Sandia National Laboratories

Enhanced Nuclear Detonation Safety (ENDS)

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Electrical

Electrical + Fire

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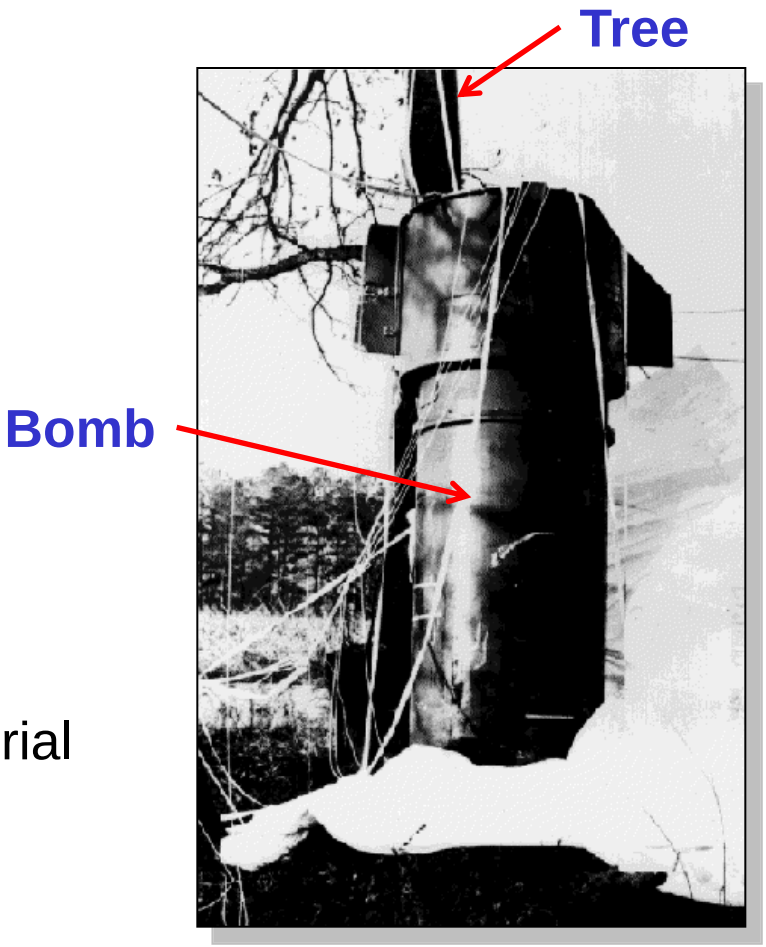
What is the Problem?

- Nuclear weapons (NW) contain large amounts of conventional explosive & radioactive material
- NWs must be transported, maintained, and stored
  - Decades
  - Accidents and Mother Nature
- Must avoid:
  - Loss of life, injury
  - Radioactive dispersal
  - Decrease in the weapon's required reliability
  - Loss of "customer confidence"
- How can we do this?

Nuclear Accidents

- Goldboro, NC, USA
  - Jan. 24, 1961
  - Weapon breakup
- Bunker Hill, IN, USA
  - Dec. 8, 1964
  - Thermal environments
- Palomares, Spain
  - Jan 17, 1966
  - Dispersal of radioactive material
- Thule, Greenland
  - Jan 21, 1968
  - Dispersal – in a frigid environment



Changes in National Policy

- Carl Walske – 1968, Chair of Military Liaison Committee (precursor to current NW Council)
  - New safety requirements mandated for nuclear weapons
  - Probability of nuclear yield (> 4 lbs TNT equivalent) shall not exceed
    - *Prior to launch, for ... normal storage and operational environments … 1 in 10^9 per warhead lifetime*
    - *Prior to launch, for … abnormal environments, 1 in 10^6 per warhead exposure or accident*
  - One in 10^6 = Probability of Failure (> 4 lbs) is *0.000001*

US Military would not accept weapons that did not meet new requirements

ENDS Safety Theme Principles

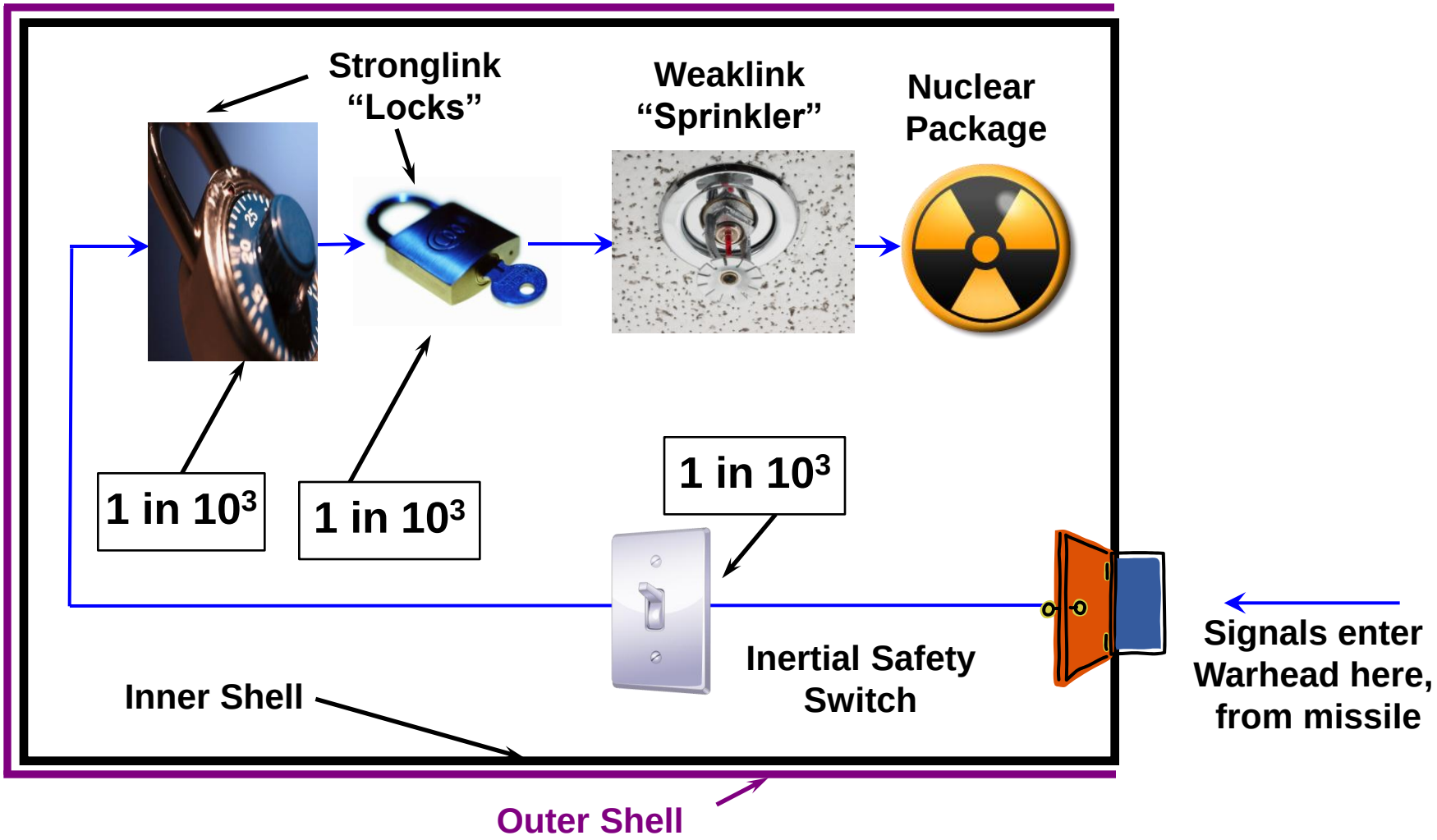
- Isolation: Isolate detonation-critical components from unintended energy (electrical, thermal, mechanical)
  - Hardened switches (stronglinks), metal barriers
- Incompatibility: Design enabling stimuli to be unique and not found in nature
  - Pseudo-random signals used for key arming steps
  - Enforce electrical incompatibility
    - Avoid: 60 Hz AC, low-voltage DC signals in bomb design
- Inoperability: Make the weapon predictably and irreversibly inoperable before isolation is lost
  - Thermal failsafe devices (weaklinks)

Implementation Aide: Independence

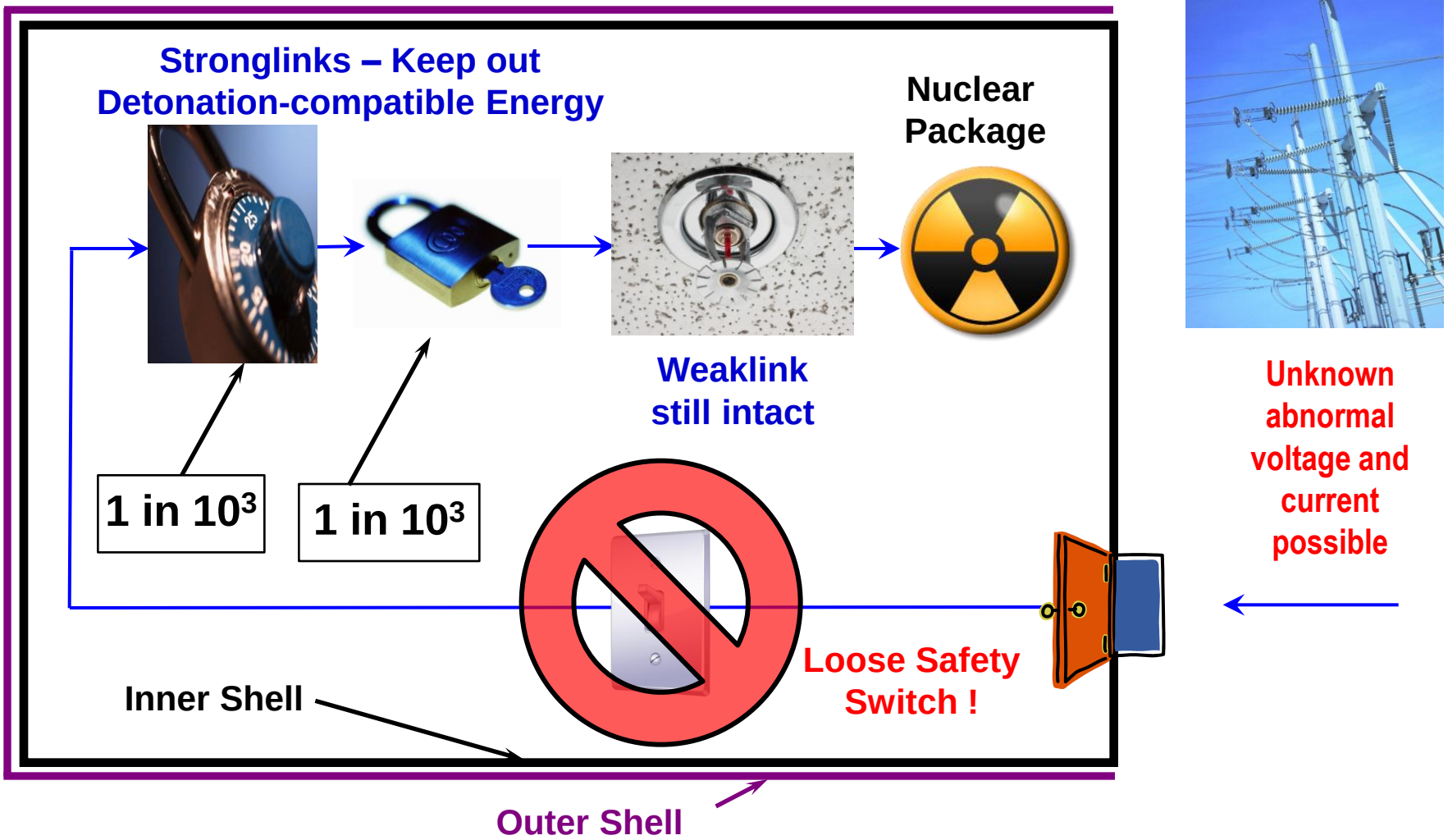
- Separate subsystems, independent operation, placed in series:
  - Inertial switch
  - Combination lock
  - Key lock
  - *All 3 very different*

- Easier to assure each component to 1 in 10^3 level
  - Three of these connected, multiply performance
  - Provides 1 in 10^9 safety, meets requirements!
- Failsafe device
  - Small red tube in sprinkler systems
  - Physically unrelated to other devices

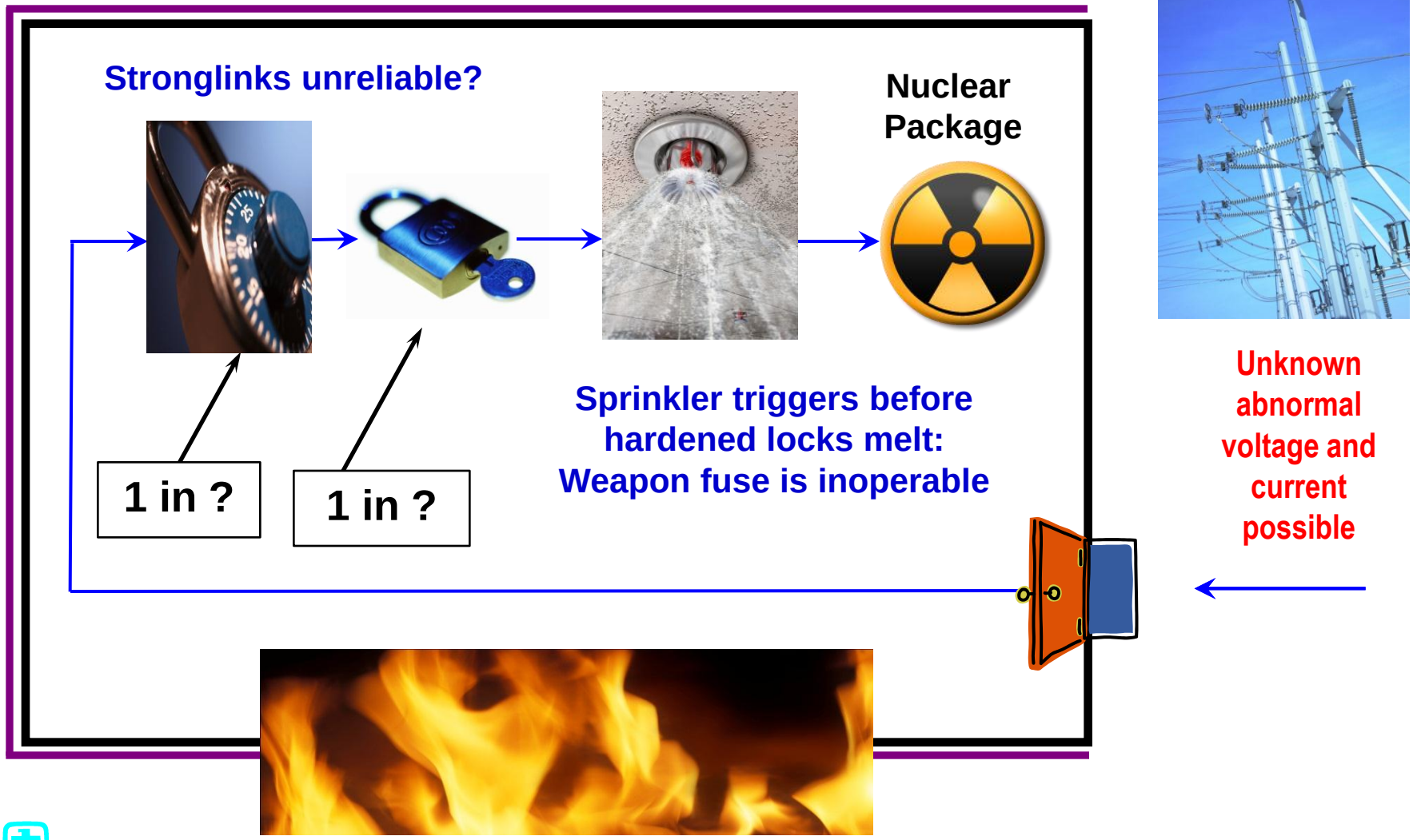
Normal Environment: One in a Billion



Abnormal Environment: Electrical



Abnormal Environment: Electrical + Fire



Summary

- Several Nuclear Weapon accidents prompted a big change to design policy in the late '60's
- Walske Criteria
  - *1* in 10^9 for normal environments, *1* in 10^6 for abnormal
- New requirements met through ENDS Theme
  - Isolation, Incompatibility, Inoperability
  - Independence allows a realistic implementation
- Modern designs adhere to this theme
  - Weaklinks fail before the stronglinks loose reliability
  - Future refurbishments, life extension programs

A method to ensure NW safety is in place;
We continue to learn more about how to implement it.