The Gadget

-The Making of the Atomic Bomb -

Kenneth Strubler

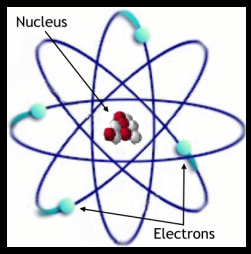
Medical Physicist

The Imaginings of the Human Mind

It is still an unending source of surprise for me to see how a few scribbles on a blackboard or on a sheet of paper could change the course of human affairs.

Stanislaw Ulam

The Atom
{Atomism}



Concepts of the Atom [a-tomos]

- Jainism – 6th BCE
- Leucippus / Democritus – 5th BCE
  - Atoms
  - Void
- Aristotle {Earth, Fire, Air, Water)
- Renaissance
  - Galileo
  - Descartes
  - Dalton
- 20th Century
  - Rutherford
  - Bohr

Χονχεπτ οφ τηε Ατομ
{Concept of the Atom}

The World Set Free
(1914)

The Shape of Things to Come
(1933)

H.G. Wells

The road to the atomic bomb began in earnest in 1919 when the first transmutation of one element into another was achieved by Ernest Rutherford.

First Anti-Jewish Law
April 1933

Revelation

"The Shape of Things to Come"

Sept. 12, 1933, Leo Szilard, Hungarian theoretical physicist, stepped off a street in London and ….

The Scientists

Ernest Rutherford
Niels Bohr
Otto Hahn
Lise Meitner
Leo Szilard
Robert Oppenheimer
Fritz Strassmann
Enrico Fermi
Albert Einstein
James Chadwick
Ernest Lawrence
J.J. Thomson

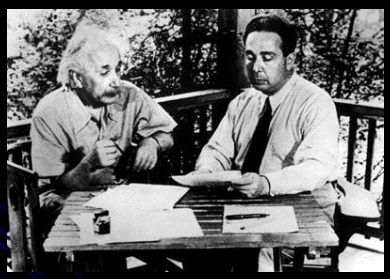
Taming Atomic Energy

"Moonshine"
{Rutherford}

Albert Einstein

$E = mc^2$

Einstein & Szilard

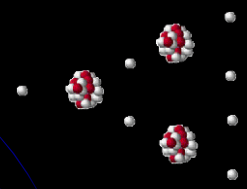


In 1933, Szilard conceived the idea of a nuclear chain reaction.

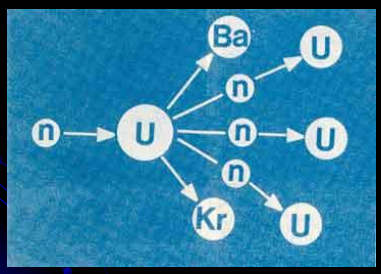
Fission

Hahn & Strassmann

(Dec. 1938)



Chain Reaction



Frisch-Peierls Memorandum

(March 1940)

First to set out how to construct an atomic bomb with a small amount of U-235 (1 kg).

The MAUD Committee

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

Albert Einstein
Old Grove Road
Peconic, Long Island
August 2nd, 1939

Sir:

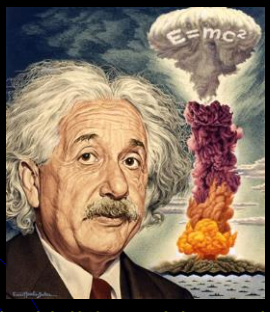
Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and 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.

……

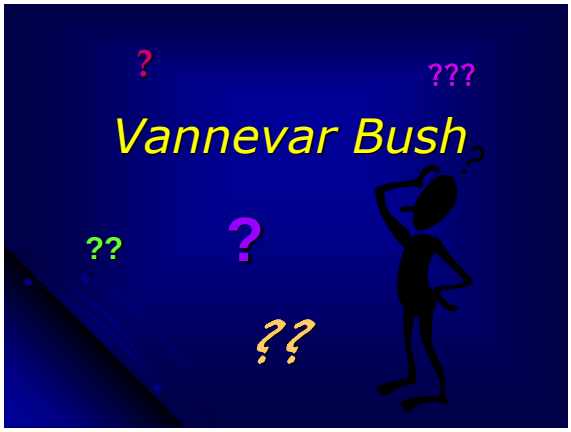
……

This new phenomenon would also lead to the construction of bombs, and it is conceivable--though much less certain--that extremely powerful bombs of this 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 too heavy for transportation by air.

Yours very truly,



Einstein's 1946 cover of Time magazine.



Vannevar Bush

- Engineer, 1st science advisor to a President
- WWI - lack of cooperation, military & sci.
- 1927 - analog computer, memex….www
- 1939 - proposed Fed. Agency in science
- 1940 - FDR {NDRC}
- PRIMARY political organizer of the Man. Project
- 1942 - Manhattan Project taken over
- Anticipates COLD WAR….

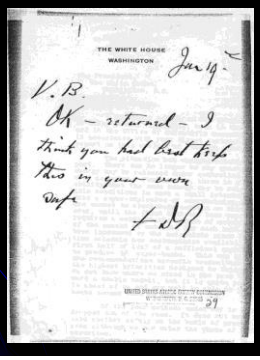
E.O. Lawrence, A. Compton, V. Bush, B. Conant, K. Compton, A. Loomis
March 1940 meeting at UC, Berkeley about cyclotron

Army involvement

Oct. 9, 1941

Bush – Army Corps of Engineers

The "Go-ahead" from FDR


THE WHITE HOUSE
WASHINGTON
Jan 19
V. B.
OK – returned – I
think you had best keep
this in your own
safe
FDR

Jan. 19, 1942

Etymology

- The Manhattan Project
- Los Alamos
- Trinity Site, Alamogordo
  {in the desert of Jornada del Muerto}
- The Gadget

General Groves

Project turned over to Army in June 1942

General Groves
& Robert Oppenheimer

Natural Uranium

Element 92

U-238: 92 protons, 146 neutrons

U-235: 92 protons, 143 neutrons

Four Possible Mechanisms

Otto Frisch Feb. 1940

- Slow neutron fission of U238
- Fast neutron fission of U238
- Slow neutron fission of U235
- Fast neutron fission of U235

The most complicated problem in making the bomb:

Uranium-235 enrichment

>99% of Uranium ore is U-238

Uranium enrichment

Natural: U-238 99.3%
U-235 0.7%

Low enriched, reactor grade
U-235 3-4%

Highly enriched, weapons grade
U-235 90%

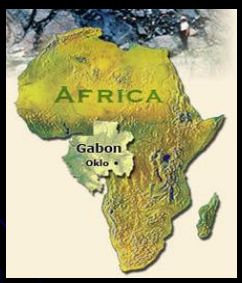
How Big is this Problem ?

Consider this:

How does one separate glucose from sucrose? !? ?

Oklo Natural Nuclear Reactor

{1.7 million years ago ! !!}



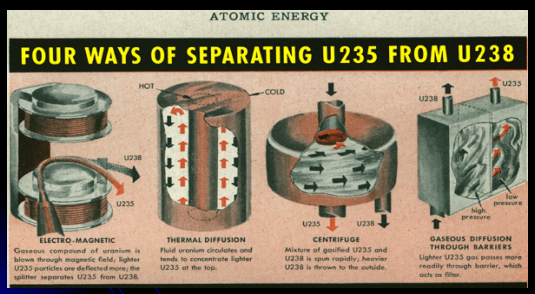
Uranium Ore Supplies

- **350 tons from Eldorado, Canada, July 1942**
- **1200 tons from Belgian Congo, Sept 1942**
- **Some from Colorado**

Enrichment of U-235

{U-235, 0.7%}

- Electromagnetic Method
- Gaseous Diffusion
- Centrifuge
- Liquid Thermal Diffusion



Enter the discovery of Plutonium

Plutonium

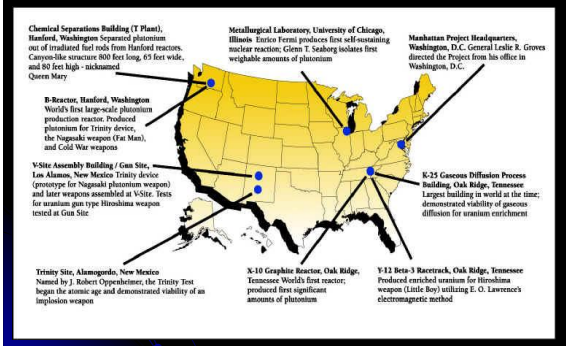
"The most toxic substance known to mankind."

Ralph Nadar

After the spring of 1942, the situation changed from too little money and no deadlines to one of a clear goal, plenty of money but too little time.

Urgency

- **Atomic concepts well known among ALL scientists of the world !**
- **Fission concepts began in Germany.**
- **Japanese scientists were discounted.**



1st Chain Reaction

University of Chicago
Dec. 2, 1942

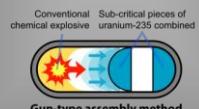
As Compton reported to Conant, "The Italian navigator has just landed in the new world." To Conant's question, "Were the natives friendly?" Compton answered, "Everyone landed safe and happy."

1st Atomic Pile

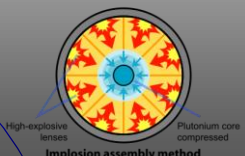
Lester Skaggs, Ph.D. Larry Lanzl, Ph.D.
Emeritus Professors, Univ. of Chicago

Trinity Site

Two Types of Assembly



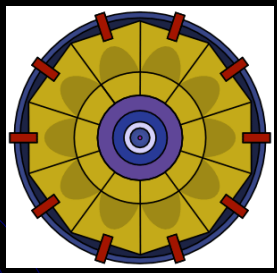
Gun-type assembly method



Implosion assembly method

The Gadget

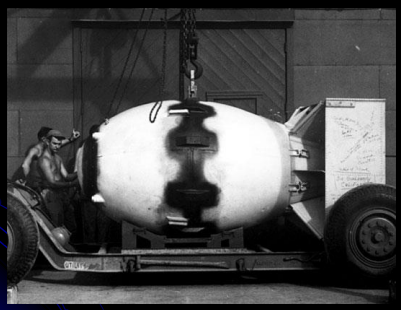
Pu Implosion Type



The Gadget(s)

- ✓ Little Boy (Hiroshima)
- ✓ Fat Man (Nagasaki)
- ✓ Thin Man (Pu Gun Design aborted)

Fat Man



Sept. 1944
Col. Tibbets drills his team by dropping orange dummy bombs.

They called them pumpkins.

1939 Political Map

Invasion of Japan

- Operation Downfall -

- 3.5 million men
- Casualties

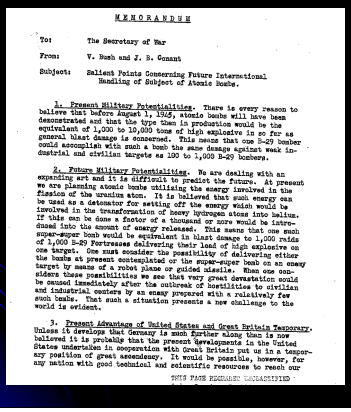
Operation Downfall

TEST PREDICTIONS

- Dud
- 18 kilotons of TNT (I.I. Rabi)
- Destruction of state of New Mexico
- Ignite atmosphere & incinerate planet

Admiral Leahy

"The bomb will never go off. And I speak as an expert on explosives!"



MEMORANDUM

To: The Secretary of War

From: V. Bush and J. B. Conant

Subject: Salient Points Concerning Future International Handling of Subject of Atomic Bombs.

1. Present Military Potentialities. There is every reason to believe that before August 1, 1945, atomic bombs will have been demonstrated and that the type then in production would be the equivalent of 1,000 to 10,000 tons of high explosive in so far as general blast damage is concerned. This means that one B-29 bomber could accomplish with such a bomb the same damage against weak industrial and civilian targets as 100 to 1,000 B-29 bombers.

2. Future Military Potentialities. We are dealing with an expanding art and it is difficult to predict the future. At present we are planning atomic bombs utilizing the energy involved in the fission of the uranium atom. It is believed that such energy can be used as a detonator for setting off the energy which would be involved in the transformation of heavy hydrogen atoms into helium. If this can be done a factor of a thousand or more would be introduced into the amount of energy released. This means that one such super-super bomb would be equivalent in blast damage to 1,000 raids of 1,000 B-29 fortresses delivering their load of high explosive on one target. One must consider the possibility of delivering either the bombs at present contemplated or the super-super bomb on an enemy target by means of a robot plane or guided missile. When one considers these possibilities we see that very great devastation would be caused immediately after the outbreak of hostilities to civilian and industrial centers by an enemy prepared with a relatively few such bombs. That such a situation presents a new challenge to the world is evident.

3. Present Advantage of United States and Great Britain Temporary. Unless it develops that Germany is much further along than is now believed it is probable that the present developments in the United States undertaken in cooperation with Great Britain put us in a temporary position of great ascendancy. It would be possible, however, for any nation with good technical and scientific resources to reach our

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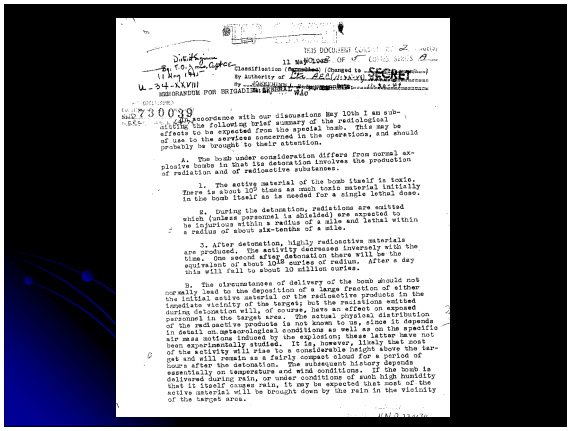


SECRET

730039

In accordance with our discussions May 10th I am submitting the following brief summary of the radiological effects to be expected from the special bomb. This may be of use to the services concerned in the operations, and should probably be brought to their attention.

A. The bomb under consideration differs from normal explosive bombs in that its detonation involves the production of radiation and of radioactive substances.

1. The active material of the bomb itself is toxic. There is about 10^5 times as much toxic material initially in the bomb itself as is needed for a single lethal dose.

2. During the detonation, radiations are emitted which (unless personnel is shielded) are expected to be injurious within a radius of a mile and lethal within a radius of about six-tenths of a mile.

3. After detonation, highly radioactive materials are produced. The activity decreases inversely with the time. One second after detonation there will be the equivalent of about 10^{18} curies of radium. After a day this will fall to about 10 million curies.

4. The circumstances of delivery of the bomb should not normally lead to the deposition of a large fraction of either the initial active material or the radioactive products in the immediate vicinity of the target; but the radiations emitted during detonation will, of course, have an effect on exposed personnel in the target area. The actual geographical distribution of the radioactive products is not known well as on the specific in detail on meteorological conditions as well as on the specific air mass motions induced by the explosion; these latter have not been experimentally studied. It is to be expected, however, likely that most of the activity will rise to a considerable height above the target and will remain as a fairly compact cloud for a period of hours after the detonation. The subsequent history depends essentially on temperature and wind conditions. If the bomb is delivered during rain, or under conditions of such high humidity that it itself causes rain, it may be expected that most of the active material will be brought down by the rain in the vicinity of the target area.

Not all scientists that worked on the bomb were satisfied that their voices were heard.

Committee on the Social & Political Implications of the Atomic Bomb

DEBATE about its USE

Sec. Stimson heads Advisory Committee

- Demonstration
  - What if it's a dud ?
  - What if they put POW's at site ?
  - What if they shoot down the plane ?
  - Lose shock value if announced.
- Dual attack
- Post-war fate of atomic energy

The Geneva Conventions

The 1st (1864) addresses issues with wounded & sick. The others (2,3,4) about prisoners, civilians…..

Many Americans think of WW II as one monumental event.

- In the battles against Germany, U.S. troops understood that one side would force the other to surrender.
- In the Pacific theater, the troops fought knowing that their war would end ONLY when one side annihilated the other!

{Essential truth noted by Hugh Ambrose, "The Pacific"}

Target Committee

May 10-11, 1945

- Height of Detonation
- Weather Conditions
- Gadget Jettisoning & Landing
- Status of Targets
- Military Objectives
- Psychological Factors
- Radiological Effects

Targets

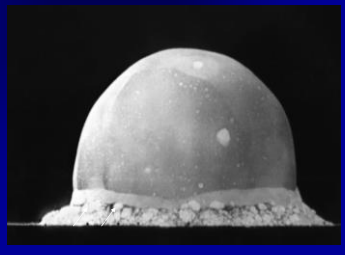
- Kyoto
- Hiroshima
- Kokura
- Yokohama
- Niigata

The First Nuclear Detonation

Trinity Test
Alamogordo, NM

July 16, 1945
5:29:45 A.M.

(Robert Loevinger)



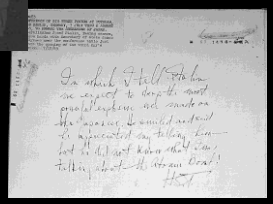
Reactions after Success

- Shock wave, momentary blindness
- Surprise, joy, relief
- Jubilation
- Euphoria gave way to somber reflections
- "Now we are all sons of bitches."
  (Kenneth Bainbridge to Oppenheimer)

More Reflections

Robert Oppenheimer

- Prometheus Bound
- Alfred Nobel - Dynamite
- Bhagavad-Gita:
  "Now I am become death,
  the destroyer of worlds."

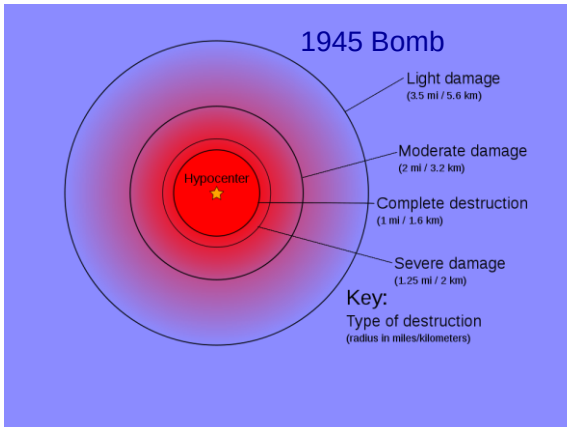


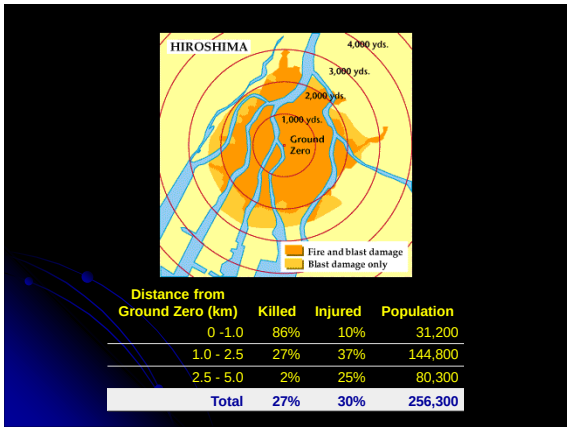
Duck & Cover


MOVE TO THE COUNTRY!
Be Safe
FROM ATOMIC ATTACK
Live in WINDEMERE ACRES

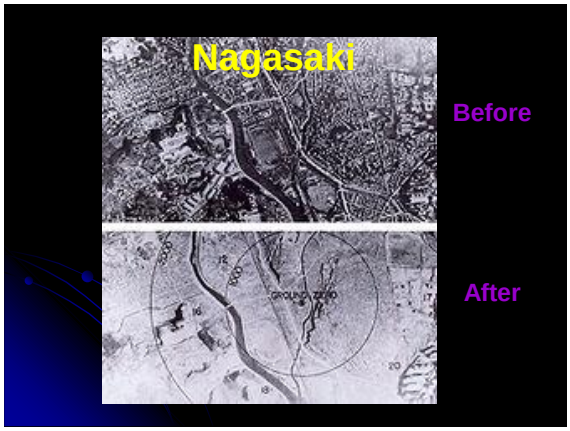

Hiroshima
Nagasaki


Hiroshima





Distance from Ground Zero (km)	Killed	Injured	Population
0 -1.0	86%	10%	31,200
1.0 - 2.5	27%	37%	144,800
2.5 - 5.0	2%	25%	80,300
Total	**27%**	**30%**	**256,300**



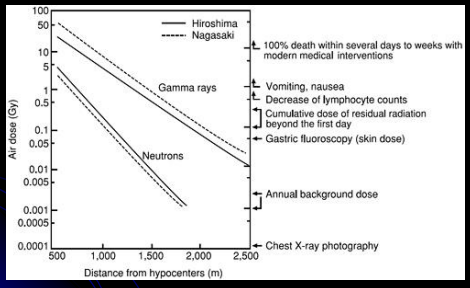
Hiroshima

TNT PERSPECTIVE

	TNT EQUIVALENT ENERGY YIELD
Large hand grenade	0.07 kg (0.16 oz)
Construction site blast	0.43 kg (0.95 lb)
WWII conventional bomb	2.4 kg (5.3 lb)
Late WWII bomb	13.6 kg (30 lb)
Hiroshima A-bomb	15,000 kg (15 ktons)
Nagasaki	32 kilotons
Haiti 2010 earthquake	476 kilotons
Largest nuke Tsar Bomba	50 megatons
Chili 2010 earthquake	238 megatons
Indian Ocean 2004 earthquake	1.3 gigatons
Chicxulub comet	476 teratons

The nucleus of one atom of uranium has 1 million times more energy than one molecule of TNT !

Radiation Dose in Air v Distance



The Peace Palace in the Hague

The Hague Conventions
1899 & 1907

No, not Hiroshima nor Nagasaki

but Tokyo

Atomic Bomb Flattens Hiroshima

Hiroshima's Peace Memorial Park 2009

Dresden

Operation Thunderclap

Caen

Hiroshima 2009

Shinran Shonin Statue
Manhattan

Were Germany, Japan & the USSR aware of the theory & science behind an atomic weapon ?

And were they trying to construct one themselves ?

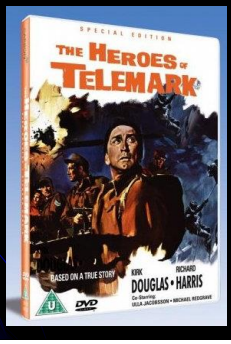
Atomic Weapon Development

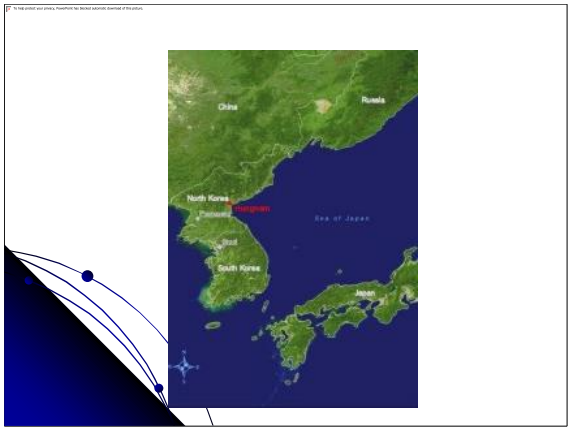
- **Germany**
  Max Planck (1933), Albert Speer (1942)
- **Japan**
  Hikoska Tadayoshi (1934), Yoshio Nishina (1939)
- **USSR**
  Stalin (1942), Klaus Fuchs

German & Japanese Efforts

- Concerns that Germany was ahead of U.S. precipitated our massive push
- U.S. was dismissive of Japan's scientists
- Germans were sending uranium oxide to Japan by submarine in spring of 1945 (U-234)
- Evidence of Japan program destroyed (Hikosaka Tadayoshi 1934 treatise; Yoshio Nishina)

The Heroes of Telemark





Espionage

- Germans & Japanese tried to infiltrate
- Soviets were good at it
- Klaus Fuchs, Theodore Hall
- Karl & Ethel Rosenberg

Julius & Ethel Rosenberg

Pros & Cons
about Dropping the Bomb

- Fanatical Resistance
- Couldn't waste 1 of 2
- Invasion - casualties
- Targeted cities fire…
- Convince world
- Prevent USSR occup.
- Ready to call it quits
- Unconditional surrender
- Tokyo harbor demo
- Nagasaki unnecessary
- Justify cost…
- Politics with Russia

The Franck Report
June 1945

Lots of Nuke Tests

- Trinity Site
- Nevada Test Site
- Bikini Island
- Christmas Island
- Eniwetok
- Johnston Island

Able
Apple
Baker
Chama
Fox
Bee
Galileo
Dakota
Mohawk
Kingfish
Oak
Yukon
Tesla
Sunset
Yeso
Starfish

Miss Atomic Bomb

1957

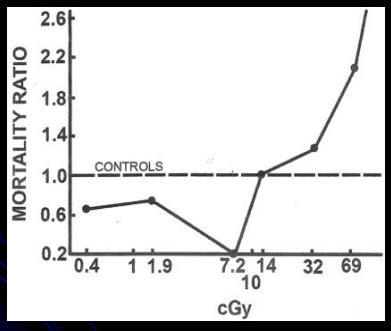
1958

Radiation Effects

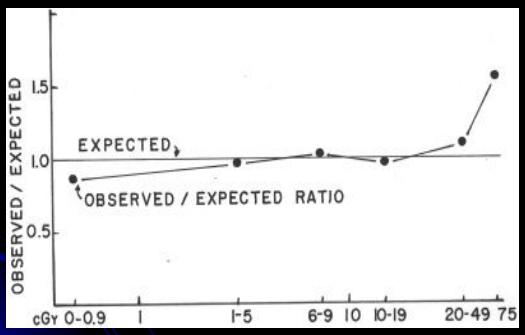
- Prominent in our closet of anxieties
- Dose dependent
- Linear Hypothesis (LNT)
- Medical radiation always newsworthy
- Fact: radiation is a weak carcinogen

Effects of Nuclear Explosions

- Blast: 40-50% of total energy
- Thermal Radiation: 30-50%
- Ionizing Radiation: 5% (more in neutron)
- Residual Radiation: 5-10%



Leukemia mortality rates in Hiroshima & Nagasaki



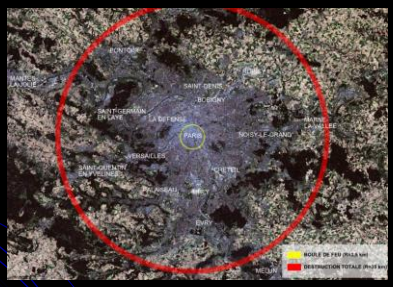
Comparison of expected with observed total cancer mortality rates of atomic bomb survivors in the two cities.

Tsutomu Yamaguchi

Survived both blasts & was within 2 miles of blast in each city! As many as 160 may have survived both blasts.

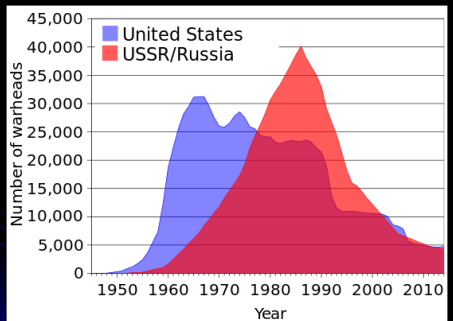
Philosophical Ruminations

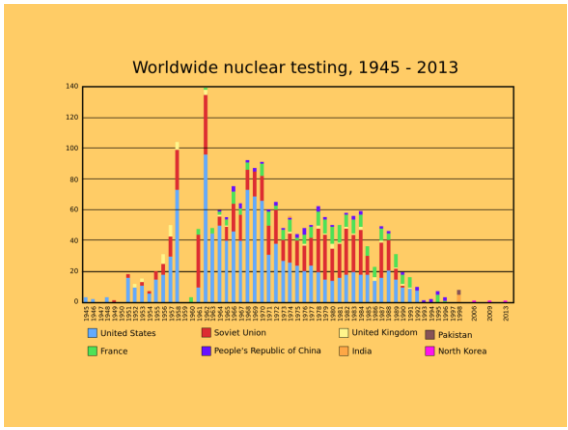
Tsar Bomba - 1961



Zone of Total Destruction

2004 Indonesian Earthquake





Number of Nuclear Weapons 2014

~ 7500 each for US & Russia

(Worldwide total of ~16,000)

By 2022 projected arsenal of 2000-3000 each (US & Russia)

2016