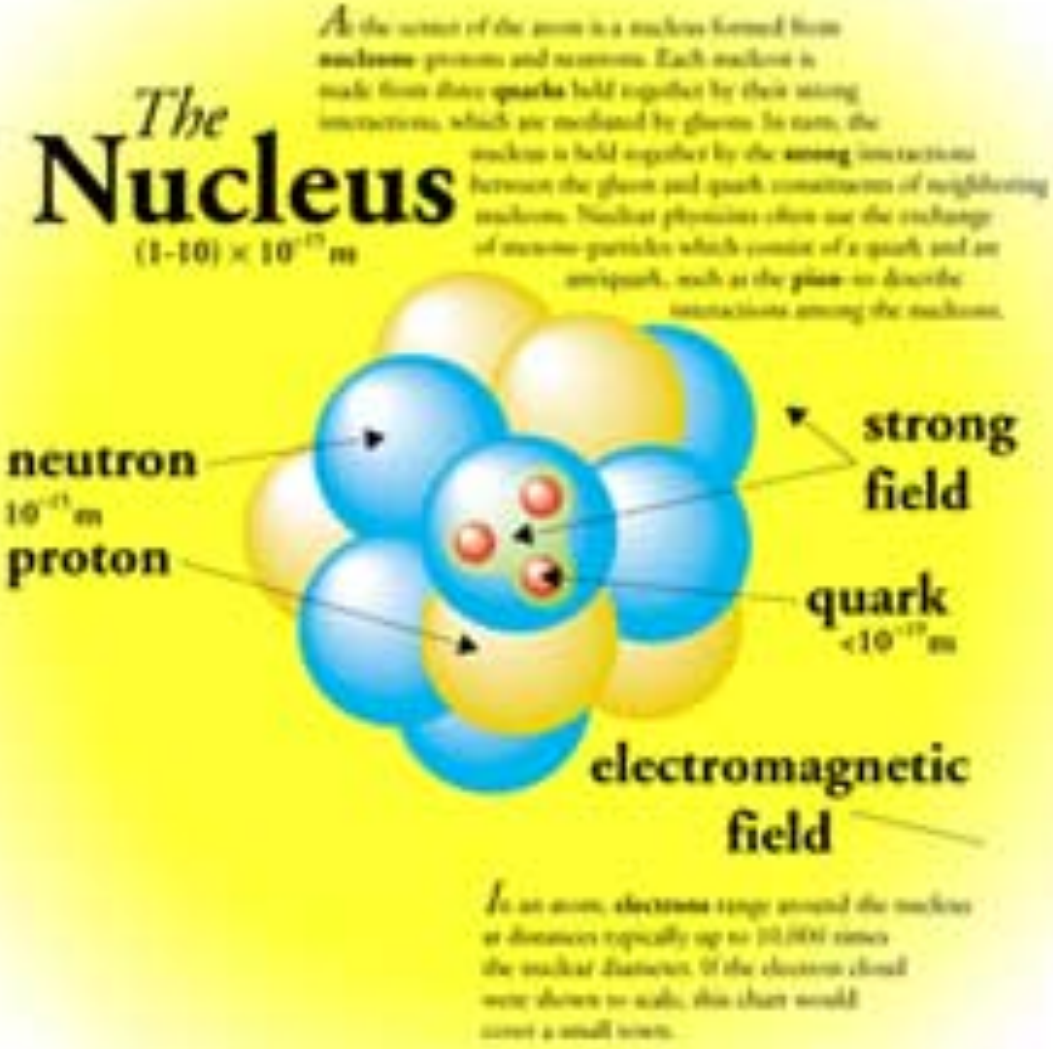


$${}^{A}_{Z}X_{N}$$

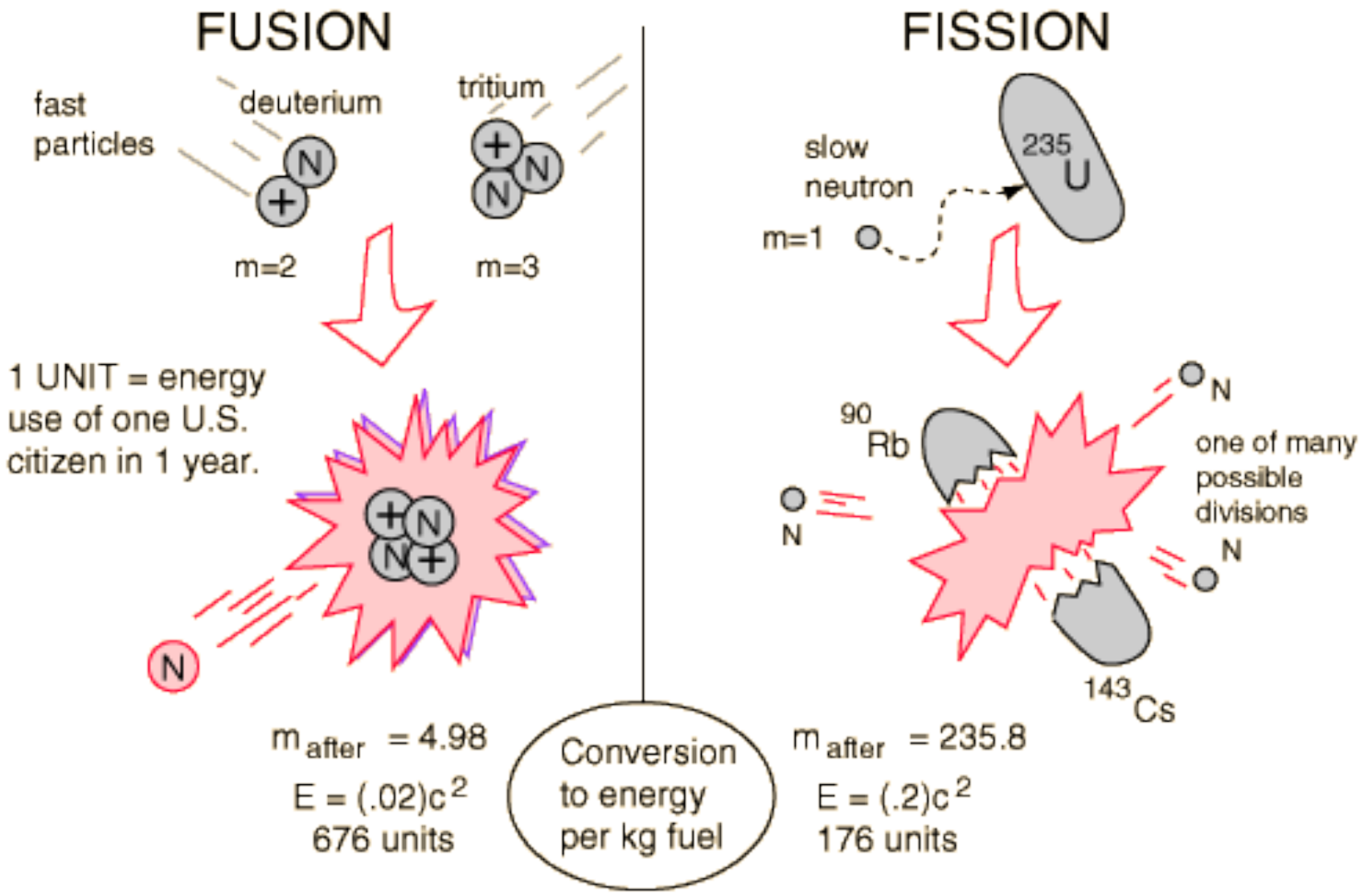
$${}^{1}_{1}H_{0}$$

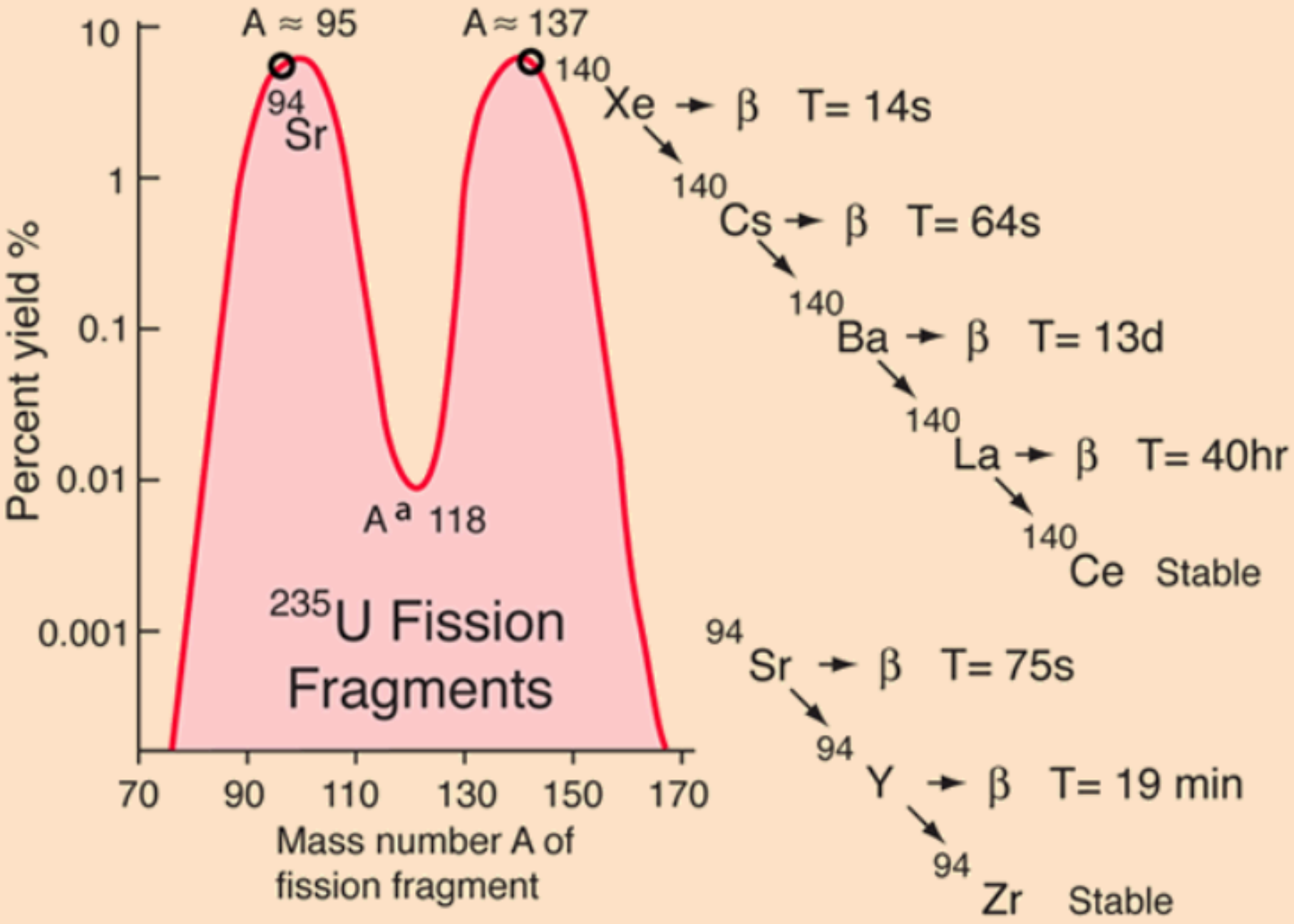
$${}^{2}_{1}H_{1}$$

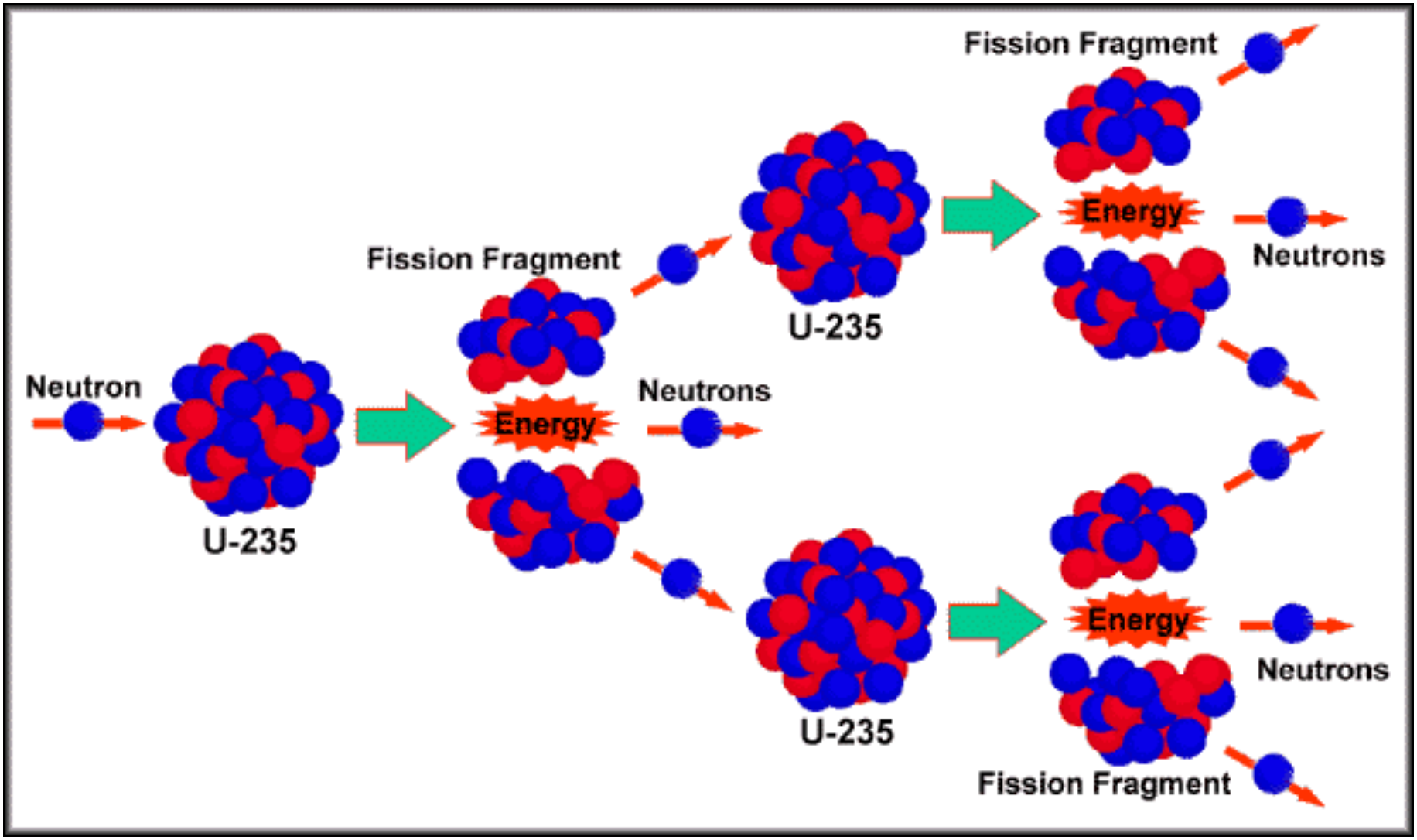
$${}^{238}_{92}U_{146}$$

$${}^{235}_{92}U_{143}$$

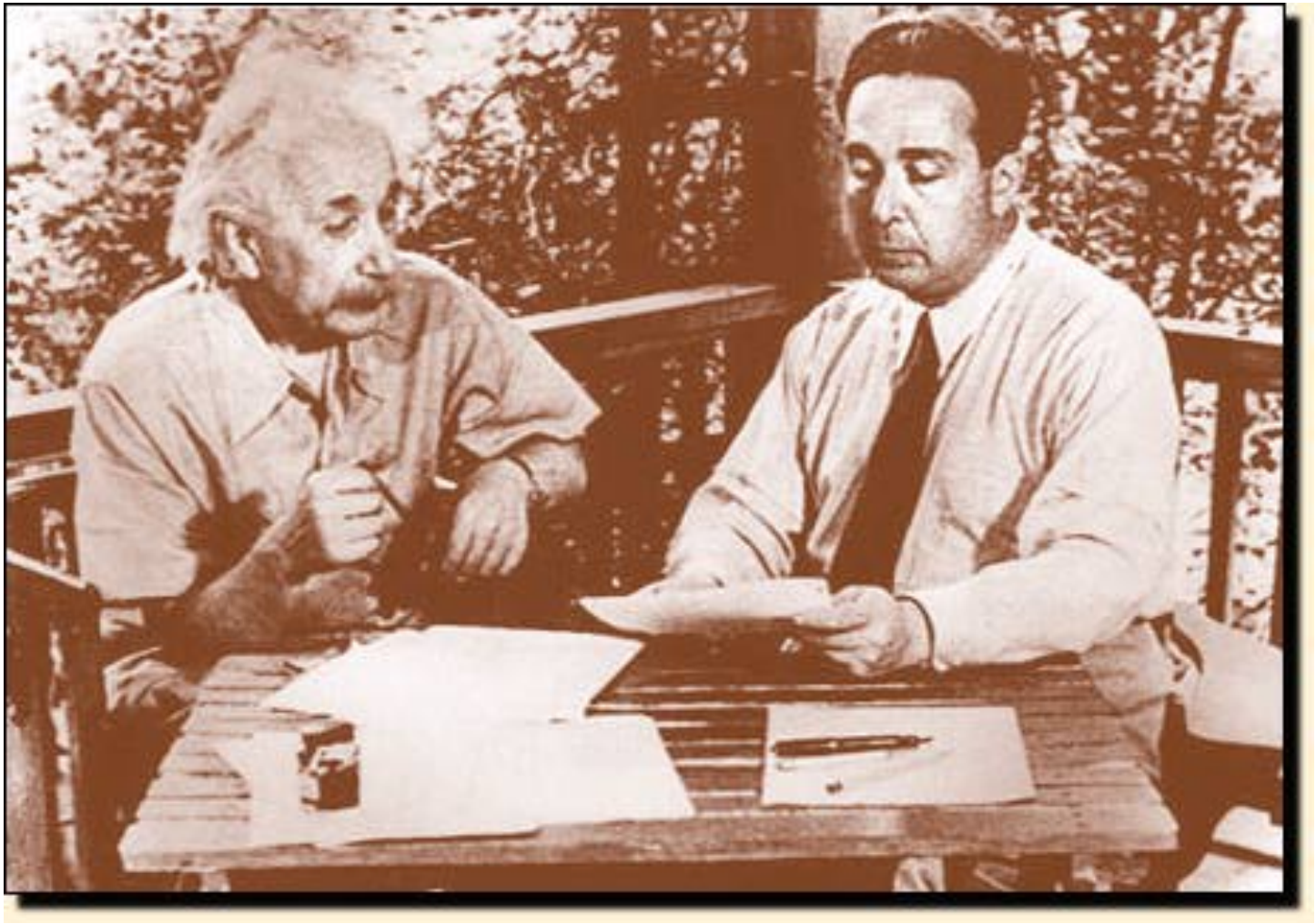
Energy from nuclei




A ≈ 95
A ≈ 137
94
Sr
140
Xe → β T= 14s
140
Cs → β T= 64s
140
Ba → β T= 13d
140
La → β T= 40hr
140
Ce Stable
A a 118
235U Fission Fragments
94
Sr → β T= 75s
94
Y → β T= 19 min
94
Zr Stable
Percent yield %
10
1
0.1
0.01
0.001
70
90
110
130
150
170
Mass number A of fission fragment



Fission Chain Reaction



Einstein & Szilard

re-enacting the signing of the letter to FDR

Franklin Delano Roosevelt

1890 - 1974

Vannevar Bush

Builds the interface between American science and the American government. He organizes and leads American science work for World War II

- Originates and heads NDRC June 1940 – May 1941
- Instigates and heads OSRD June 1941 – 1946

1892 -1962

A. H. Compton

1927 Nobel Prize in Physics

Showed the existence of photons by scattering them from electrons in 1922.

Scientist Leaders

Radiation Laboratory, University of California, Berkeley, March 1940.
Left to right: Ernest O. Lawrence, Arthur H. Compton, Vannevar Bush, James B. Conant, Karl T. Compton, and Alfred Loomis.

Rudolph Peierls

1907 -- 1995

Derived a better formula for critical mass

Otto Frisch

1904 -- 1979

March 1940 Frisch-Peierls memorandum to Oliphant.

Observed no one had examined the effect of fast neutrons on ^{235}U and he applied Peierls' formula for critical mass and got a value of about 10 kg !!

1901-2000

Marc Oliphant

in 1939

Australian physicist who working in Britain helped discover tritium and played a key role in urging the US to launch the Manhattan Project

James B. Conant

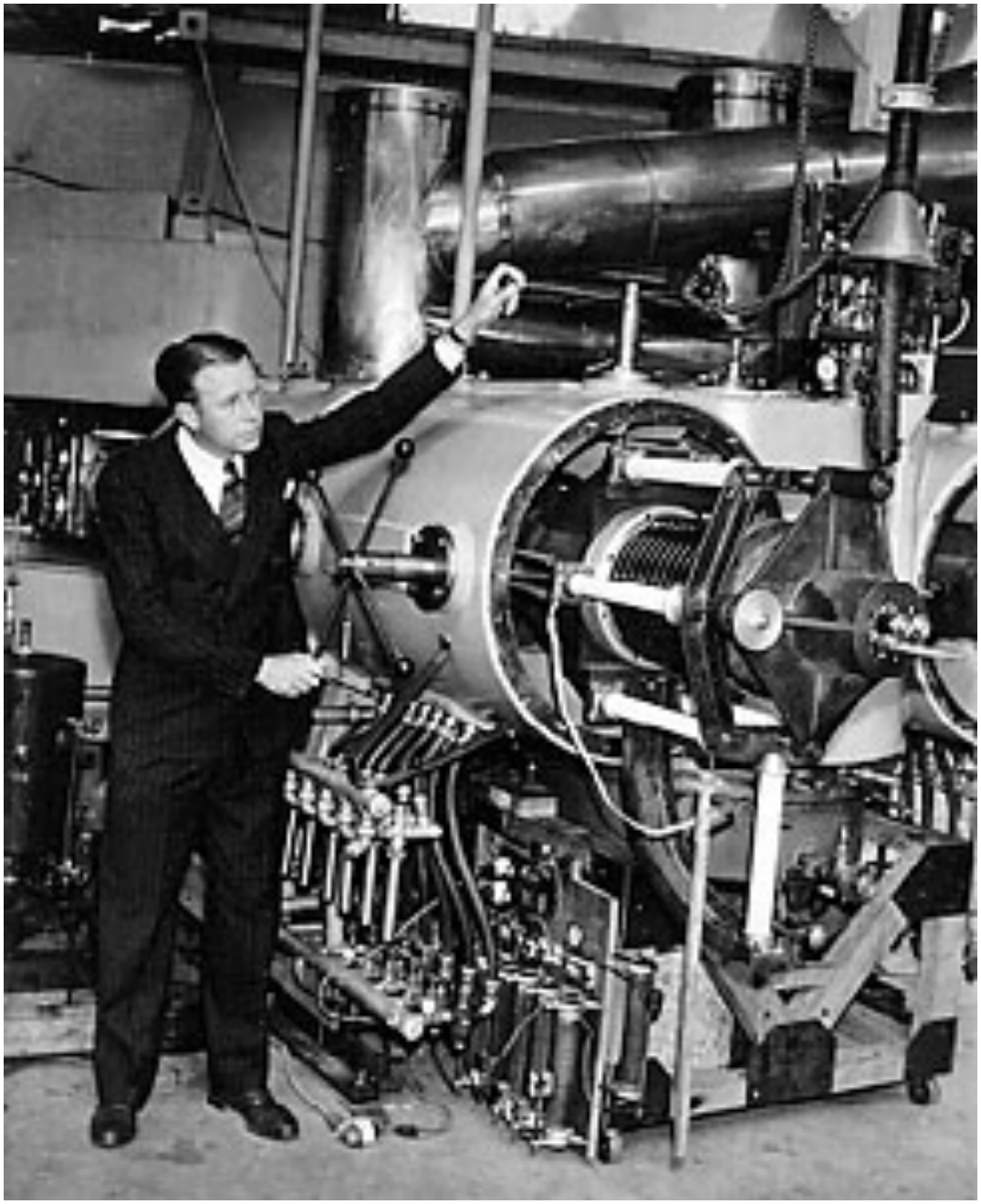
President of Harvard

Heads NDRC after Bush takes charge of OSRD

He chairs S-1 Committee successor to uranium advisory committee

Is Bush's alternate on the Military Policy Committee of the Manhattan Project

Szilard and E. O. Lawrence -- 1935



E. O. Lawrence

1901 - 1958

1939 Physics Nobel Prize

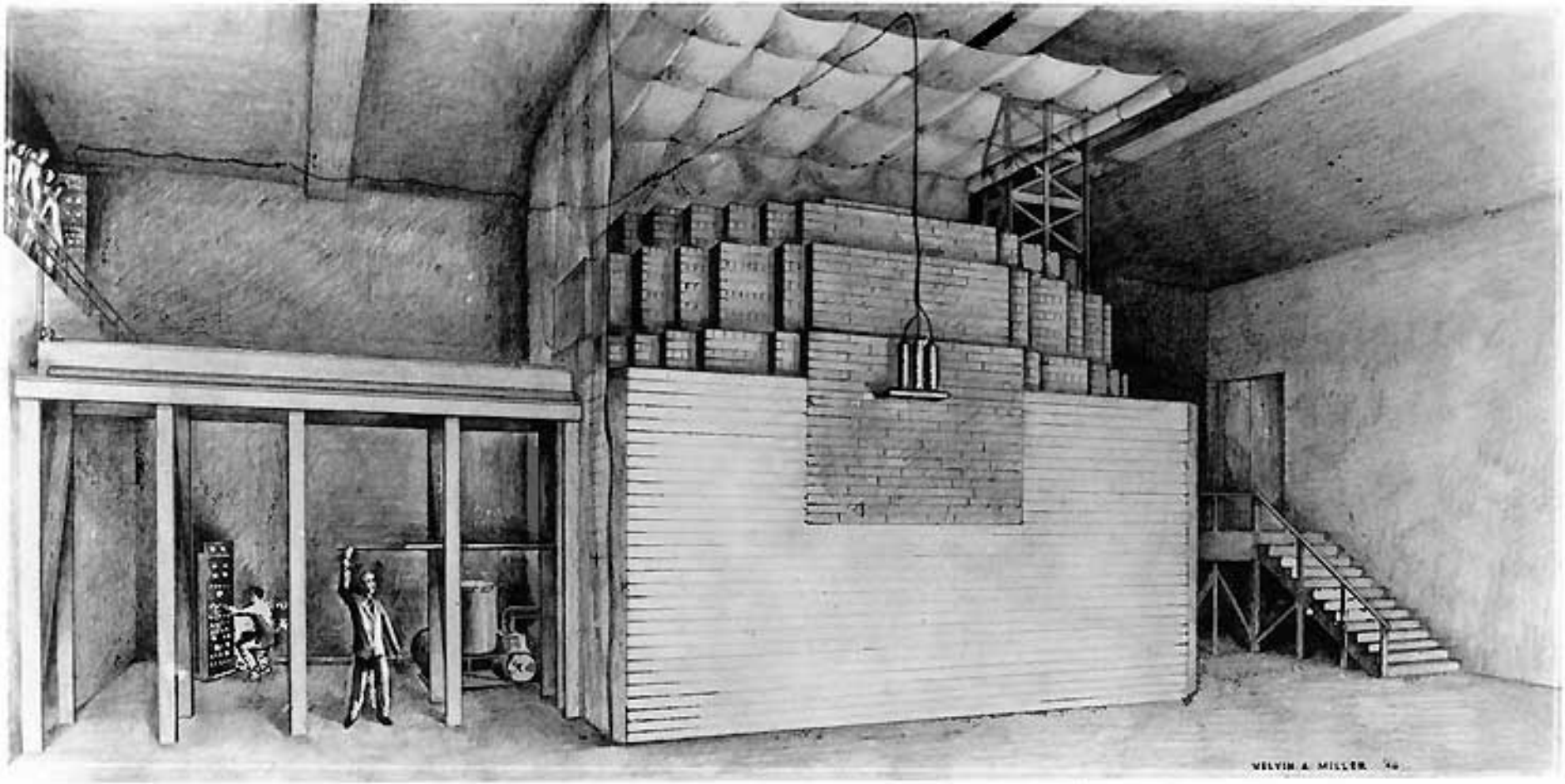
1901 - 1954

Enrico Fermi

1938 Nobel Prize in Physics

for his discoveries of neutron induced artificial radioactivities and the effects of slow neutrons

1942 built the first device to produce sustained controlled chain reaction releasing nuclear energy – a nuclear reactor



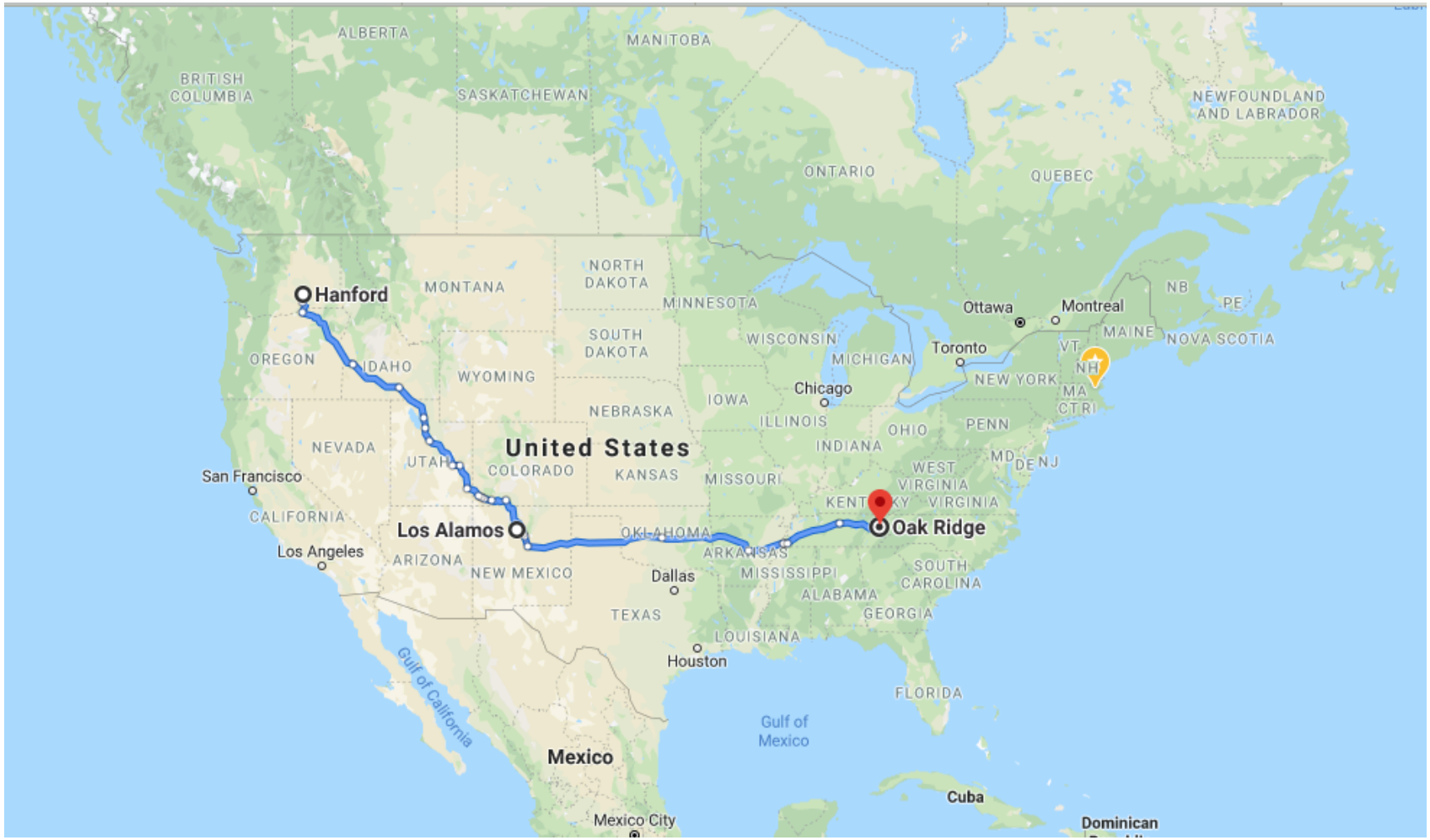
Chicago Pile I (CP-I), World's First Reactor

1896-1970

Maj. Gen. Leslie Groves

- directed construction of the Pentagon 1941-1942

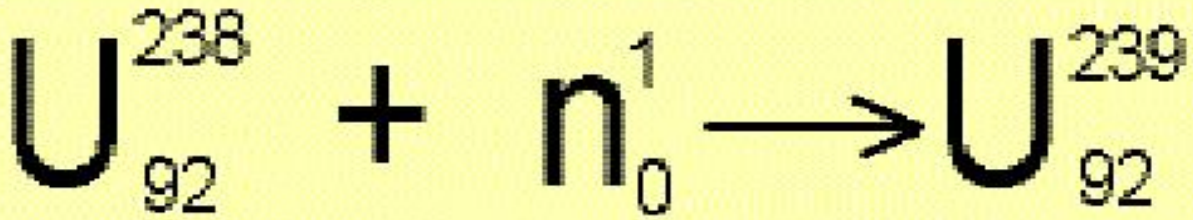
- in charge of the Manhattan Engineering District 1942-1946


ALBERTA
MANITOBA
BRITISH COLUMBIA
SASKATCHEWAN
NEWFOUNDLAND AND LABRADOR
ONTARIO
QUEBEC
Hanford
MONTANA
NORTH DAKOTA
MINNESOTA
Ottawa
Montreal
NB
PE
SOUTH DAKOTA
WISCONSIN
MAINE
NOVA SCOTIA
OREGON
IDAHO
WYOMING
MICHIGAN
Toronto
VT
NH
NEW YORK
MA
CTRI
Chicago
IOWA
NEBRASKA
ILLINOIS
OHIO
PENN
NEVADA
United States
UTAH
COLORADO
KANSAS
INDIANA
MD
DE
NJ
WEST VIRGINIA
San Francisco
MISSOURI
KENTUCKY
VIRGINIA
CALIFORNIA
Los Alamos
OKLAHOMA
Oak Ridge
Los Angeles
ARIZONA
ARKANSAS
NEW MEXICO
Dallas
MISSISSIPPI
SOUTH CAROLINA
ALABAMA
GEORGIA
TEXAS
LOUISIANA
Houston
Gulf of California
FLORIDA
Gulf of Mexico
Mexico
Cuba
Mexico City
Dominican

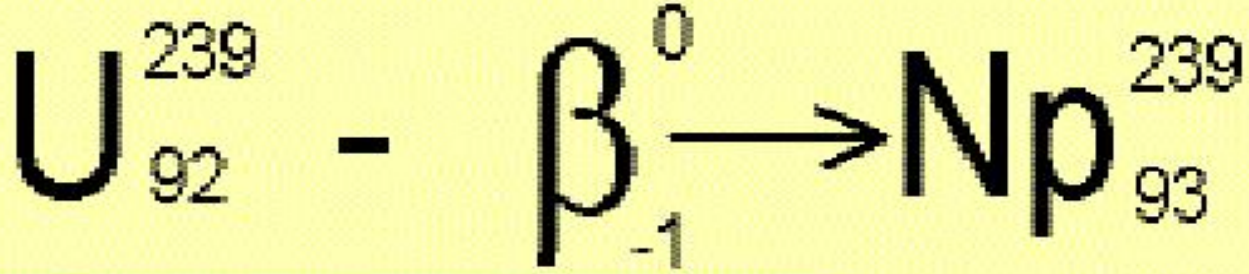
Two Paths to a Bomb

- separate U-235 from U-238 and build a fission weapon out of U-235
- build a nuclear reactor out of natural U and convert U-238 into Pu-239 and separate the Pu out chemically and build a fission weapon from Pu

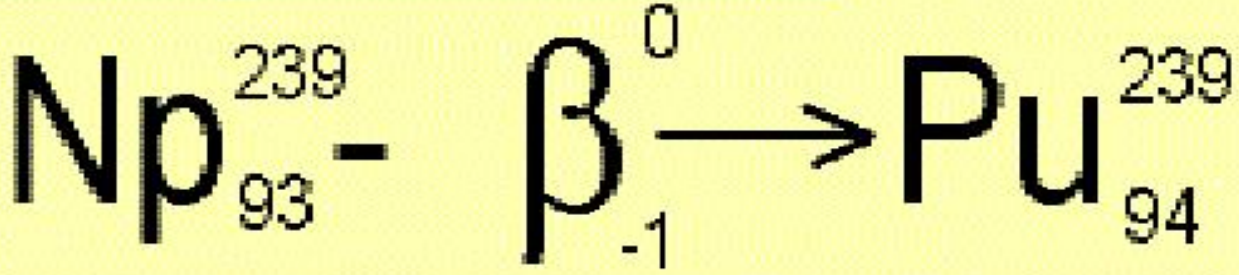
Common Uranium isotope 238 absorbs a neutron to become Uranium 239



This is a beta emitter. It decays to produce Neptunium 239



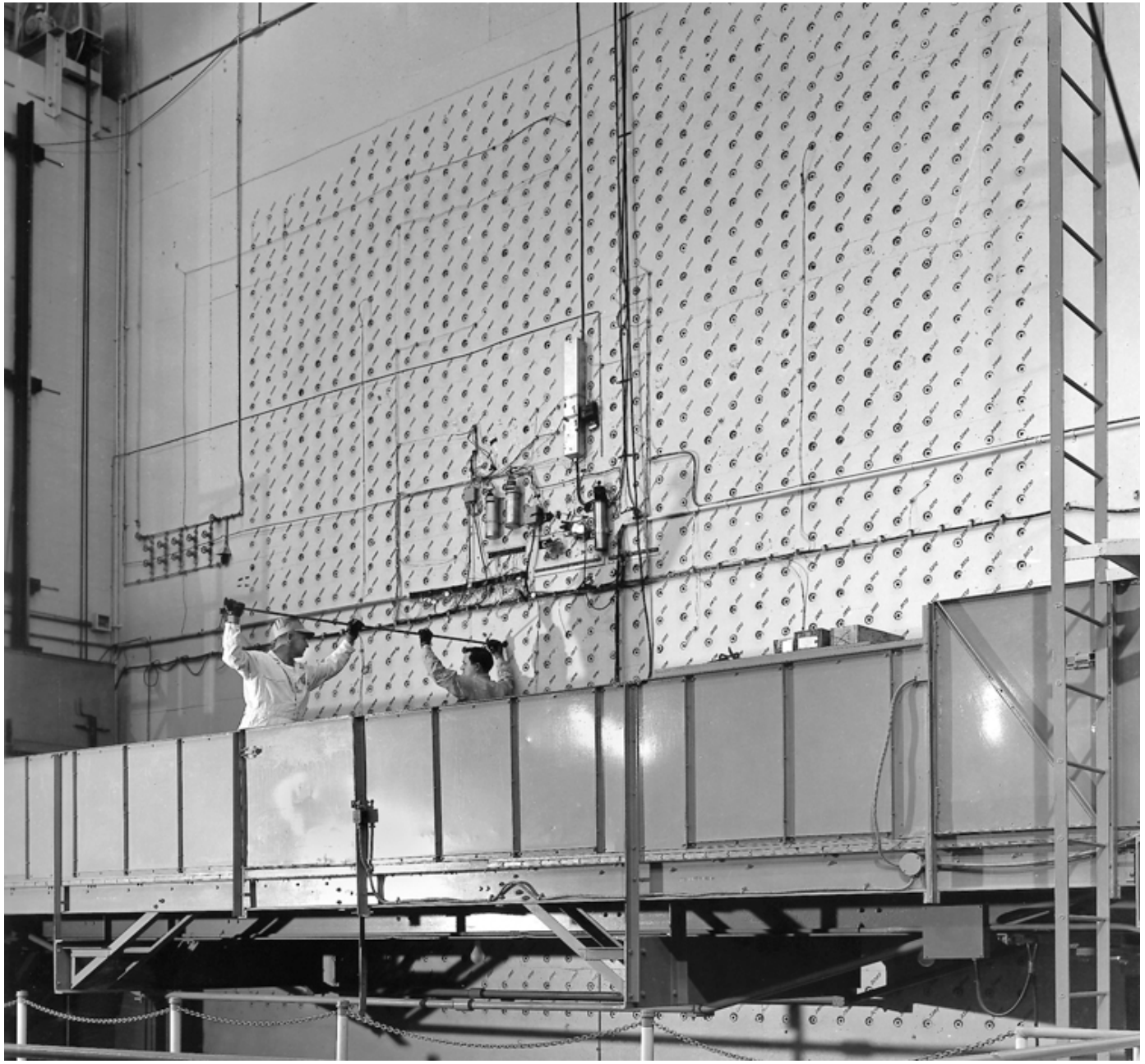
which in turn decays to produce Plutonium 239



Glenn Seaborg

1912-1999

1951 Nobel Prize in chemistry



X-10 Test Reactor designed at Met Lab and built at Oak Ridge

Groves & Oppenheimer

J. Robert Oppenheimer 1904-1967

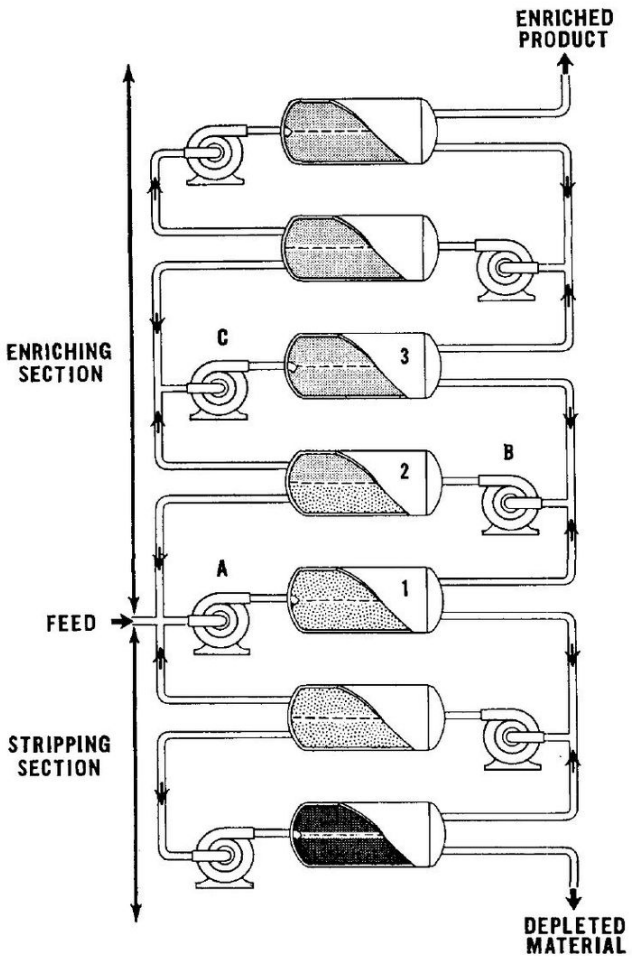
1942 Berkeley Summer Study

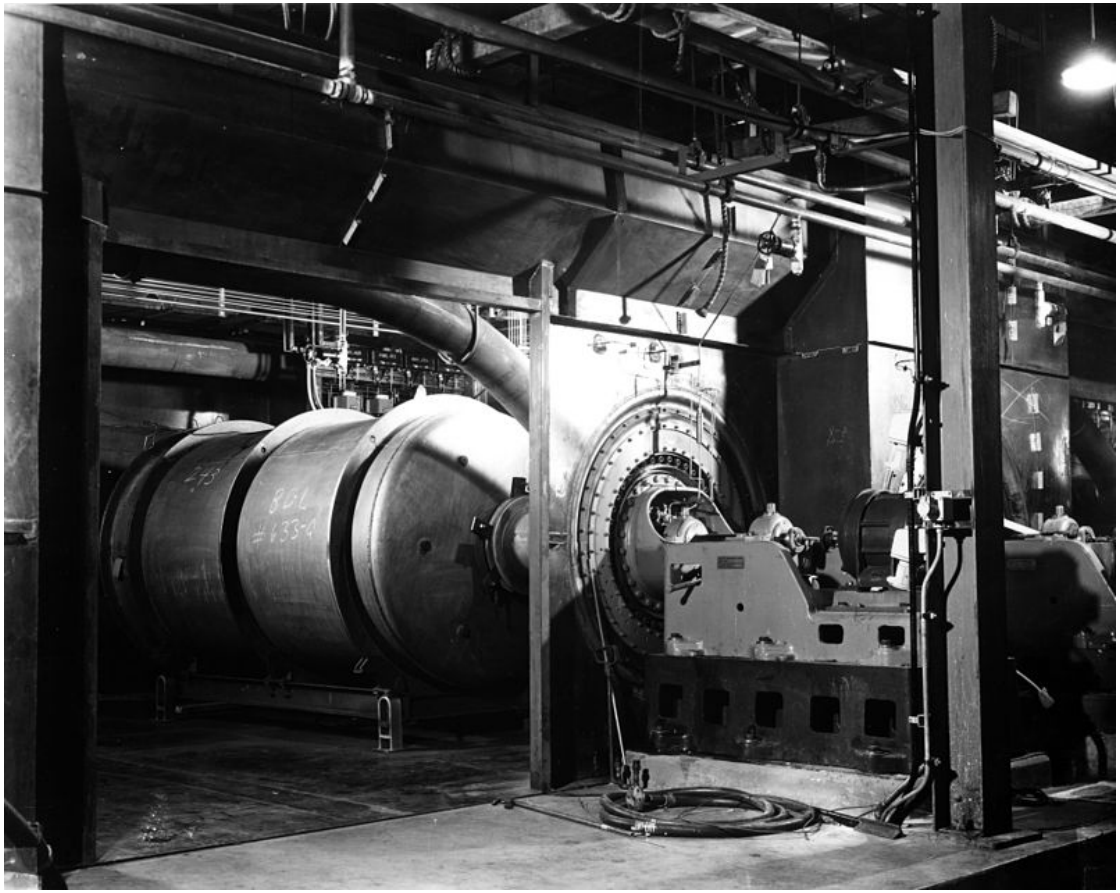
1943-1945 Director of the Los Alamos laboratory where he oversaw the invention, design, assembly and successful testing of the first atomic bomb.

"He was incredibly quick and perceptive in analyzing human as well as technical problems…. Los Alamos' amazing success grew out of the brilliance, enthusiasm and charisma with which Oppenheimer led it."

-- Edward Teller

Oak Ridge

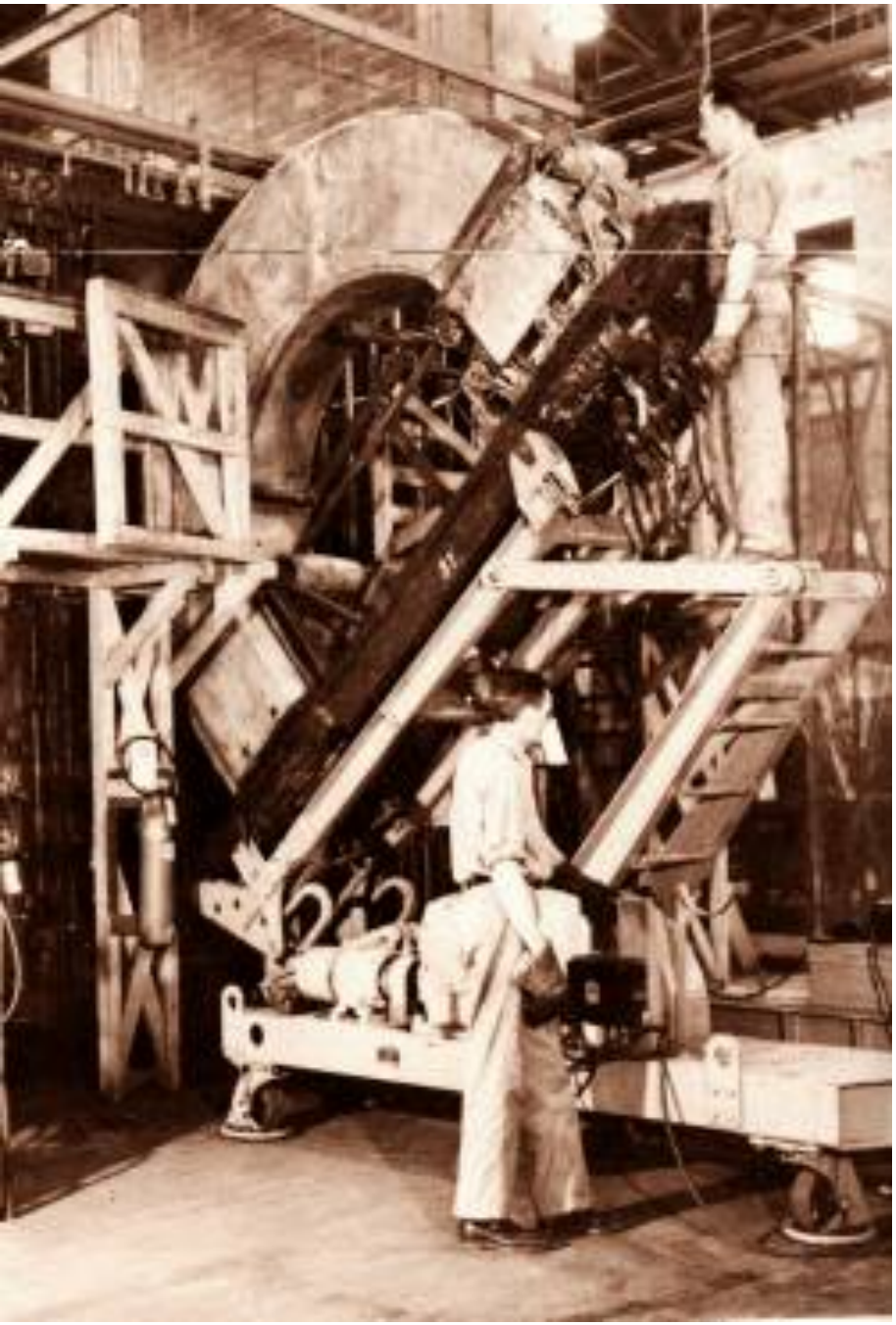




2892 of these

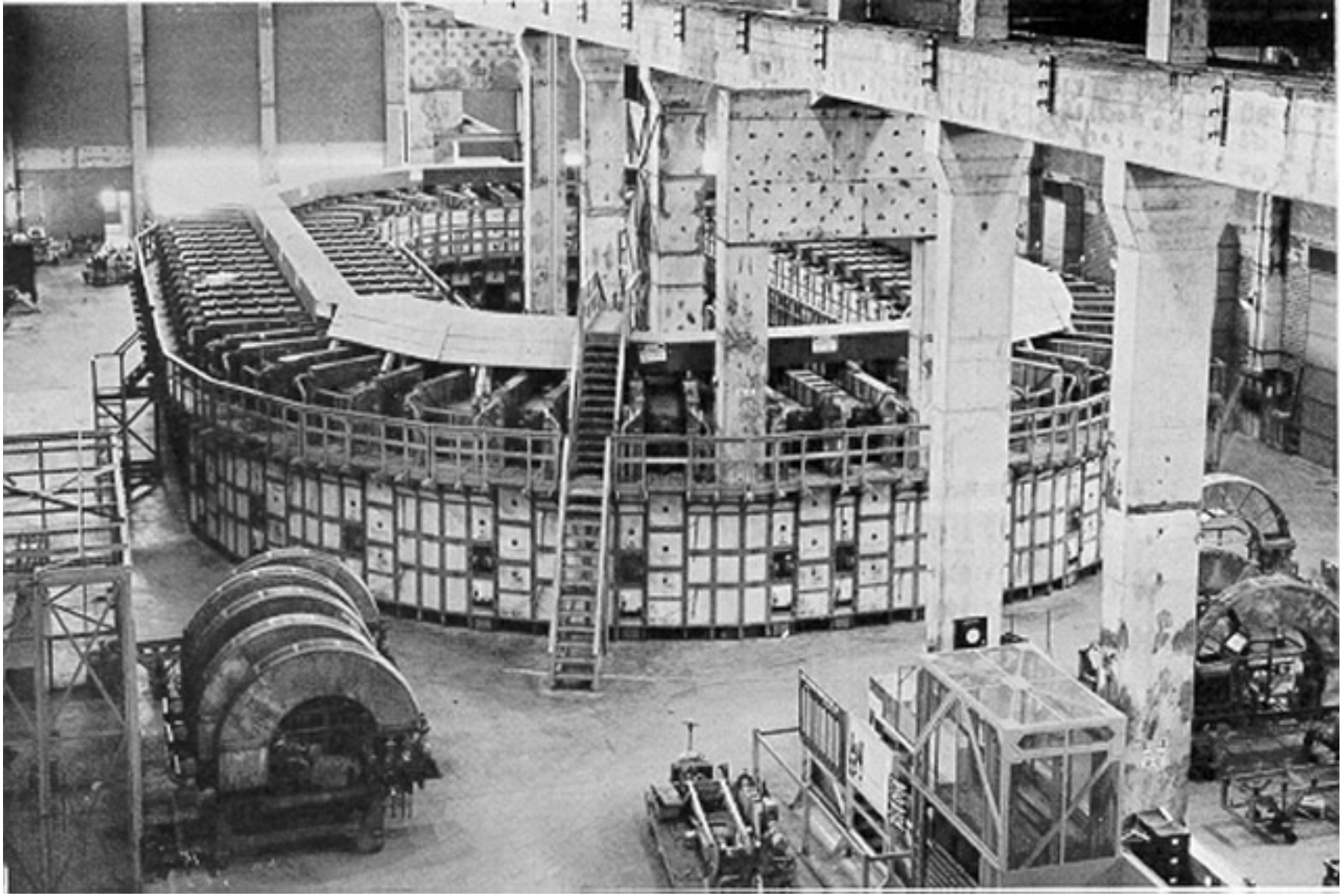
Gaseous Diffusion

K-25 plant under construction. Oak Ridge, June 1944



Tank for alpha calutron

Oak Ridge, Tennessee
late 1943



Y-12 Racetrack

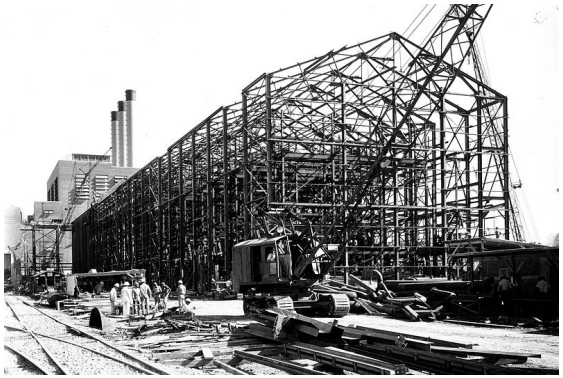
Cu, Ag, 1943 pennies

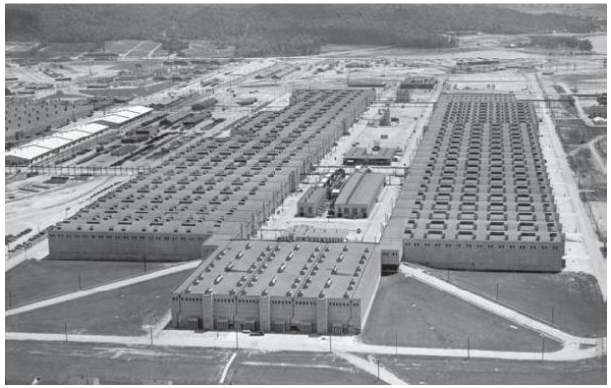
Cubicle operators at Y-12, Oak Ridge, 1944

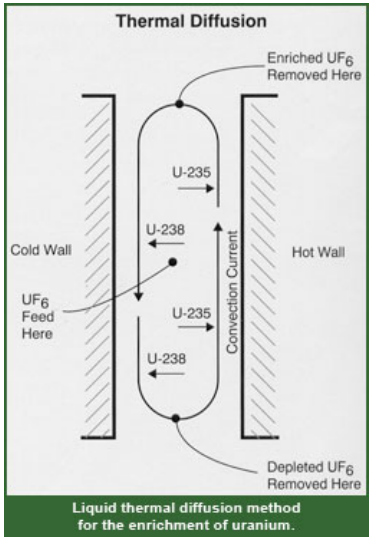
In January 1945 after 27 months Oak Ridge is producing

$$\textbf{S-50} \rightarrow \textbf{K-25} \rightarrow \textbf{Y-12}\alpha \rightarrow \textbf{Y-12}\beta \rightarrow \textbf{20 g of 90\% } ^{235}\textbf{U per day}$$

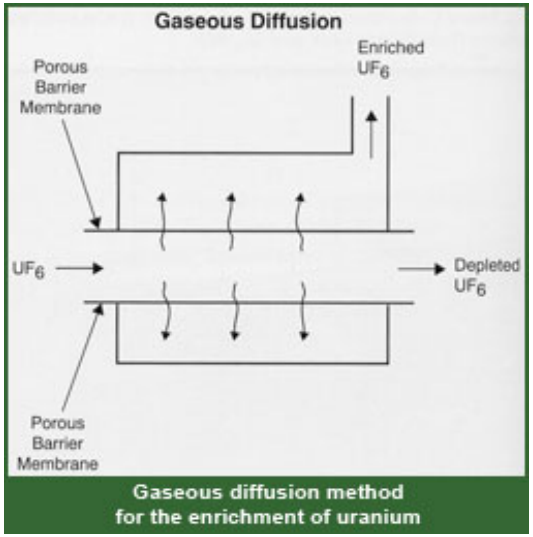
approximately one bomb every 200 days



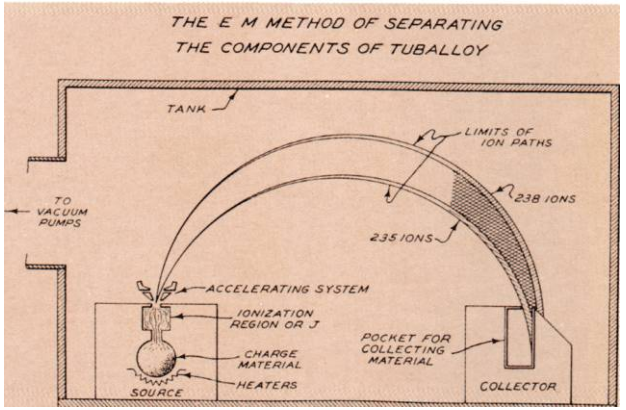




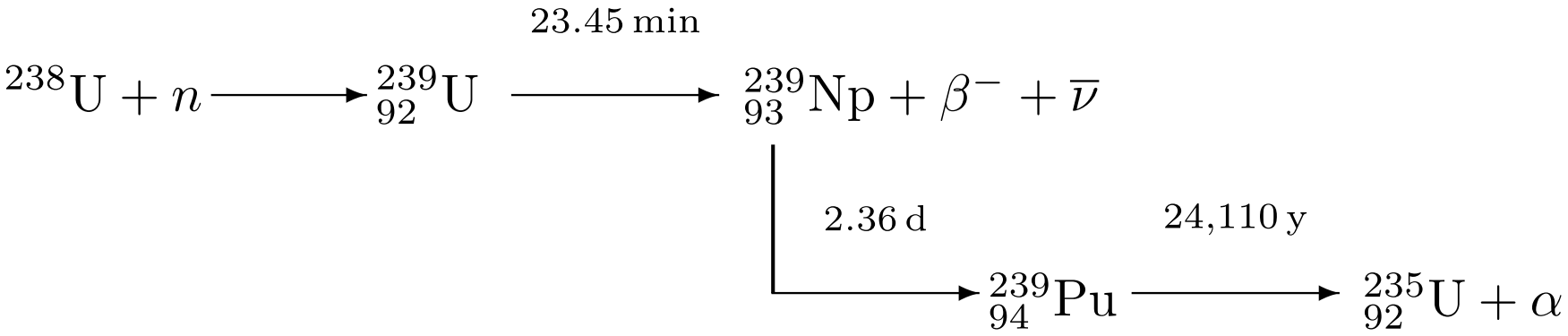
2142 48-foot tall tubes



2892 of these



864 α tanks + 36 β tanks

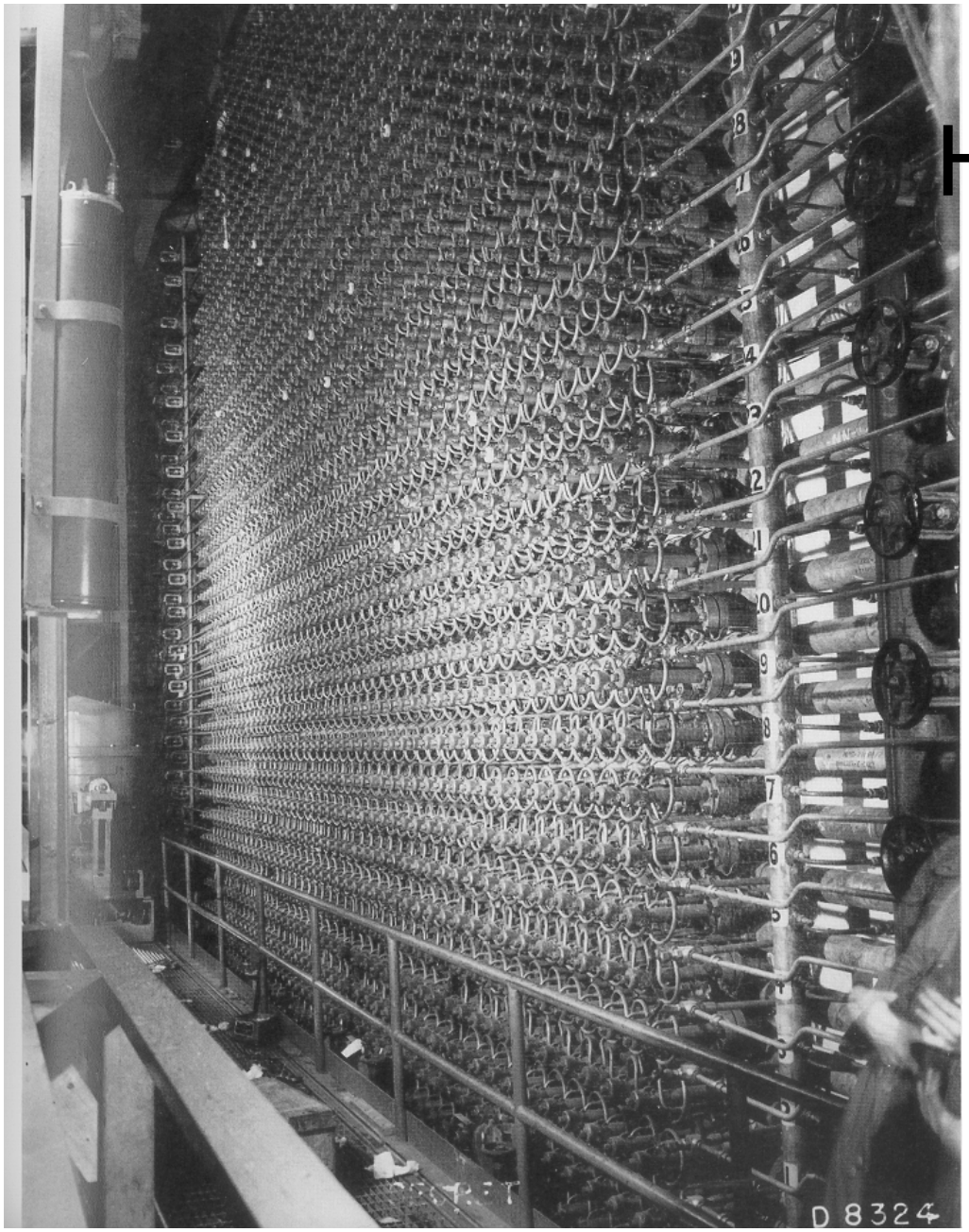


The fate of Nagasaki

Hanford B-Reactor Area 1944

One of three Pu producing reactors at Hanford, 1944

100-F area Hanford



Hanford Reactor

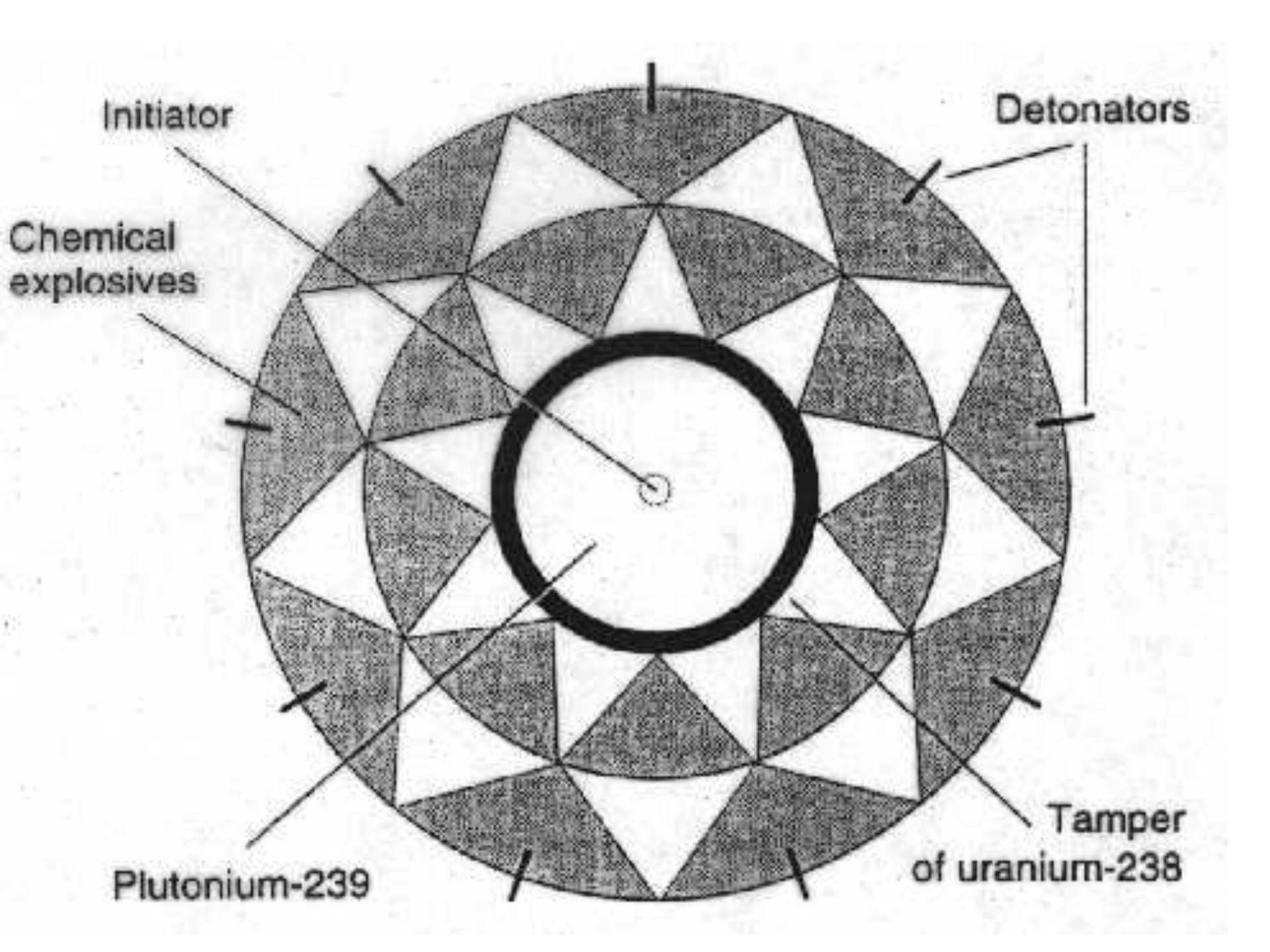
Front face of Pu producing reactor in 100 F area, Hanford, Feb. 1945


LOS ALAMOS
PROJECT
MAIN GATE
PASSES MUST BE
PRESENTED TO
GUARDS
POST
No. 1

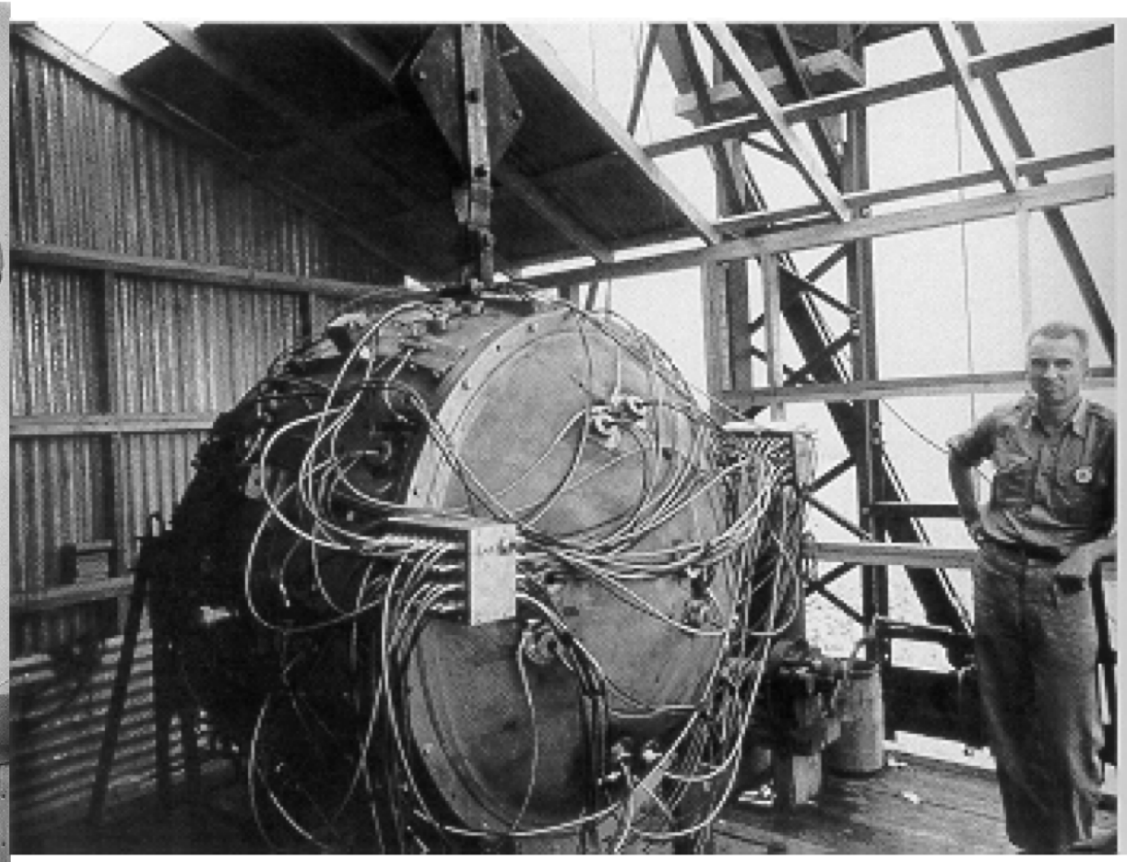
Los Alamos in 1950

Criticality Test

Tickling the dragon’s tail: Recreation of 1946 fatal accident

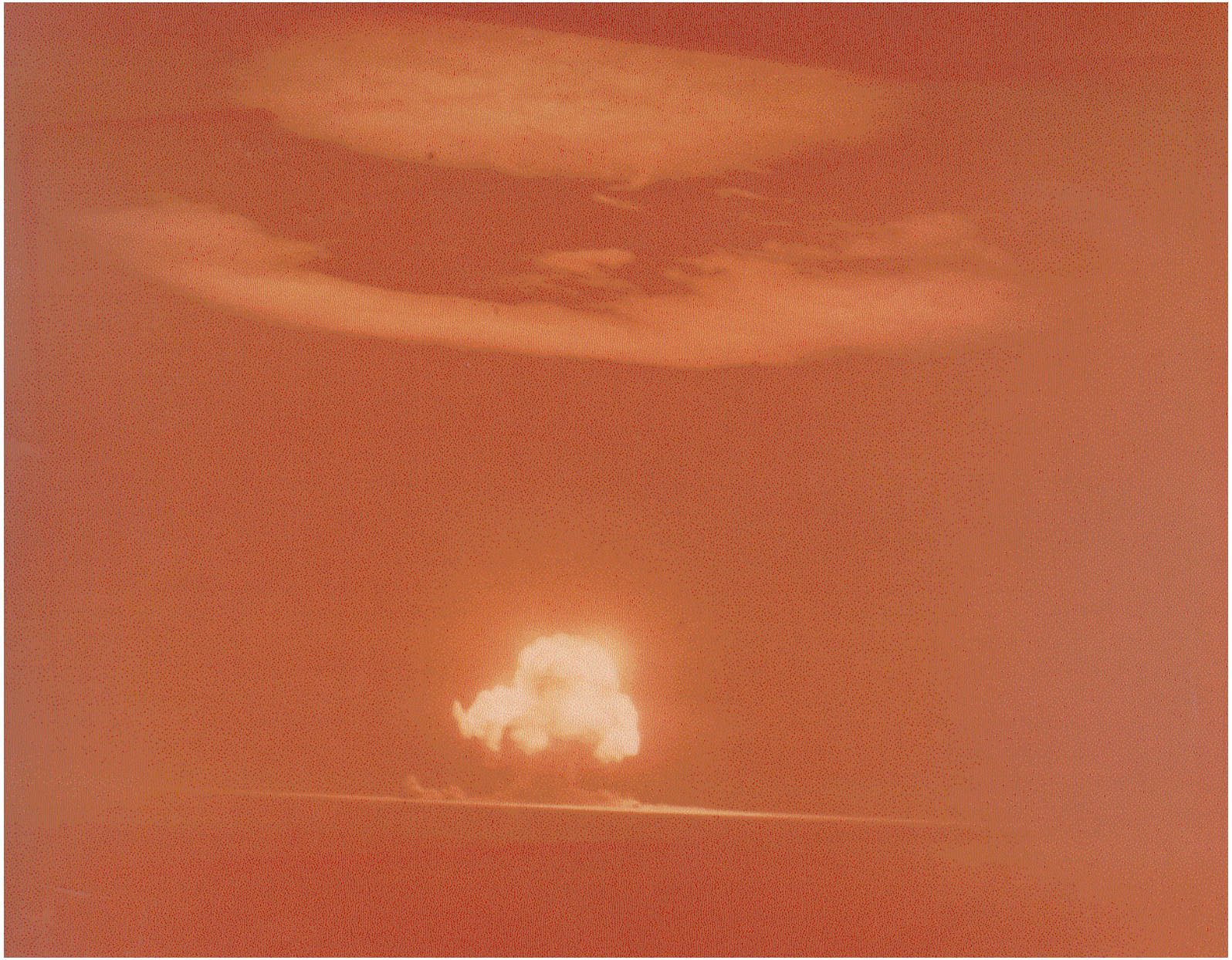

Initiator
Detonators
Chemical explosives
Tamper of uranium-238
Plutonium-239

SED Herbert Lehr with Pu core for Trinity Bomb



The Trinity bomb set up in the detonation tower.

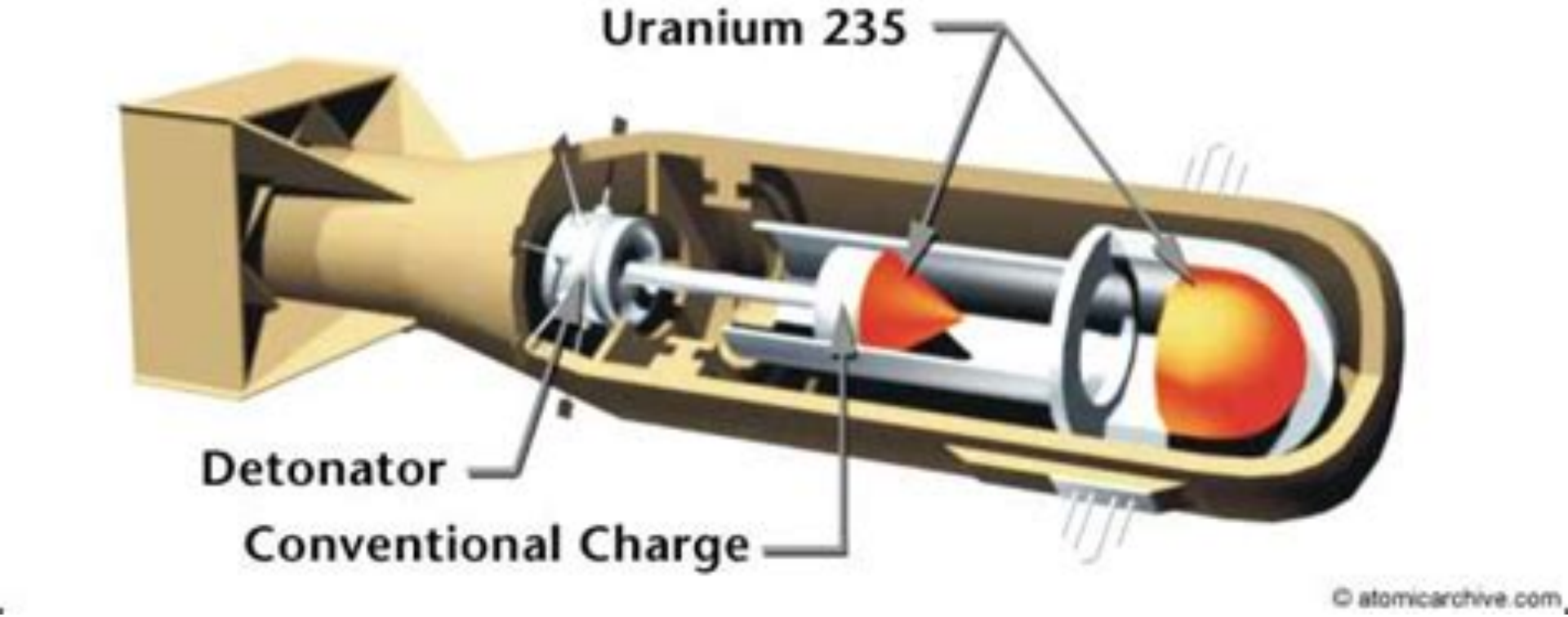
Trinity Bomb



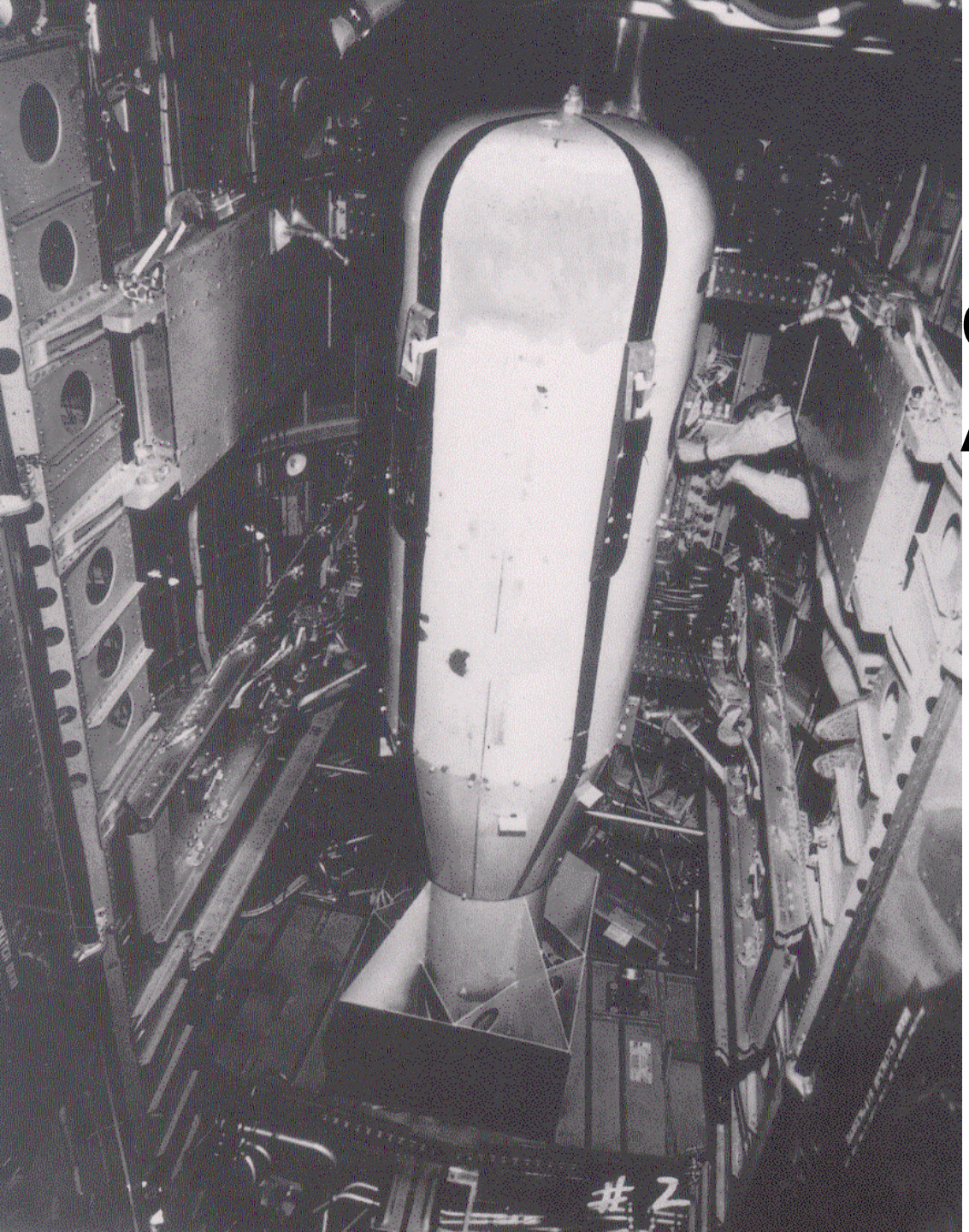
Trinity test blast 05:29 War Time July 16, 1945

trinitite


Japan
Hiroshima
Nagasaki
Tokyo
HONSHU
SHIKOKU
KYUSHU



Little Boy Gun-Type Detonator



Little Boy in bomb bay of Enola Gay, August 5, 1945

Target committee 10 and 11 May 1945

Franck Report 11 June 1945

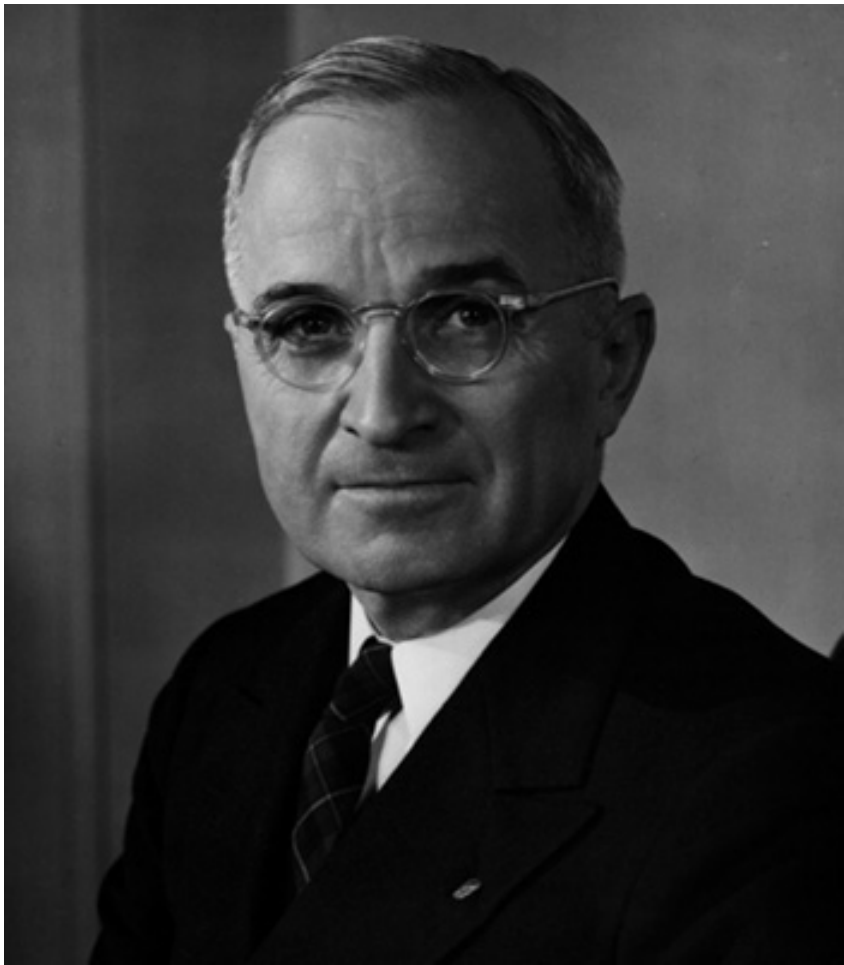
Scientific Panel of Interim Committee 16 June 1945

Szilard petition 17 July 1945

Official bombing order 25 July 1945

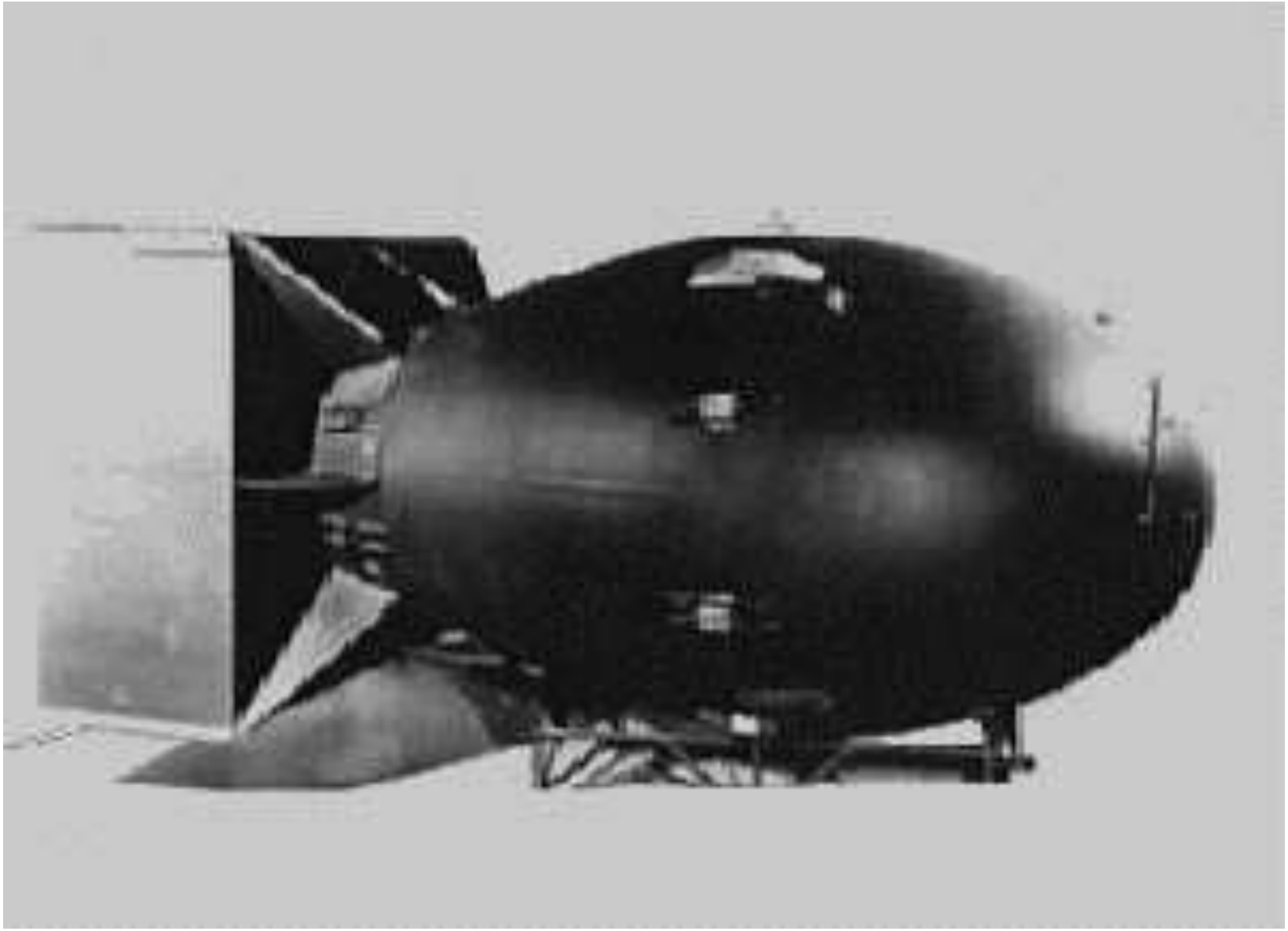
The written order for the use of the atomic bomb against Japanese cities was drafted by General Groves.

President Truman and Secretary of War Stimson approved the order at Potsdam.



Hiroshima

1.2 km from ground zero



Fat Man

Nagasaki: A City Destroyed

Nagasaki bomb kills >45,000 People

The Atomic Bomb

Site/Project	estimated cumulative cost through 1945	Constant 1996 Dollars
OAK RIDGE		
K-25 Gaseous Diffusion Plant	$512 million	$5.85 billion
Y-12 Electromagnetic Plant	$478 million	$5.45 billion
Clinton Engineer Works, HQ and central utilities	$156 million	$1.78 billion
Clinton Laboratories	$26.9 million	$307 million
S-50 Thermal Diffusion Plant	$15.7 million	$179 million
HANFORD ENGINEER WORKS	$390 million	$4.45 billion
SPECIAL OPERATING MATERIALS	$103 million	$1.18 billion
LOS ALMOS PROJECT	$74.1 million	$845 million
R&D	$69.7 million	$795 million
GOVERNMENT OVERHEAD	$37.3 million	$425 million
HEAVY WATER PLANTS	$26.8 million	$306 million
GRAND TOTAL	$1.89 billion	$21.6 billion

Total Cost in 2020 Dollars: ~ $38 billion

Niels Bohr

Humanity will be confronted with dangers of unprecedented character unless, in due time, measures can be taken to forestall a disastrous competition in such formidable armaments and to establish an international control of the manufacture and use of powerful materials.

A REPORTER AT LARGE AUGUST 31, 1946 ISSUE

HIROSHIMA

By John Hersey

August 24, 1946

SECRECY

How effective?

Secret from whom?

Groves and Alsos

Consequences for America and the U.S. political system

WHO WAS LUCKY?

What if fission had been discovered in 1933?

What if the bomb had been ready only six months later?

What if the bomb had been ready six months earlier?