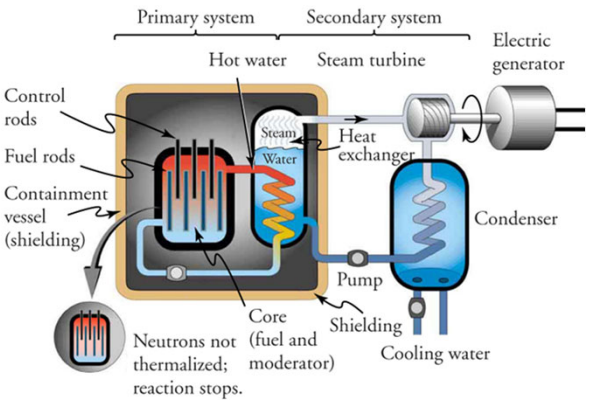
Alex Tihonov (Adobe Stock)

Uses of Radioactivity

Nuclear Power Plant – x1klima (CC BY-ND 2.0)

Nuclear Reactor

- Fission reaction generates energy in the form of heat.
- Heat is used to generate steam.
- Steam drives a turbine attached to a generator to produce electricity.
  - Approximately 10% of the world's electricity is generated by nuclear reactors.

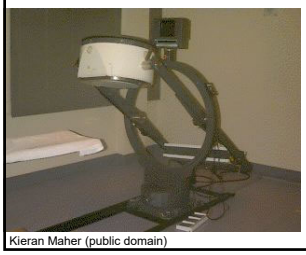


OpenStax, Rice University (CC BY 4.0)

Radiopharmaceuticals

- Radiation detectors external to the body can determine the location and concentration of a radiopharmaceutical to yield medically useful information.
  - ^{47}Ca: bone metabolism
  - ^{11}C: brain tumor imaging
  - ^{51}Cr: red cell volume heart scan
  - ^{57}Co: gastrointestinal absorption

- Once a radioactive compound has been administered, a device is used to monitor nuclear activity.
  - Gamma camera (scintillation camera or Anger camera)
    - Produces a two dimensional image



Kieran Maher (public domain)

Vila H. (CC BY-NC-ND 2.0)

- SPECT (Single-photon-emission computer tomography)
  - A gamma camera is used to acquire multiple 2-D images from multiple angles.
    - Multiple cameras are sometimes used.
  - A 3-D image is reconstructed from the images.

Ytrottier (CC BY-SA 3.0)

- PET (Positron emission tomography)
  - Detects β^+ particles
  - Produces a 3-D image

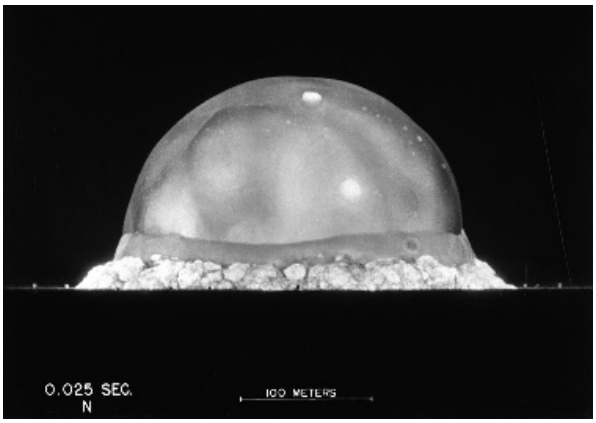
Jens Maus (public domain)

liz west (CC BY 2.0)

Atomic Bomb

- In the early 1940s Hitler banned the sale of Uranium from the Czech mines he had taken over.
- Einstein wrote a letter to President Roosevelt informing him that nuclear fission could be used for a bomb and that Germany may have already begun development on one.

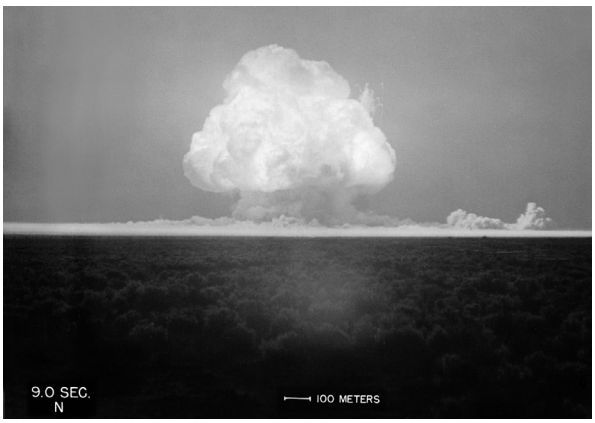
- The Manhattan project was started in the town of Los Alamos under the direction of J. Robert Oppenheimer.
- A fission bomb relies on the fact that a critical mass of uranium produces a supercritical reaction.
- An alternate version uses TNT to compress plutonium such that a supercritical reaction occurs
- The first fission bomb (Trinity) was tested on July 16, 1945.



U.S. Department of Defense

U.S. Department of Defense

Exposed wiring of “The Gadget,” the nuclear device that exploded as part of Trinity. At the time of this photo, the device was being prepared for its detonation.

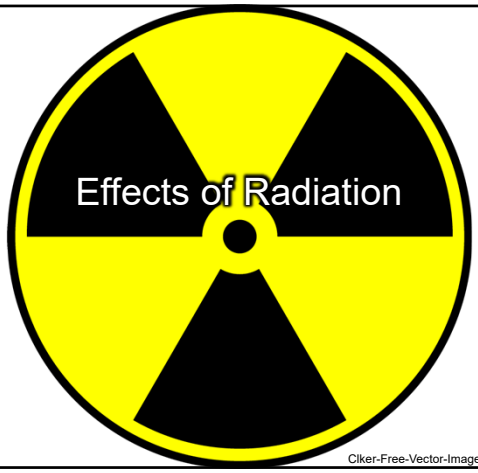


U.S. Department of Defense

But when you come right down to it, the reason that we did this job is because it was an organic necessity. If you are a scientist you cannot stop such a thing. If you are a scientist you believe that it is good to find out how the world works; that it is good to find out what the realities are; that it is good to turn over to mankind at large the greatest possible power to control the world and to deal with it according to its lights and values.
(Regarding the atomic bomb project.)

— J. Robert Oppenheimer

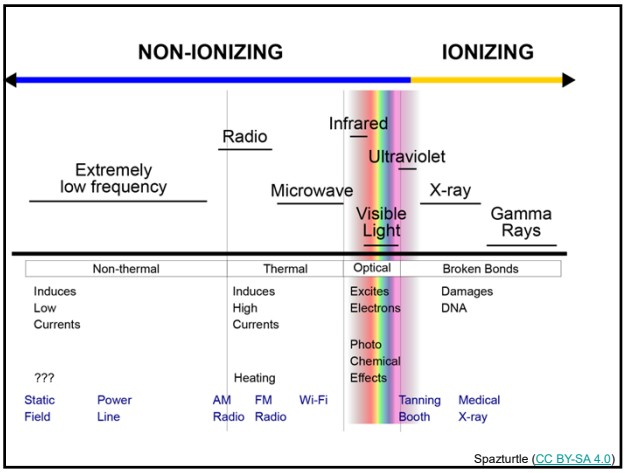
From speech at Los Alamos (17 Oct 1945). Quoted in David C. Cassidy, J. Robert Oppenheimer and the American Century (2009), 214.



Clker-Free-Vector-Images (Pixabay)

Types of Radiation

- Ionizing
  - The particles have enough energy to ionize atoms either directly by knocking electrons out of orbit or indirectly due to secondary processes.
- Non-ionizing
  - The particles do not have enough energy to ionize atoms.



Health Effects of Ionizing Radiation

- Any living tissue in the human body can be damaged by ionizing radiation in a unique manner.
- The body attempts to repair the damage, but sometimes the damage is of a nature that cannot be repaired, or it is too severe or widespread to be repaired.
- Also, mistakes made in the natural repair process can lead to cancerous cells.

Short Term Effects

- Radiation burns
- Radiation sickness (radiation poisoning)
  - premature aging or even death
  - The symptoms of radiation sickness include nausea, weakness, hair loss, skin burns or diminished organ function.

Long Term Effects

- Cancer
- DNA mutation
- Death

Dosimetry

- There is a saying, “the dose makes the poison.”
- This is true for everything including radiation.
- Dose is a measurement of the amount of radiation absorbed by the body.

- rad
  - The amount of radiation which deposits energy at a rate of 1.00×10^{-2} J/kg in any absorbing material.
- gray (Gy)
  - 1 Gy = 100 rad

Effective Dose

- Some types of radiation can do more damage than others.
- The effective dose multiplies the dose by a quality factor (QF) to account for this difference.
- Measured in **rem** (rad equivalent man) or **Sv** (Sievert).

$$\text{rem} = \text{rad} \times \text{QF} \qquad \text{Sv} = \text{Gy} \times \text{QF}$$

$$1 \text{ Sv} = 100 \text{ rem}$$

Background Radiation

- Radioactive material is found everywhere.
  - rocks, soil, air, living things, water
- The level of this background radiation is around 2 mSv per year.
- Regulations place an upper limit of 1 mSv above background per year for civilians up to 50 mSv per year for radiation workers (people working directly with radiation).

Exposure (rem)	Health Effect	Time to Onset (without treatment)
5-10	changes in blood chemistry	
50	nausea	hours
55	fatigue	
70	vomiting	
75	hair loss	2-3 weeks
90	diarrhea	
100	hemorrhage	
400	possible death	within 2 months
1,000	destruction of intestinal lining	
	internal bleeding	
	and death	1-2 weeks
2,000	damage to central nervous system	
	loss of consciousness;	minutes
	and death	hours to days