# Nuclear Deterrence: Past, Present, and Future


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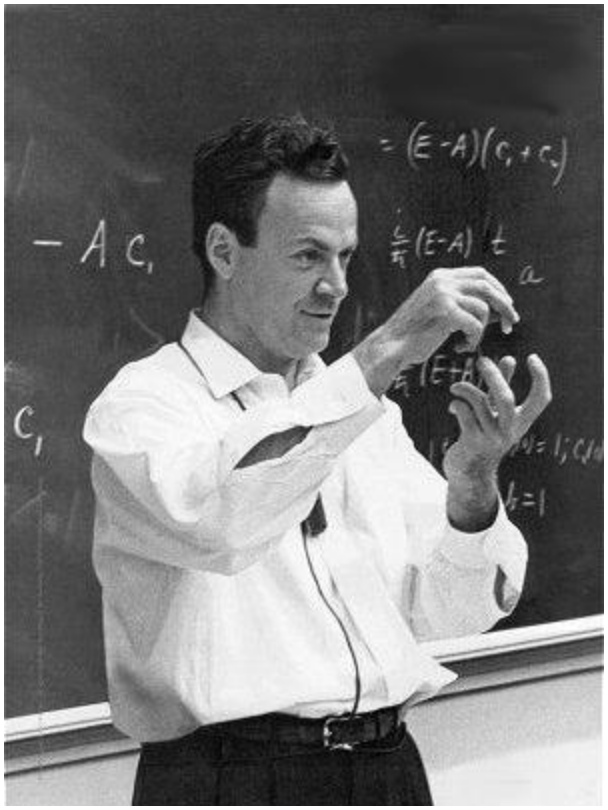
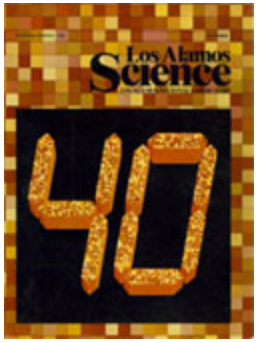
**Los Alamos National Laboratory**


**May 4, 2010**

# April 1983: 40th Anniversary Reunion of the Manhattan Project



Richard Feynman

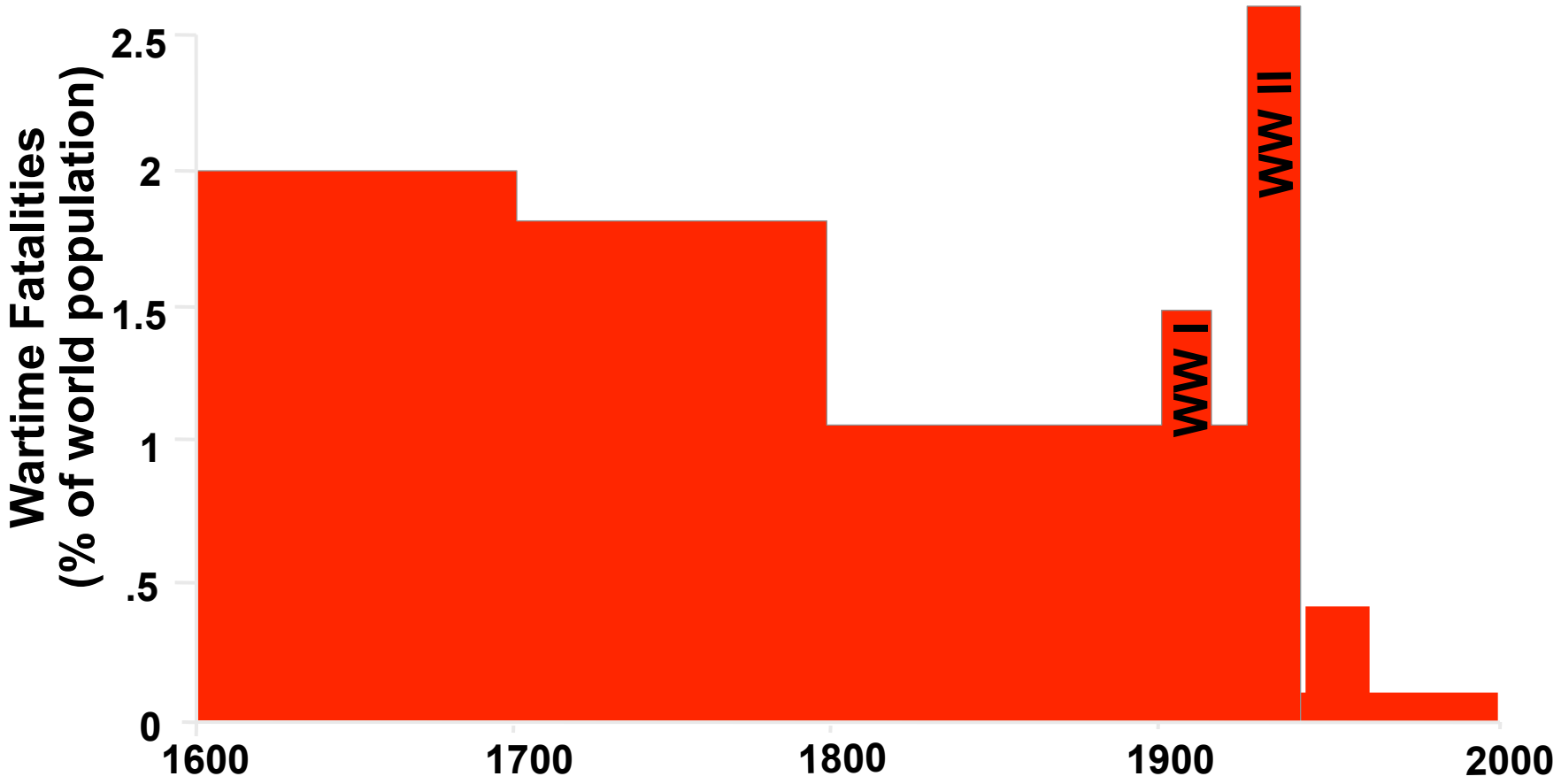

Los Alamos Science
Spring 1983 Volume

Hans Bethe

# Preamble

# Nuclear Deterrence: What is deterrence?

# Wartime Fatalities




Source: R.G.Joseph and R.F. Lehman II, "US Nuclear Policy in the 21st Century: A Fresh Look at National Strategy and Requirements" (1998) Diane Publishing
C.A.Murdock, "The Department of Defense and the Nuclear Mission of the 21st Century", CSIS Report, March 2008.

# Deterrence Definitions

Deterrence can be simply defined as:

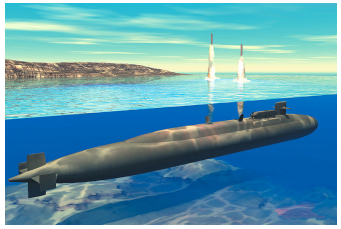
*"The ability to inflict unacceptable cost upon an adversary – such that that adversary is deterred from conducting an undesired act."*

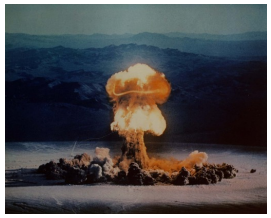
Implementation of specific words and concepts in this definition:

***"ability to inflict"*** – assured, survivable, credible, and communicated

***"unacceptable cost"*** – identifiable, meaningful, targetable, destroyable

***"adversary"*** – known, communicated, rationale



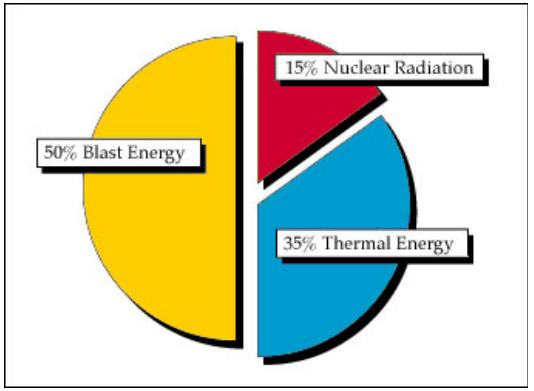



**Nuclear weapons** provide unrivaled ability to meet many of these requirements: destructive power, ease of delivery, stealthy and survivable

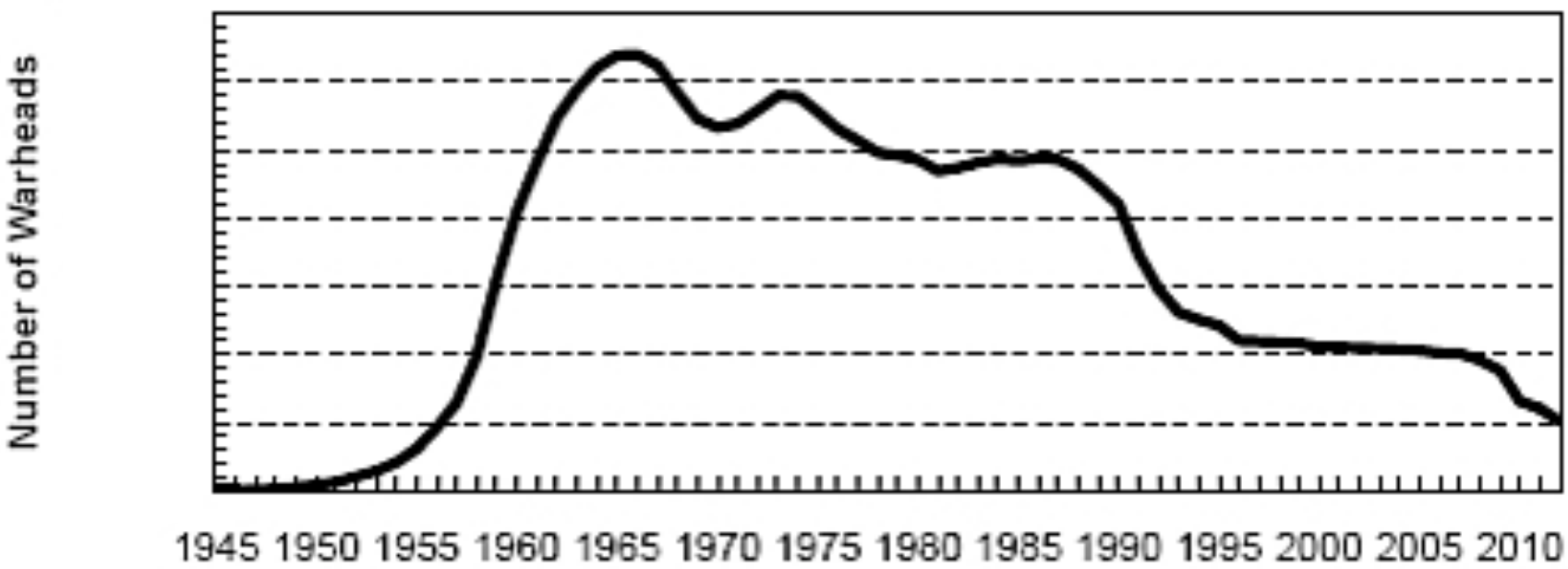
Blast

Heat

Radiation



# The Number of United States Nuclear Weapons Has Decreased since 1965

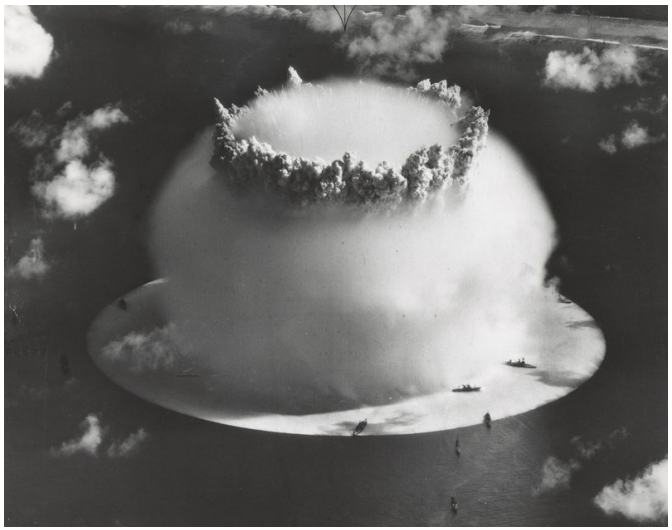



2008 Stockpile is ~10% of the 1965 peak

# Nuclear Deterrence: Past

# Nuclear Effects Testing

- First priority: survivability of US military forces
  - Crossroads test series, 1946



Crossroad Baker – July 26, 1946

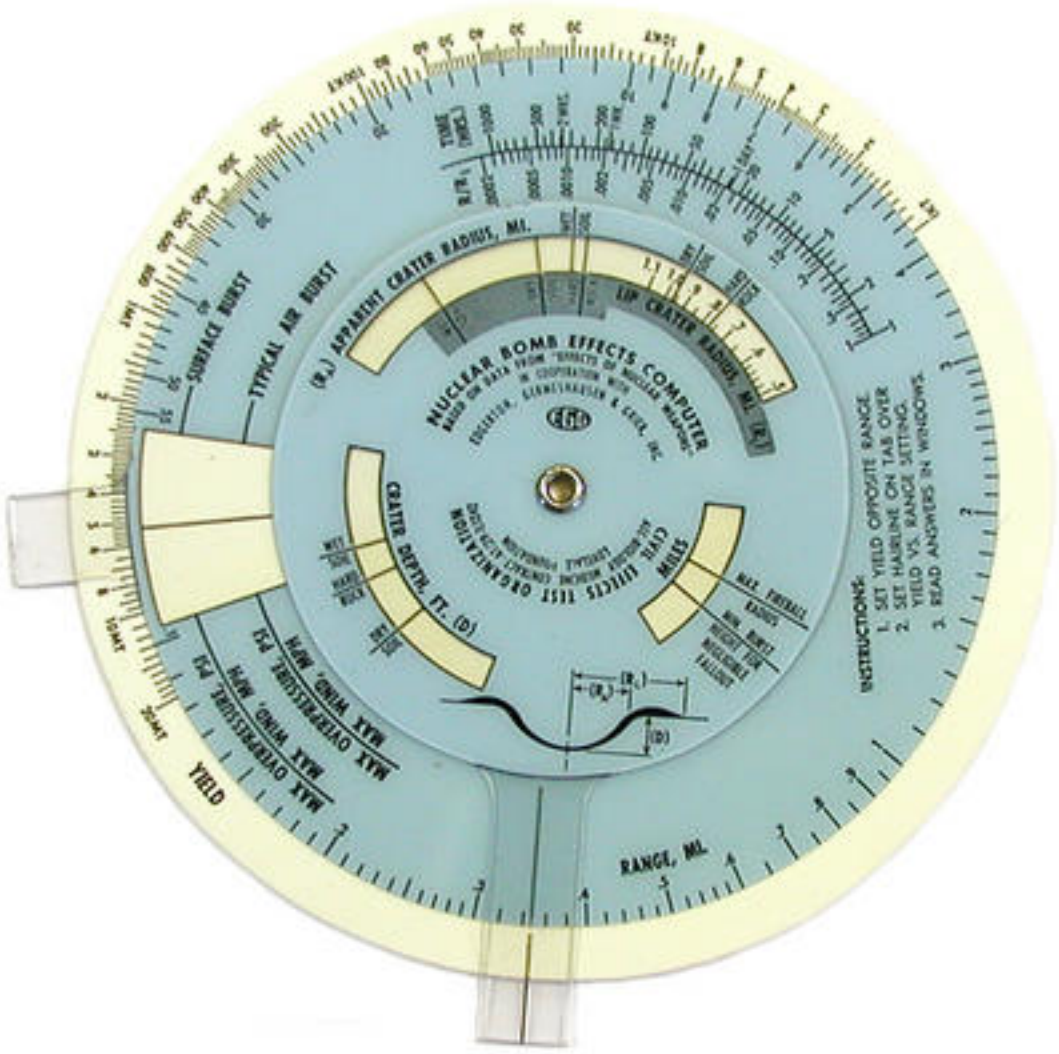
- Civil Effects
  - Teapot Series, 1952-1955

Surviving House from Teapot Apple II



Teapot Apple II – May 5, 1955

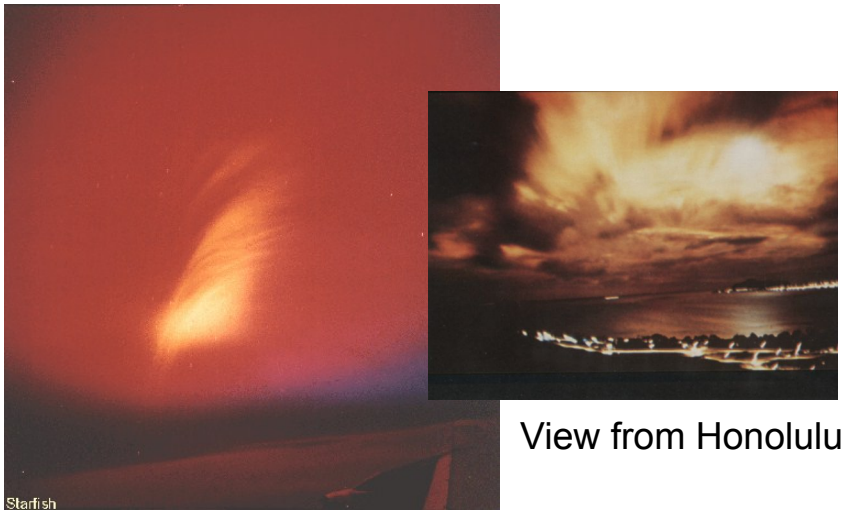
# Nuclear Effects Testing – Civil Defense




Analog Nuclear Weapon Effects Calculator

# Nuclear Effects Testing

- Nuclear Detonations in Space – electromagnetic pulse
  - Dominic Starfish, 1962




View from Honolulu

Dominic Starfish Prime – July 9, 1962

- Civil Engineering - Plowshare
  - Storax Sedan Cratering Shot

July 6, 1962

Storax Sedan, 104 kT

640’ emplacement depth

1300’ diameter crater
330’ deep

# Advancements in Nuclear Weapon Design

Early, first generation weapons were fission-only devices, 10's of kT of yield, 1000's of kg in mass

The first test series, Operation Crossroad, did not advance nuclear weapon design.

Priority was more efficient use of nuclear material. Operation Sandstone was this effort

Sandstone X-Ray – 6$^{th}$ nuclear explosion, 37 kT, April 14, 1948
Sandstone Yoke – 7$^{th}$ nuclear explosion, 49 kT, April 30, 1948

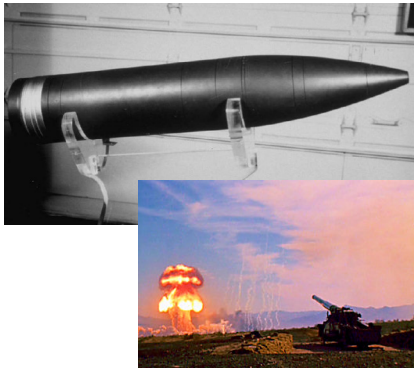
Sandstone X-Ray

Sandstone Yoke

# Advancements in Nuclear Weapon Design

- Beginning with Sandstone, advances in nuclear weapon design allowed a **reduction** in mass of the implosion device by a **factor of 30** from 1948 to 1956
  - Development of “boosting” was key: use of fusion in the primary
  - **Diameter** was reduced a factor of 3
  - Plastic-bonded explosives (PBX) were developed in 1956

- This dramatic reduction in weight and size enabled a huge diversity of new delivery systems
  - Tactical Missiles
  - Depth charges
  - Artillery shells
  - Landmines
  - And many, many more



Mk33 Artillery Shell

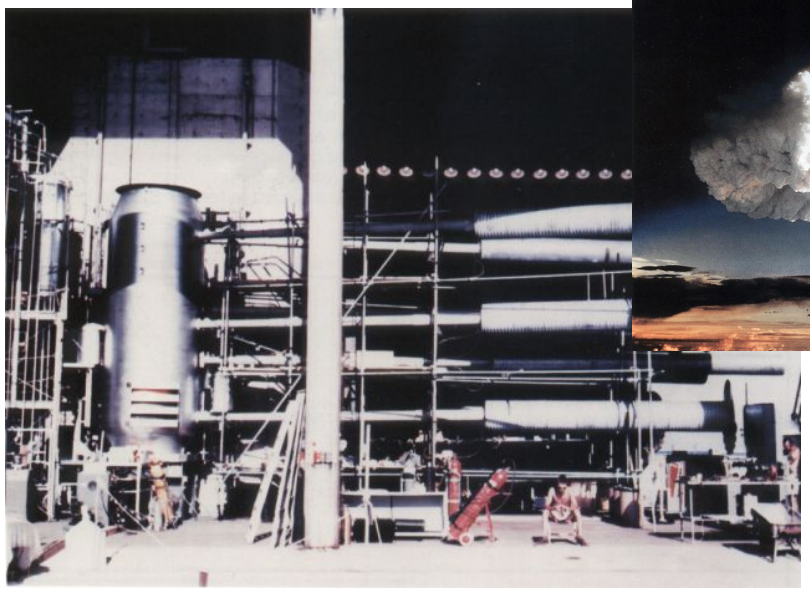
Davy Crockett W-54 SADM
(Special Atomic Demolition Munition)

B54 “Backpack” SADM

Mk7 Nuclear Depth Charge

# Development of the Hydrogen Bomb

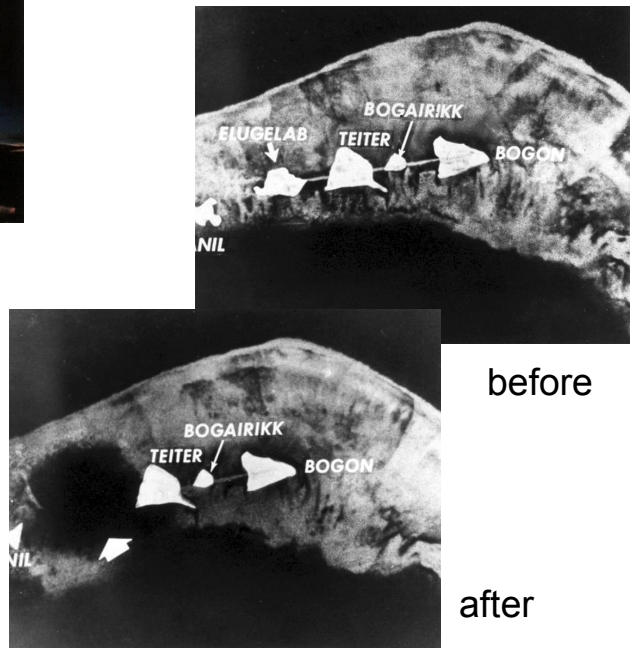
- Megatons vs. kilotons; unlimited yield vs. critical mass limitations for fission only
  - *radiation implosion*
  - Tested in Ivy Mike – Oct. 31, 1952 (33 months from initiation of development!)
  - "physics" test; difficult to weaponize configuration with liquid deuterium fuel
  - Andrei Sakharov of the USSR independently proposes the same concept



Ivy Mike device with diagnostic pipes

Ivy Mike, 10.4 MT

Elugelab Island is vaporized




before

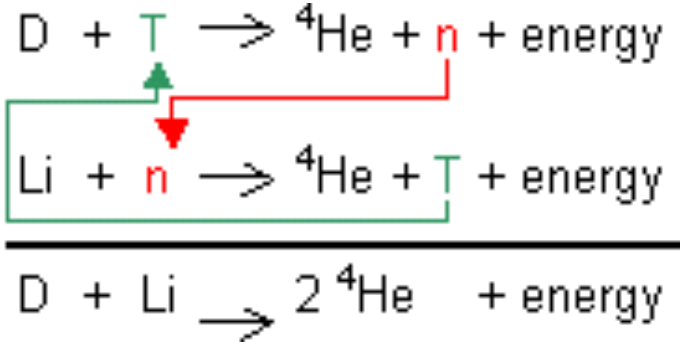
after

Enewetak Atoll

# Advancements in Thermonuclear Weapon Design

- Ivy Mike was a spectacular physics success, but several key problems remained to weaponize this new concept:
  - Cryogenic fuels were a nightmare
  - Tritium has a short half life (12.3 years)
  - The race to develop a long-range missile delivery system required dramatic reductions in mass and size

- The solution? “dry” thermonuclear fuel
  - lithium deuteride, LiD
  - Breeds tritium *in situ* with neutrons



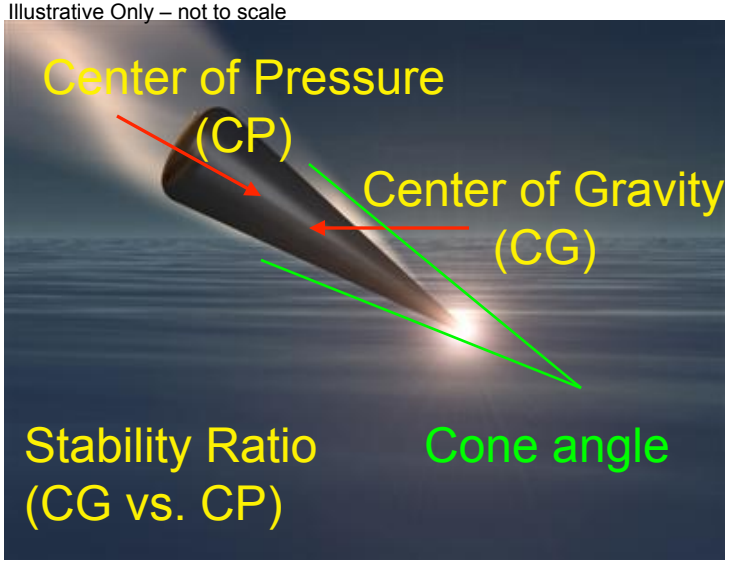

lithium deuteride

Castle Bravo – March 1, 1954
First test of staged, dry thermonuclear fuel
Largest US nuclear detonation – 15 MT

# Advancements in nuclear weapon miniaturization enabled dramatic improvements in accuracy

- Nuclear Weapon Blast effects scale with the cube-root of yield
- Given a choice between accuracy and yield, accuracy is far superior!

Illustrative Only – not to scale




1959 Air Force Test Vehicle

This conflict – placing the center of gravity forward in narrow cones – defines many decades of weapon development

# The miniaturization of warheads enabled successful long-range missile development

- Twin goals in development:
  - Long range strike potential
  - Survivability, especially after an opponents nuclear strike
- USSR's Sputnik – a soviet R-7 long-range missile – was launched on Oct. 4, 1957
  - The US Atlas-A missile (also known as Mercury in manned space flight) was tested 4 months later on Dec. 17, 1957
- ICBMs – Intercontinental Ballistic Missiles – were deployed starting in 1959
  - Continual upgrades in both warheads and missiles
  - Generally, based at fixed locations with hardened silos
- SLBMs – Submarine Launched Ballistic Missiles were deployed starting with the Polaris A-1 system in 1961

Atlas A1 ICBM

Minuteman III ICBM

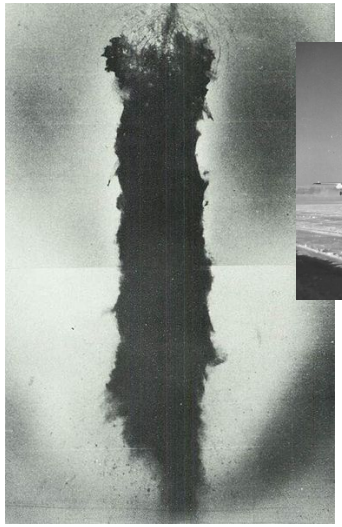
Trident D5 SLBM

# Nuclear Weapon Accidents

- The constant patrols and alert status of nuclear forces meant that nuclear weapons were on-board aircraft with constant handling and movement

- Department of Defense cataloged 32 significant US nuclear weapon accidents from 1950 to 1980
  - *No US accident has resulted in nuclear yield* – and *this* was no accident
  - Safety of weapons in accidents has always been considered
  - Often, high explosives did detonate, and nuclear material was spread

January 17, 1966
Palomares, Spain
B-52 collides with KC-135 refueling tanker
2 bombs have HE detonation
3rd bomb lost in the Mediterranean



January 21, 1968
Thule, Greenland
B-52 has fire on board
crashes 7 miles from runway
while attempting emergency landing
At least one bomb has HE detonation
Plutonium spread for 600 yards on either side

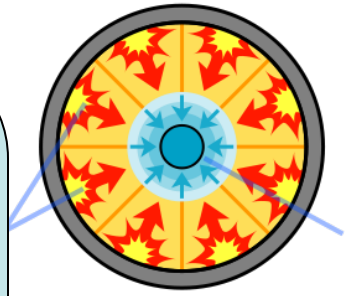
# Nuclear Weapon "Surety"

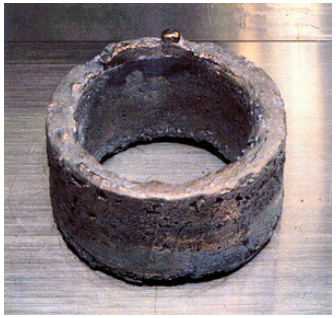
- In response to these incidents, an increased focus on nuclear weapon safety and security occurred

- This became known as "Surety"
  - Safety
  - Security/Use Control

**Safety**

- Avoid nuclear yield!
- One-point safety
  - 1 in 1,000,000 of less than 4 pounds
- Insensitive High Explosives
- Fire resistant pits
  - Plutonium containment in aircraft fires
- Stronglinks/weaklinks





Plutonium metal

**Security**

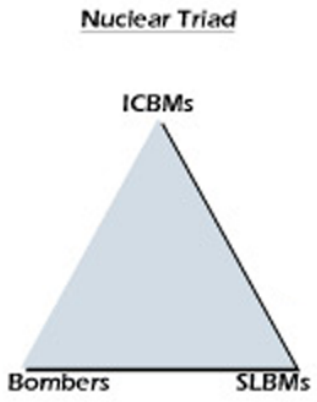
- Permissive action links
  - Coded locks
- Launch environment detectors
  - Unique sequence to arm
- Stronglinks/weaklinks


Permissive Action Link (PAL) controller

# Nuclear Deterrence: Present

# The advent of long-range missiles gave rise to the nuclear triad for deterrence

- The diversity of delivery systems was known as the “triad”
  - Land-based missiles (ICBMs)
  - Submarine-based missiles (SLBMS)
  - Air-carried platforms (bombs and cruise-missiles)



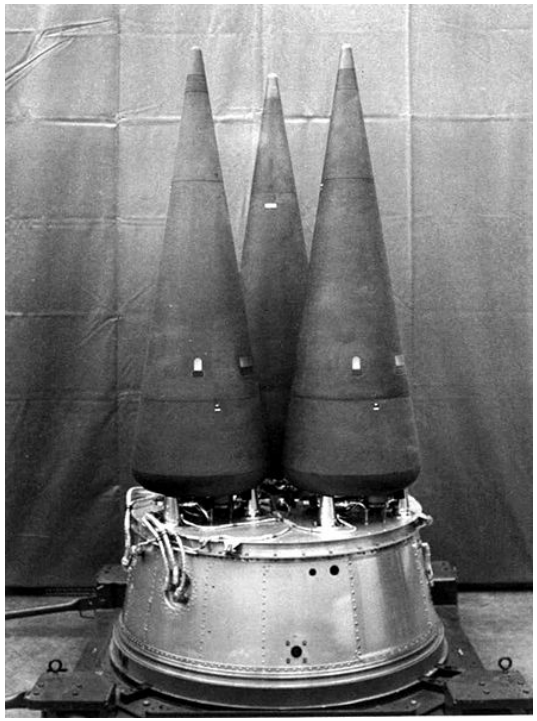

- Twin goals again represented here:
  - Assured ability to hold an adversary's assets at risk
  - Survivability against a first-strike

- Each leg of the triad has unique abilities in support of deterrence
  - Land-based Missiles (ICBMs)
    - Visible, constant observable commitment, counterforce target
  - Sea-based missiles (SLBMs)
    - Survivable, second-strike assuredness
  - Air-carried bombs
    - Flexible, recallable, ideal for “posturing” during crisis – signaling short of full-launch

W87 Peacekeeper RVs on reentry

# The US Enduring Stockpile - ICBMs

- All of these developments came to fruition in the mid 1970s
  - surety, compact delivery systems, robust performance
- Triad was composed of several highly-developed systems

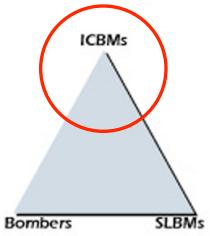


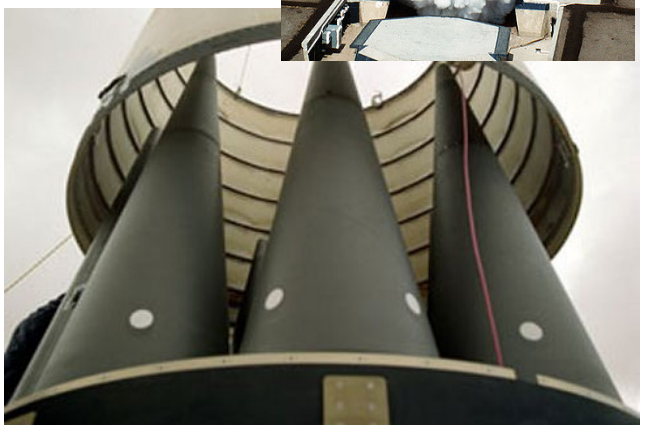
W78/Mk12a RVs on a “bus”

## ICBMs

Ease of maintenance at remote sites
Optimized yield/weight
MIRVed - multiple reentry vehicles/missile

- W78
  - Minuteman III
- W87
  - Peacekeeper
  - 8-RV MIRV
  - IHE, fire-resistant

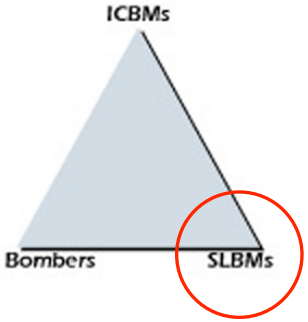


W87/Mk21 RVs

The Air Force refers to the delivery vehicle as a Reentry Vehicle - RV

# The US Enduring Stockpile - SLBMs




## SLBMs

Highly compact RBs for submarine deployment

Highly optimized yield/weight to extend range

Maintenance at 2 sub bases
- Kings Bay, Georgia
- Bangor, Washington

- W76
  - Trident C4 Missile
  - Compact RB
  - 8-RB MIRV
- W88
  - Trident D5 Missile
  - 8-RB MIRV

Trident D5

W76/Mk4a RBs on maintenance stands

The Navy refers to the delivery vehicle as a Reentry Body - RB

# The US Enduring Stockpile – Air Carried

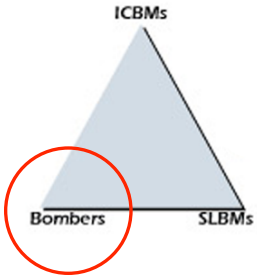
## Air-Carried Platforms

B61-11 loading

Bombs and cruise missiles
- enhanced surety features
- extended STS environment compatibility
  - all have IHE, PALs

- B61 Gravity Bomb
  - many variants
  - B61-11 earth penetrator
    - latest US "mod"
- B83 Gravity Bomb

- W80 Cruise Missile




B83 Gravity Bomb

AGM 86 Cruise Missile

W80-0 Warhead

# Issues in the Current Nuclear Weapon Stockpile

- The period from 1989 to 1992 saw incredible change
  - US production complex shutdown
  - US test moratorium begins
  - Soviet Union dissolves – the Cold War ends

Berlin wall falls

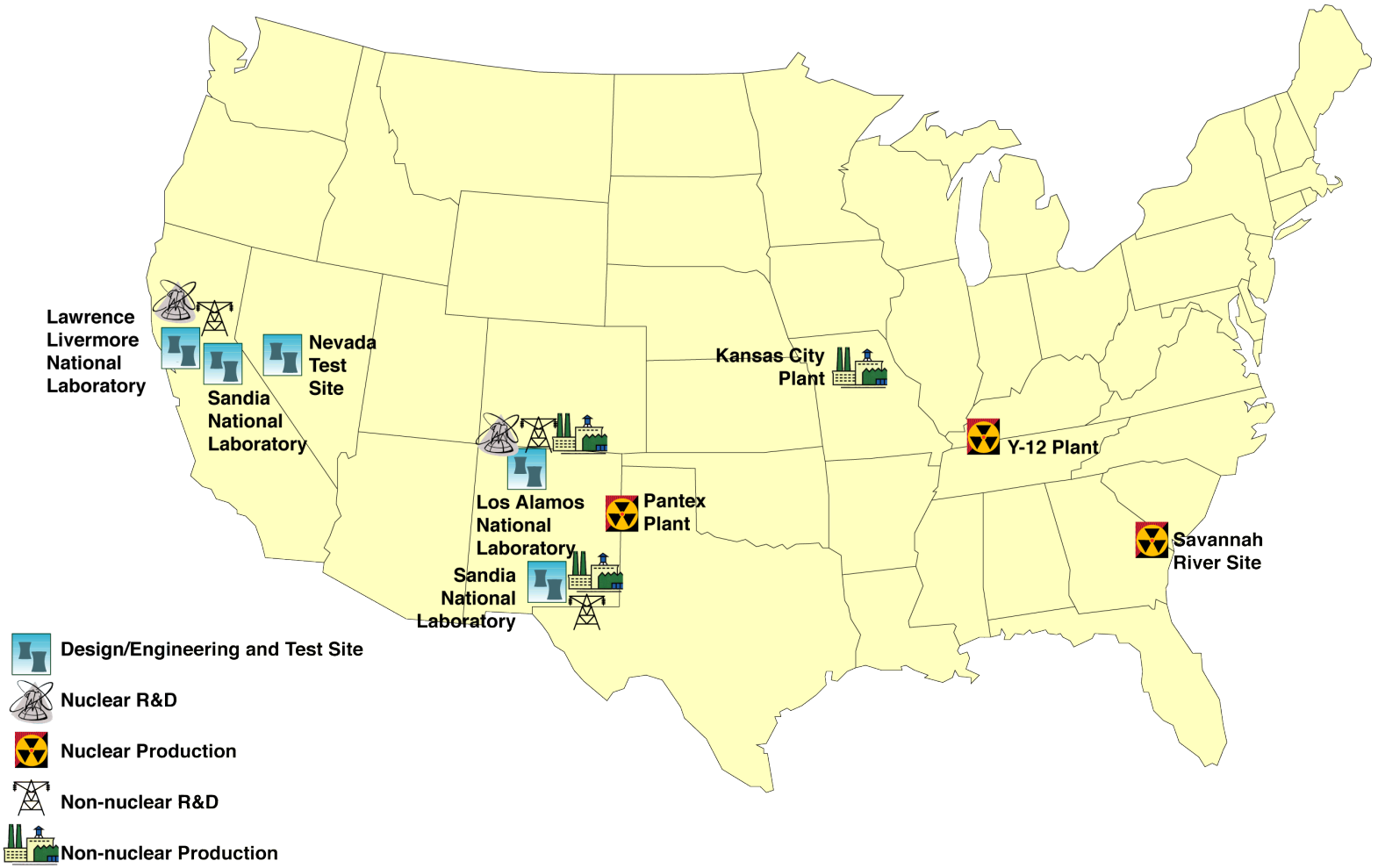
- These changes drive several new issues in ensuring a safe, reliable deterrent
  - Can weapons be maintained in the long term without testing?
    - A science-based approach, *stockpile stewardship*
  - Can a stockpile be reliable and safe without regular new production?
    - Perhaps the biggest unknown of all – weapons do age!
    - Stockpile changes are a simple fact – either aging or remanufacture

IBM Roadrunner
World's fastest computer


plutonium aging
Pu-238 accelerated-aged ingot

Non-nuclear testing
RRW "hydro" test

# Current US Nuclear Weapons Complex



# Nuclear Deterrence: Future

# Embracing a New Goal: A Recommitment to a World Free of Nuclear Weapons

- Obama and others have called for a new paradigm
  - Goal of a world without nuclear weapons
  - George P. Shultz, William J. Perry, Henry A. Kissinger and Sam Nunn

- How can we achieve this goal? What strategies or "roadmaps" might we follow to realistically reduce – and one day eliminate – the need for nuclear weapons?

- What role might the nuclear weapons complex play, if any?
  - Historically, weapon design enabled stockpile reductions
    - Safety, reliability, accuracy
  - Is our history a guide to the future?

# Recent Developments in Nuclear Deterrence

(Obama White House Staffer on April 2010: “all nuclear, all the time”)

- April 2009: Obama embraces the goal of a “world free of nuclear weapons”
  - October 2009 Nobel Peace Prize

- November 2009: Congressional Strategic Posture Commission releases its report
  - Weapons still serve a deterrent role
  - Can accomplish this at reduced numbers
  - Weapon complex infrastructure has been neglected

- April 2010: New Nuclear Posture Review is released

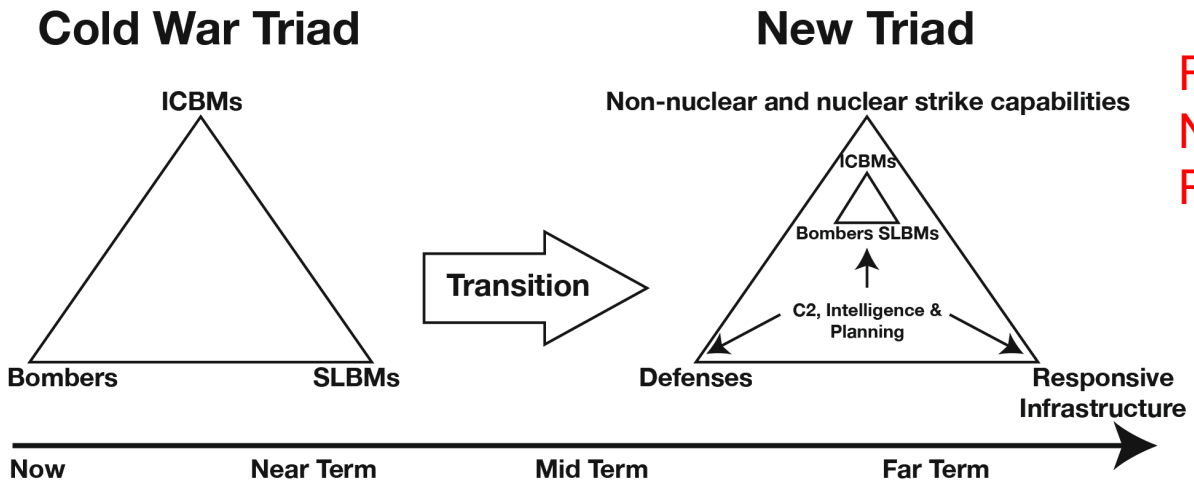
- April 2010: Russia/US sign “New START” Treaty
  - Overall limit 1550 “deployed, strategic weapons”
  - Submitted to the Senate for ratification (Perry testimony last week!)

- April 2010: International Nuclear Security Summit
  - 44 World Leaders, most since UN founding in the US
  - Agreements to limit fissile material spread

- Happening now:
  - May 2010 NPT Review Conference
  - CTBT re-submission to the Senate

# An Evolution in Nuclear Deterrence – the Nuclear Posture Reviews

Three examinations of the role of nuclear weapons post Cold-war have occurred: 1993, 2001, 2010




From the 2001 Nuclear Posture Review

"First, the United States will take concrete steps towards a world without nuclear weapons. To put an end to Cold War thinking, we will reduce the role of nuclear weapons in our national security strategy, and urge others to do the same. Make no mistake: As long as these weapons exist, the United States will maintain a safe, secure and effective arsenal to deter any adversary, and guarantee that defense to our allies ." – President Obama, Prague, 2009

# Capability-Based Deterrence

The idea of capability as deterrence has been suggested by many.

Jonathan Schell, *The Abolition,* 1984

Ted Gold and Rich Wagner, *Long Shadows and Virtual Swords,* 1990

*"The fact is nuclear deterrence is increasingly hazardous and decreasingly effective. We have to change our way of thinking about it… including ways of stretching out time for decision making during a nuclear crisis and relying increasingly on an ability to reconstitute nuclear forces as a safer form of nuclear deterrence."* - George Shultz, *in A World Without Nuclear Weapons: End State Issues, Sid Drell and James Goodby, 2009*

# Key Questions for a Capability-Based Deterrent

**How agile do we need to be?**

*3 – 5 – 10 years?*

**How do we assess this?**

*historic weapon development times?*
*expert assessment?*
*negotiated via arms control?*

TA-55 Plutonium Complex at Los Alamos

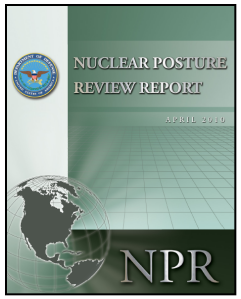
**What about military readiness?**

*Dual use delivery platforms?*
*Dedicated platforms?*

**How will capability be perceived by –**

*Allies? Adversaries? The rest of the world?*
*Must linkage to stockpile goals and a CTBT be explicit?*
*Will transparency play an important role?*
*Do we design transparency into weapons? The complex?*

# The Nuclear Posture Review of 2010 adopts elements of a capability-based deterrent

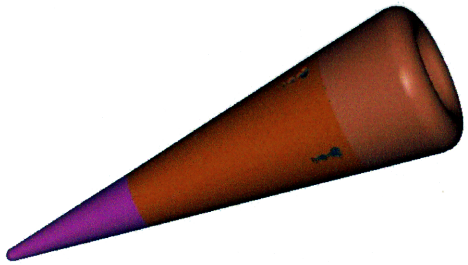



- Released April 7, 2010

"Second, implementation of the Stockpile Stewardship Program and the nuclear infrastructure investments recommended in the NPR will allow the United States to *shift away from retaining large numbers of non-deployed warheads as a hedge* against technical or geopolitical surprise, allowing major reductions in the nuclear stockpile. These *investments are essential to facilitating reductions* while sustaining deterrence under New START and beyond."

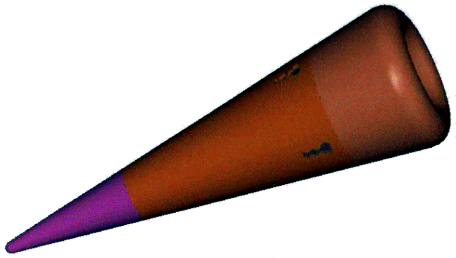
– 2010 NPR, page 30

# A comparison of the Reliable Replacement Warhead (RRW) to the legacy stockpile



Legacy Design

- Optimized for high yield-to-weight ratio
- Relatively low margin-to-failure
- Energetic high explosives
- Limited security features
- Exotic materials
- Hard to manufacture components
- Frequent surveillance
- Dismantlement difficult



RRW Design

- Optimized for high margin-to-uncertainty ratio
- Insensitive high explosive
- Enhanced security
- Ease of manufacturer
  - Eliminate exotic materials
  - Alternate materials
  - Reduced process steps
- Reduced surveillance requirements
- Improved dismantlement and material disposition

Agile, assured ability to produce RRW enables a capability-based deterrent

# Important US Decisions in the Near-Term & Things You Can Do!

- Ratify the New START Treaty – US Senate, hearings have begun
- Ratify the Comprehensive Test Ban Treaty – US Senate, not yet resubmitted
- Support and Endorse the Nuclear Nonproliferation Treaty – review conference underway this week in New York
- Support our statesman and leaders in their efforts to recommit to a world free of nuclear weapons
- Pay attention to these issues, be informed, and be heard!

# Recommended References


G.P. Shultz, W.J. Perry, H.A. Kissinger, and S. Nunn, “A World Free of Nuclear Weapons,” *Wall Street Journal*, 4 January 2007. http://www.hoover.org/publications/digest/6731276.html.

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