method with little delay, "**Exploding-bridgewire detonator"** has been developed.

The final delay time achieved is
0.025μsec (= 25nsec)

Why so fast?

1. Robert Oppenheimer has a talent of project manager

2. Single purpose and concentration of resources

3. 21 Nobel Prize winners participated

4. Things were definitely moving forward every week.
（Huge budget + Military direct project）

5. Efficiency was prioritized over safety
（The risk level of the subject was sometimes not understood）

6. Atomic bomb dose not require control

Hydrogen Bomb

After the Manhattan project,
hydrogen bombs were developed
by **Edward Teller.**

E. Teller insisted that
the development of the
hydrogen bomb should
be promoted in the Manhattan Project.

The hydrogen bomb uses
the atomic bomb as a detonator.
(Teller-Ulam configuration)

Theoretically, the scale can be
increased without limitation.

https://upload.wikimedia.org/wikipedia/commons/thumb/0/08/EdwardTeller1958.jpg/1024px-EdwardTeller1958.jpg

Out coming (Negative things…)

Atomic bombs were used in Hiroshima and Nagasaki.

These attacks were triggered to finish WWII.

And, many countries started to develop Atomic bomb.
(Some members in Manhattan project intendedly leaked
a top secret to Soviet Union)

Currently, many atomic bombs are still stored in the silo of each countries and some countries are developing atomic bombs (**Deterrence theory**)

Conclusions

If you focus on one goal, you can achieve
a huge project even in a short period of time
（Japanese space development needs selection
and concentration）

Even a theoretical physicist can be a good project leader.
But if the person has a talent.

Of course, it is better that there are many excellent
human resources.

Even today, new weapons
(new bombs, satellite destruction weapons, computer viruses)
have been devised somewhere in the world.

Refernce

われらの時代に起ったこと―原爆開発と12人の科学者 (1979年) (岩波現代選書―NS〈502〉)
All in Our Time edited by Jane Wilson

フランケンシュタインの誘惑E＋・選 #2「原爆誕生 科学者たちの罪と罰」

フランケンシュタインの誘惑E＋・選 #3「水爆 欲望と裏切りの核融合」