Title: Introduction to Nuclear Weapons

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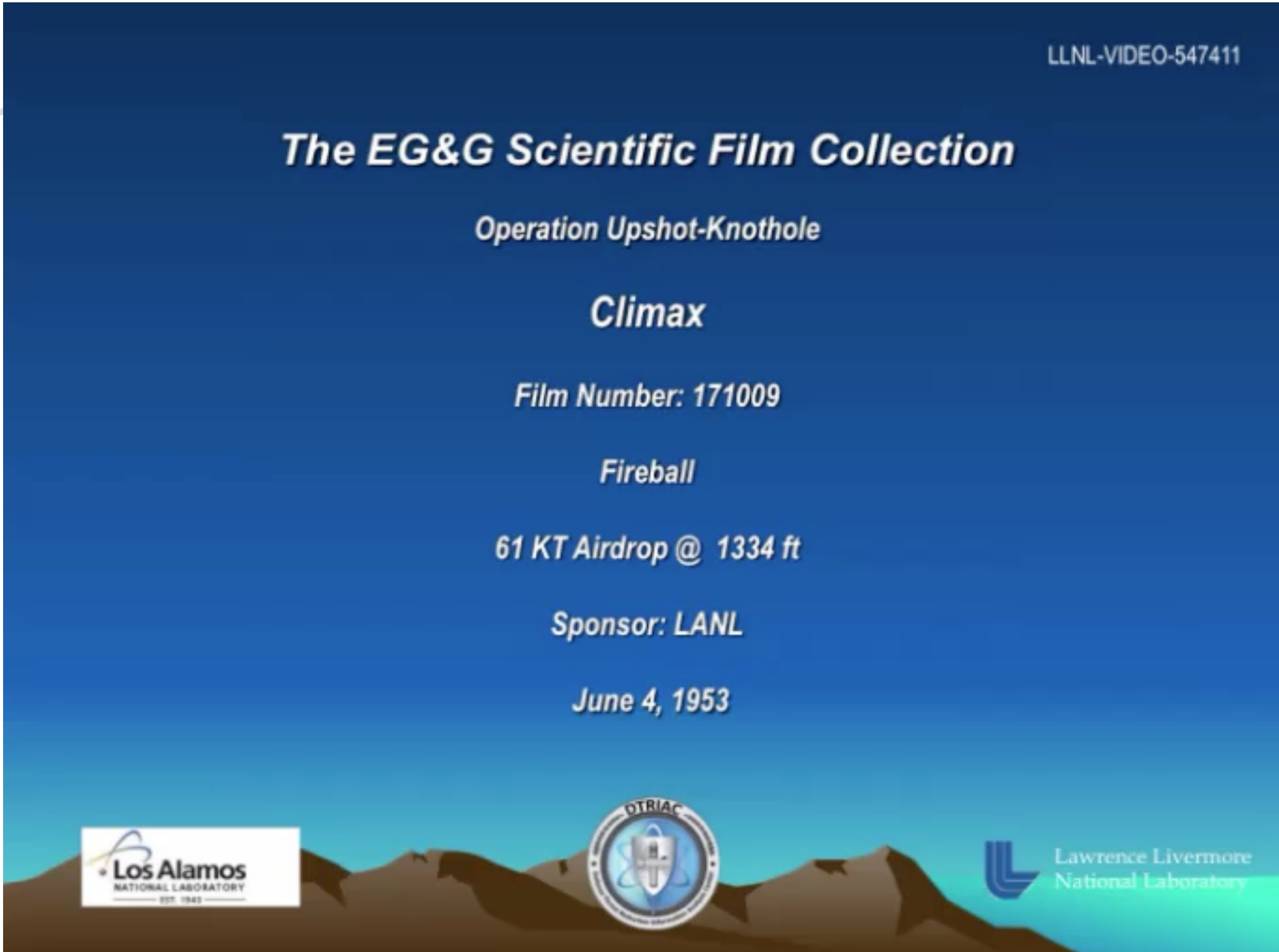
Los Alamos
NATIONAL LABORATORY
EST. 1943

Introduction to Nuclear Weapons

For Actinide Sciences Lectures

20 August 2020

NNSA
National Nuclear Security Administration


LLNL-VIDEO-547411
The EG&G Scientific Film Collection
Operation Upshot-Knothole
Climax
Film Number: 171009
Fireball
61 KT Airdrop @ 1334 ft
Sponsor: LANL
June 4, 1953
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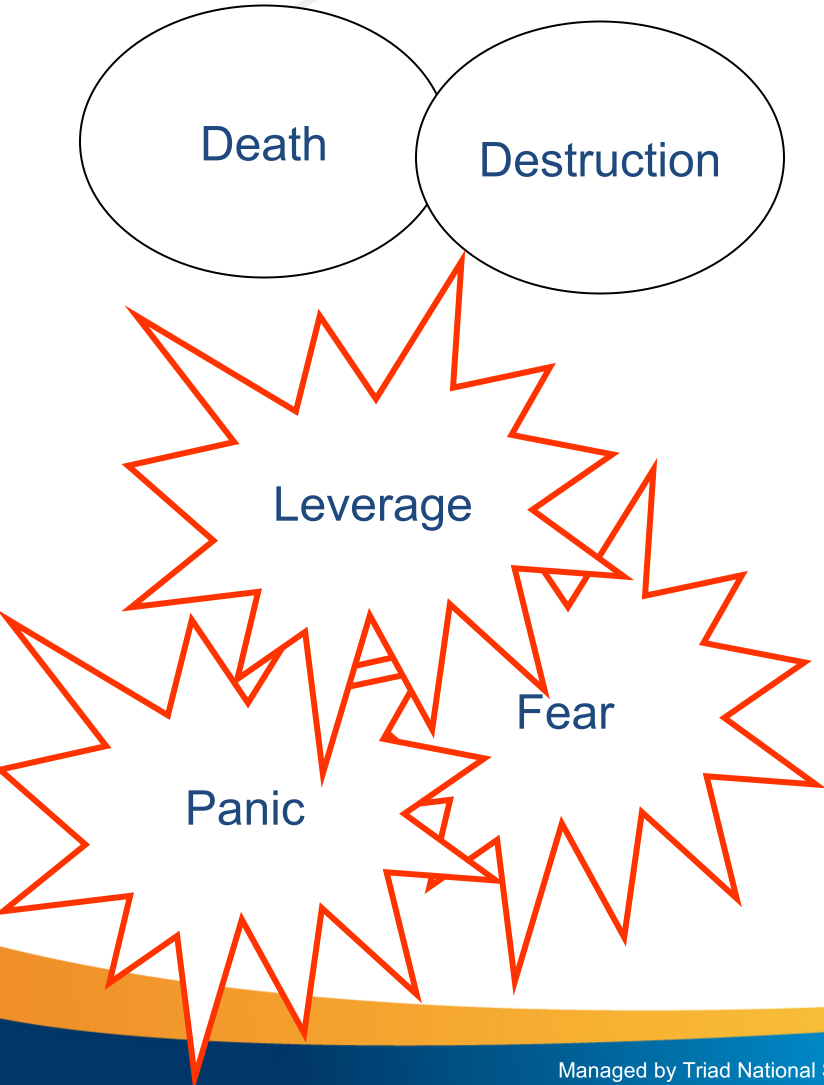
National Laboratory

What makes a weapon?



Can it be delivered?

Can it be made?

Where can it be used?

What will it affect?

High-Explosive vs Nuclear Explosions

- **Conventional explosions** involve a chemical reaction in which atoms (ie. hydrogen, carbon, oxygen, and nitrogen) are rearranged primarily at molecular level.
- **Nuclear explosions** are a result of the formation of different atomic nuclei by redistribution of protons and neutrons of interacting nuclei. (ie. fission and/or fusion events)

- The nuclear binding energy is much greater than the forces between atoms resulting in nuclear explosions that:
  - are millions of times more powerful
  - are thousands of degrees hotter
  - emit radiation and produce fallout

Nuclear versus Chemical

Nuclear	Chemical Explosives
Reactions occur on the order of 10^{-8} seconds (shakes)	Reactions occur on the order of milliseconds (10^{-3}) to microseconds (10^{-6})
Approximately 185 MeV of energy released per reaction	Approximately 19 eV of energy released per reaction
Generates temperatures around 10000000 K (hotter than the sun)	Generates temperatures around 5000 K (hotter than a blast furnace)
60% of the energy is released as X-Rays	Energy released as kinetic energy

Bomb Comparison

- The largest conventional bomb the US ever had was the "Bomb, General Purpose, 44,000-lb., T12", which weighed 43,600 lbs (~20 T)
- The smallest nuclear bomb was the “Davy Crockett”, with very low weight and low yield

What is a Nuclear Weapon?

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A device that fissions in a chain reaction, which results in the release of a large amount of energy

- Fission: A nuclear reaction where a nucleus is split
- Chain Reaction: A sequence of reactions where one or more products causes more reactions to occur
- Large: A million times more powerful than a chemical explosive on a per-reaction basis
- Energy: Kinetic and electromagnetic radiation

Nuclear Explosive

- Fission
  - Assemble supercritical mass in NON critical geometry (usually by conventional explosives)
    - Cylindrical
    - Spherical
  - Assemble quickly into supercritical shape
    - Fast supercritical condition
    - Held together long enough for high energy release
- Fusion
  - Compress D T under high pressure and at high heat until D-D or D-T fuses.

Fission Model

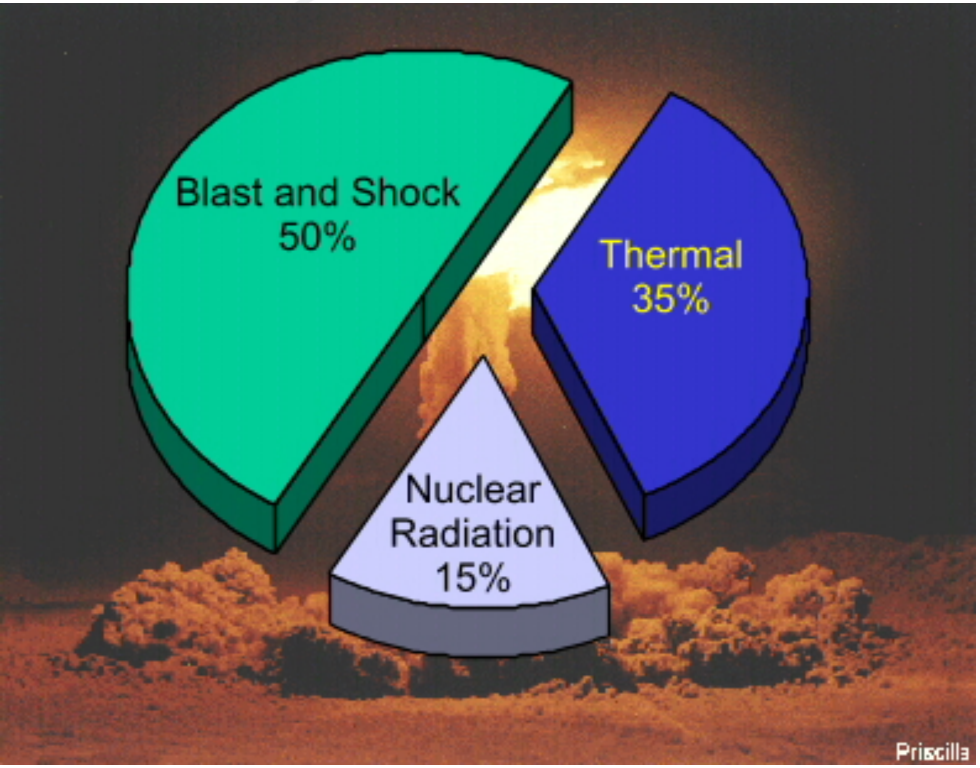
- https://youtu.be/vjqIJW_Qr3c

Very Simple Model

I like to view the sequence of events for a nuclear explosion as follows:

1. Explosives change the geometry to achieve a supercritical geometry
2. Neutrons are produced to build a large population quickly before the device mechanically disassembles.
3. Once a large population of neutrons is produced, yield production begins in earnest
4. Material kinetic energy shuts down yield production

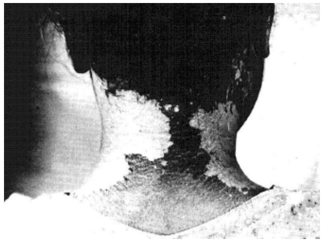
Primary Effects from a Nuclear Explosion



Approximately 70% to 80% of total yield of nuclear device is emitted initially as x-rays
(for altitudes<40kft).

X-rays are absorbed by the air
→ air is heated
→ fireball
→ reradiates thermal radiation
→ drives intense shock front

Characteristics of a Nuclear Explosion

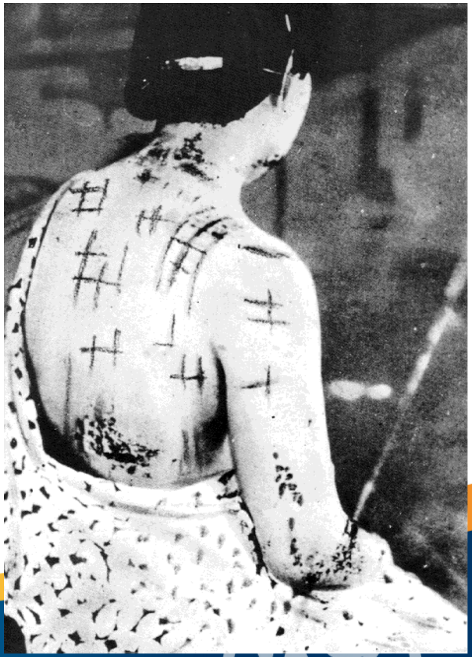


- Blast and Shock (50%)
  - **Sudden increase and then decrease in air pressure**
  - **For 20 kT: at 1 km, increase of 1 atm. (can destroy a brick bldg), at 2 km can destroy wood building and scatter debris at 100 mi/hr**
- Thermal Radiation (35%)
  - **At 2 km from a 20 kT blast, heat wave arrives in ~2 s and can cause 3rd degree burns on exposed skin**
- Initial Nuclear Radiation (5%)
  - **Neutrons and gammas**
  - **Lethal dose at ~ 1 km for unprotected people**
- Residual Nuclear Radiation (10%)
  - **Longer lived radioactive products create downwind hazards and can be lethal**
  - **^{90}Sr is a typical radioactive product that is chemically similar to Calcium and so can be absorbed into bones and cause bone cancer.**

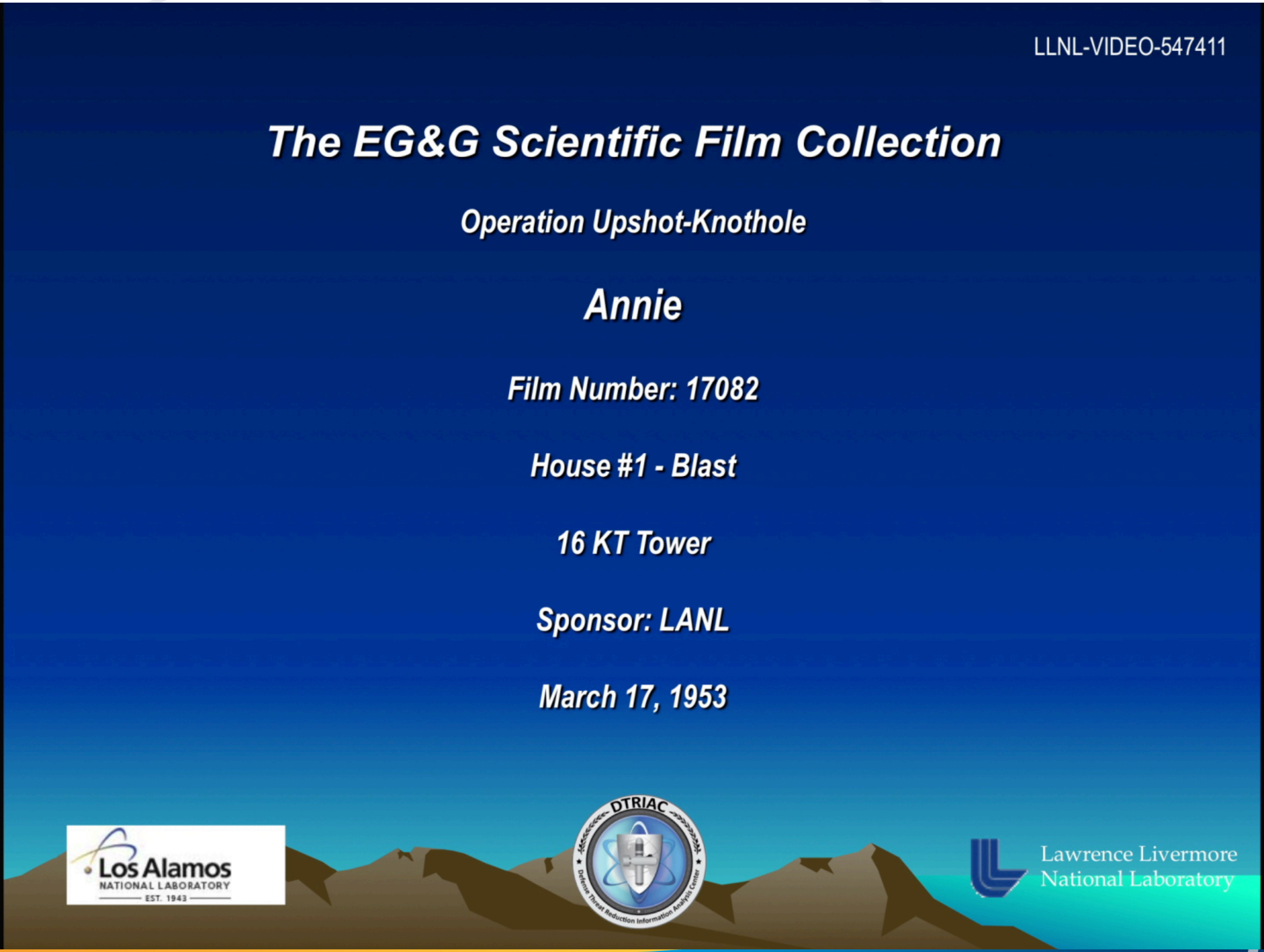
Fireball Formation

Thermal Radiation Absorption

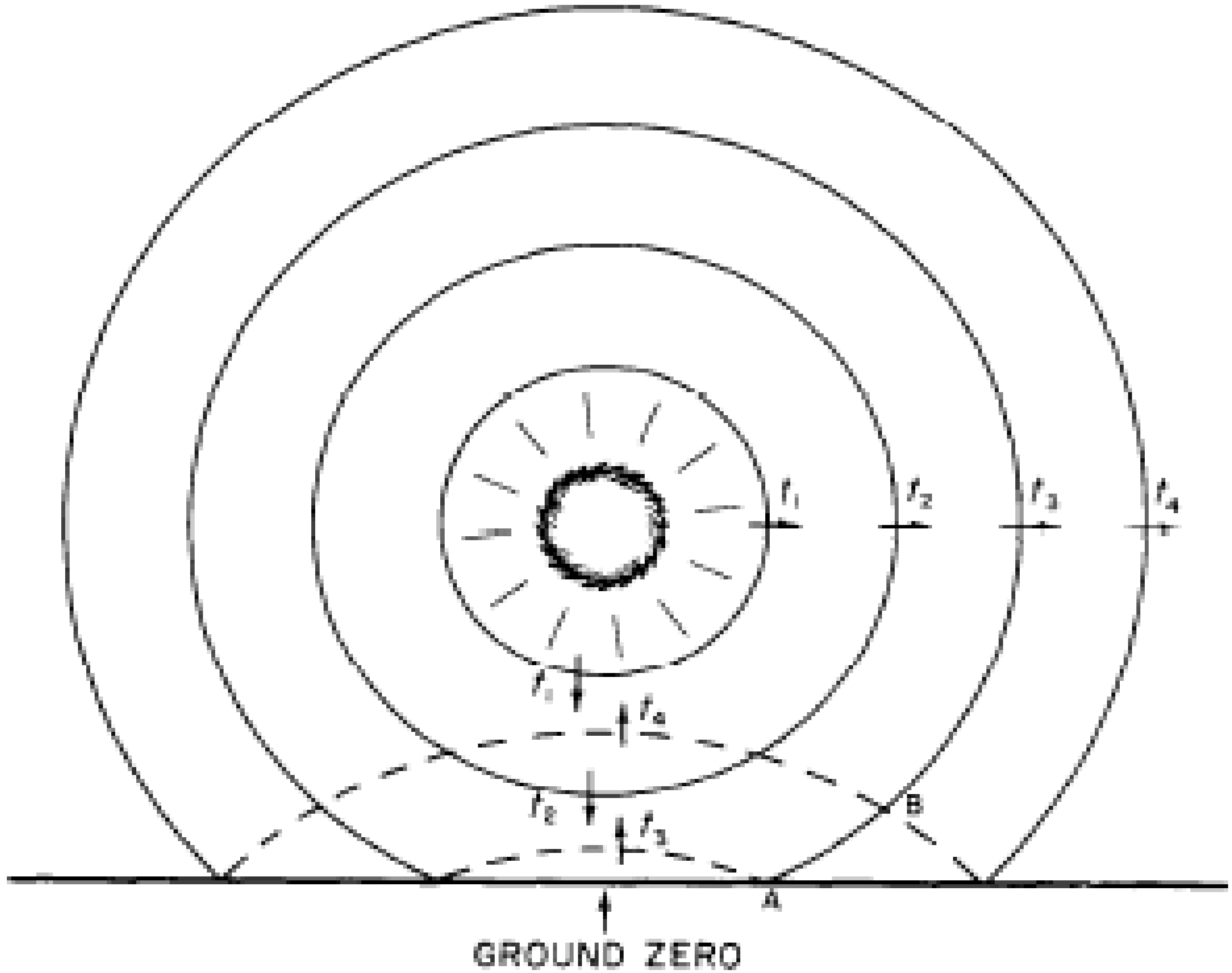
- Essentially all of the thermal radiation absorbed serves to raise the temperature of the material.
- The extent to which thermal radiation is absorbed depends upon the nature and color of the material or object.



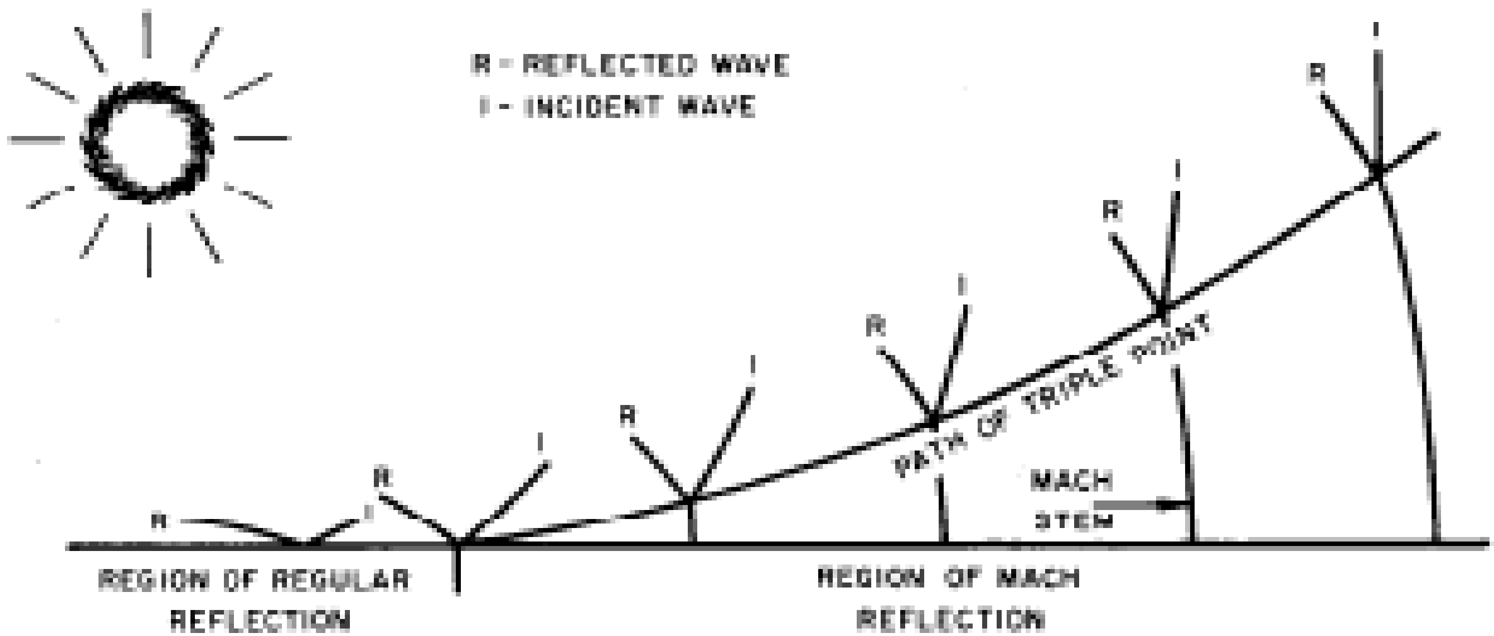
Blast and Thermal Effects

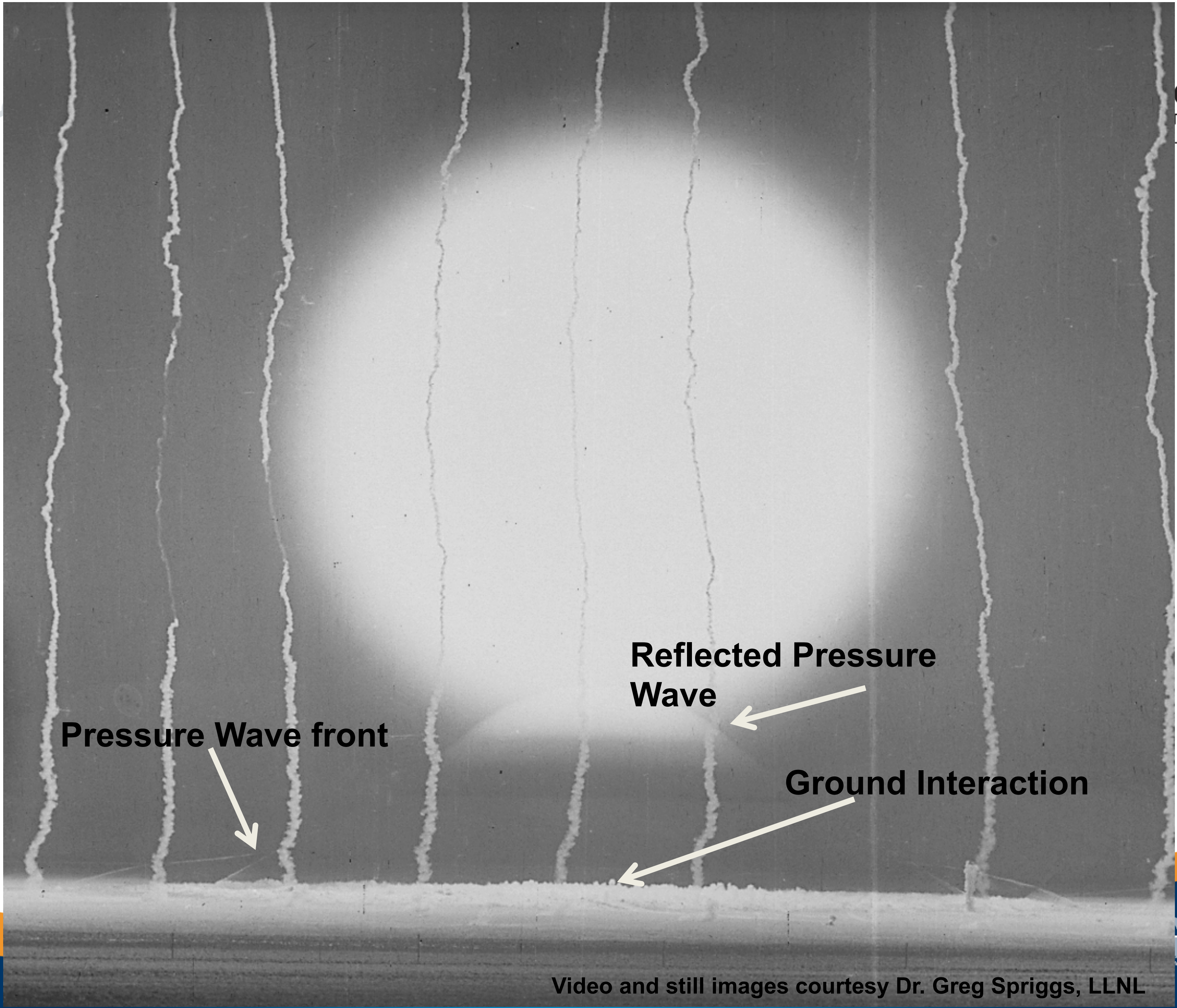


Interaction with the ground



Path of Triple Point

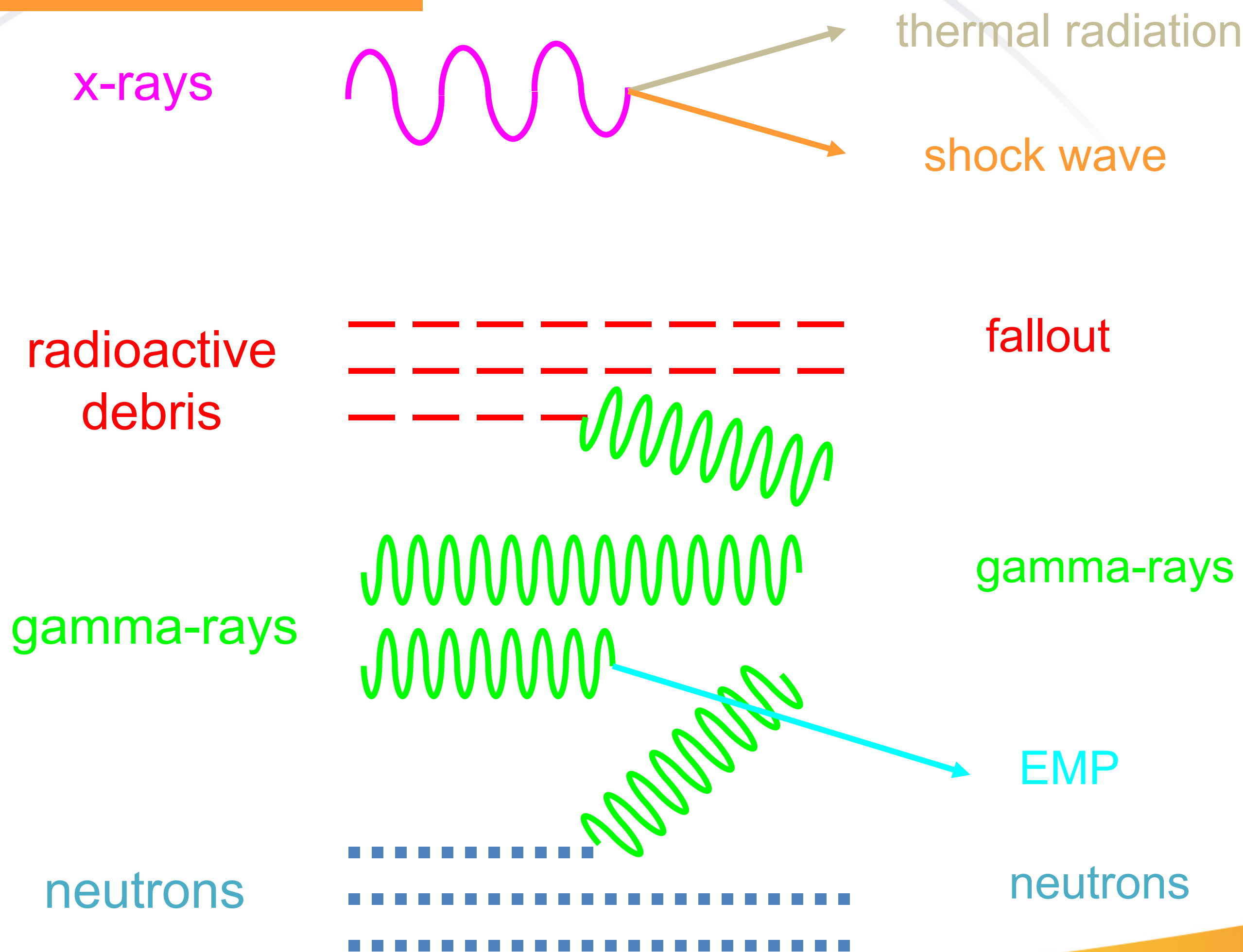



Reflected Pressure Wave
Pressure Wave front
Ground Interaction
Video and still images courtesy Dr. Greg Spriggs, LLNL

Nuclear Explosion Products

Primary Explosion Products

Secondary Explosion Products

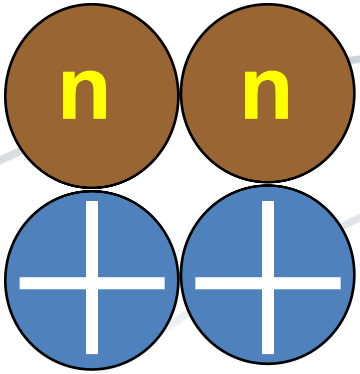


Types of Radiation in a Detonation

- Alpha (α)
- Beta (β)
- Gamma (γ)
- Neutrons (n)

Residual (Alpha, Beta)

Initial (Gamma, Neutrons)



Alpha Particle

- Helium Nucleus (no electrons)
- Limited Range
- NOT external hazard

Beta Particle

- High speed electron
- **<u>CAN</u>** penetrate skin, but stopped by few layers of clothing
- Minor skin burns possible if uncovered may be long term if ingested

Gamma Ray

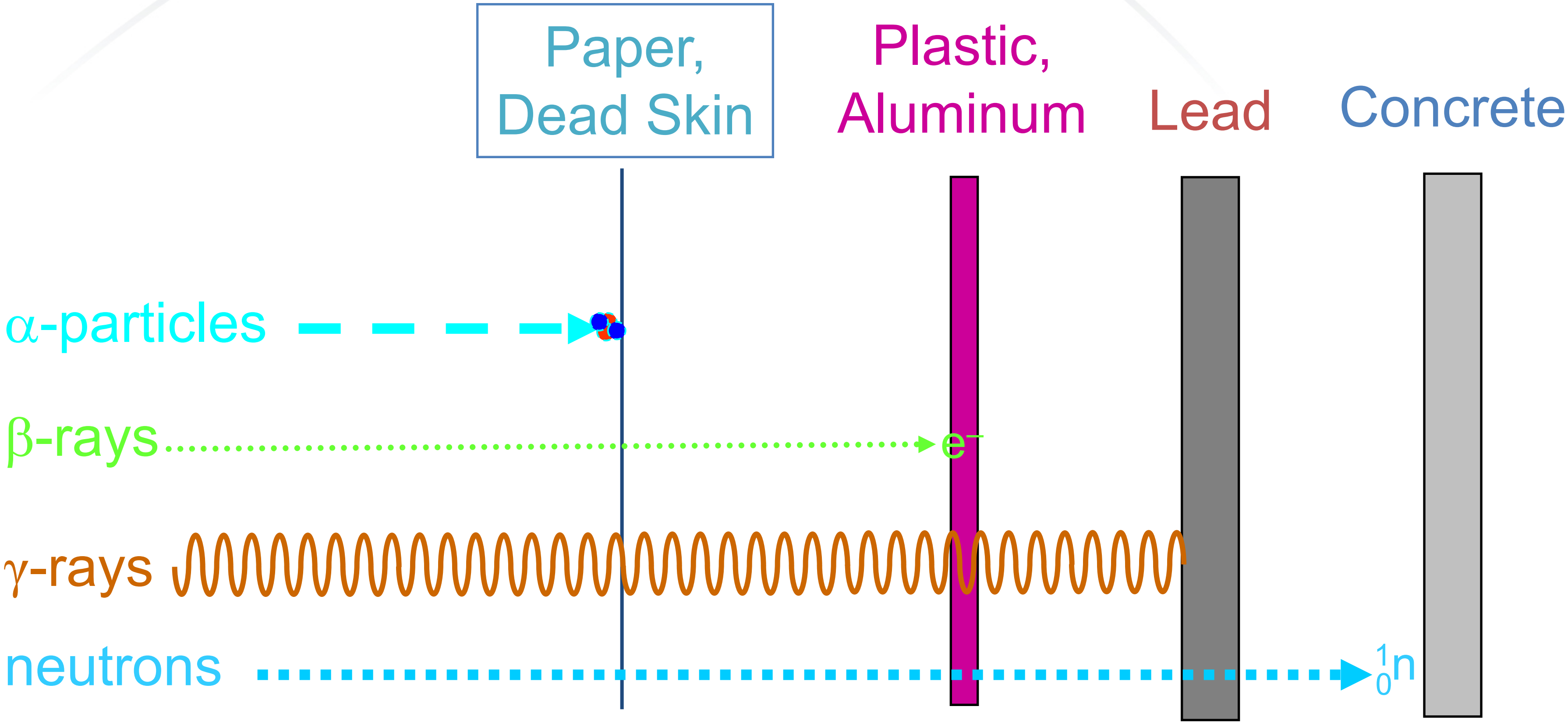
- Energetic X-RAY
- VERY penetrating, WHOLE-BODY hazard
- Shield with DENSE material
- Potentially LARGE casualty producer

n

Neutron

- Initial Radiation Pulse ONLY
- VERY penetrating, use hydrogenous shield
- Whole-body exposure hazard
- Energy spectrum of neutrons dependent on type of nuclear blast

Range Comparison



Questions?

Nuclear Myths & Misconceptions

- A nuclear weapon will generate vast quantities of radioactive material
  - About 55 grams of fission products/KT of yield is produced
  - A few hundred kilograms of activation products from the casing
  - 0.3 tons to 0.8 tons of activated dirt per ton of yield
- A nuclear reactor can explode like a nuclear bomb
  - The fuel in a nuclear does not have the appropriate geometry to sustain a chain reaction in order to produce the required energy density
  - Reactors are designed to work with thermal neutrons—bombs are designed to work with fast neutrons
- Nuclear bombs are difficult to build
  - A basic weapon is easy to construct
  - A viable weapon system is difficult
  - The real challenge is in obtaining the material