Nuclear Deterrence: Past, Present, and Future

Dr. Joseph Martz
William J. Perry Fellow, CISAC
Los Alamos National Laboratory

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April 1983: 40th Anniversary Reunion of the Manhattan Project

Richard Feynman

Hans Bethe

Los Alamos Science
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Preamble

Nuclear Deterrence: What is deterrence?
Wartime Fatalities

(WWII % of world population)

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

- 15% Nuclear Radiation
- 50% Blast Energy
- 35% Thermal Energy
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

• Civil Effects
  • Teapot Series, 1952-1955

Crossroad Baker – July 26, 1946

Teapot Apple II – May 5, 1955

Surviving House from Teapot Apple II
Nuclear Effects Testing – Civil Defense

Analog Nuclear Weapon Effects Calculator
Nuclear Effects Testing

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

- Civil Engineering - Plowshare
  - Storax Sedan Cratering Shot

July 6, 1962

Storax Sedan, 104 kT

Dominic Starfish Prime – July 9, 1962

View from Honolulu

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 – 6th nuclear explosion, 37 kT, April 14, 1948
- Sandstone Yoke – 7th nuclear explosion, 49 kT, April 30, 1948
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

B54 “Backpack” SADM

Mk33 Artillery Shell

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

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

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 \textit{in situ} with neutrons

\[ D + T \rightarrow ^4\text{He} + n + \text{energy} \]
\[ \text{Li} + n \rightarrow ^4\text{He} + T + \text{energy} \]

\[ D + \text{Li} \rightarrow 2^4\text{He} + \text{energy} \]

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

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

1959 Air Force Test Vehicle
The miniaturization of warheads enabled successful long-range missile development

- Twin goals in development:
  - Long range strike potential
  - Survivability, especially after an opponent's 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

[Images of Atlas A1 ICBM, Minuteman III ICBM, and 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

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

Plutonium metal
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

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

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

The Navy refers to the delivery vehicle as a Reentry Body - RB
The US Enduring Stockpile – Air Carried

Air-Carried Platforms

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

AGM 86 Cruise Missile

W80-0 Warhead

B61-11 loading
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

• 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

[Map showing locations of various nuclear facilities across the United States, including Lawrence Livermore National Laboratory, Nevada Test Site, Kansas City Plant, Y-12 Plant, and Savannah River Site.]

Legend:
- Design/Engineering and Test Site
- Nuclear R&D
- Nuclear Production
- Non-nuclear R&D
- Non-nuclear Production
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

"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.


“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?

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


