Strategic Weapons in the 21st Century: Rethinking Nuclear and Non-Nuclear Elements of the Deterrent

Science and Deterrence

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January 25 & 26, 2007
Washington, DC

The Task: Science and Deterrence

What are the science and technology opportunities and challenges associated with maintaining a credible strategic deterrent in the 21st century?

- Science and technology will be applied to support non-nuclear and nuclear technologies.
- Highly flexible capabilities are required to work effectively in a rapidly changing threat environment.
- Deterrence policy is evolving into a broader, full-range set of capabilities that seeks to assure security partners that threats can be effectively countered.
- Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) modernization is essential in the modern network-centric political and military environment.

Nuclear Capability-Based Deterrence

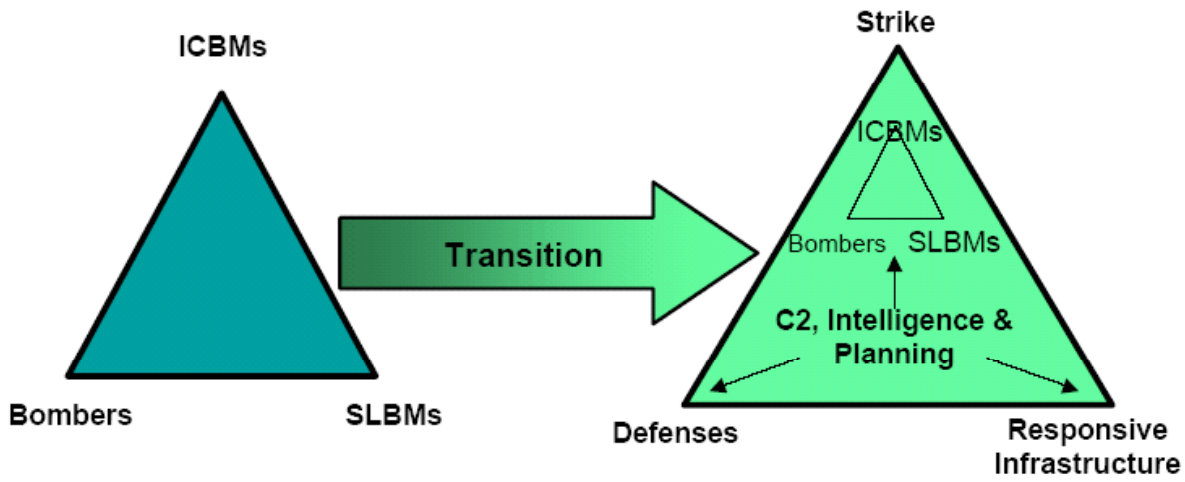
Nuclear Posture Review Calls for New Triad

Existing Triad

Nuclear strike forces: ICBMs, SLBMs, Bombers

New Triad

Strike (non-nuclear and nuclear), defenses, infrastructure; 1700-2200 operationally deployed nuclear weapons



"Threat-based" → "Capabilities-based"

Nuclear Capability-Based Deterrence

- In the context of the “new triad”, “capability” was emphasized in Nuclear Posture Review (NPR) 2001 - and similarly in the 1994 NPR – because it:
  - Enables lower numbers of active and inactive nuclear weapons.
  - Enables responsiveness / adaptation to new threats or technical surprise as well as new opportunities (e.g., nonproliferation, nuclear weapons security for other Nuclear Weapons States).
  - Essential to understanding nuclear intelligence / threat of proliferation.
  - Essential to anticipating vulnerabilities to nuclear terrorism.
  - Essential to sustaining stockpile confidence without nuclear testing (with or without Reliable Replacement Warhead).

21st Century Science and Technology Setting

Transition from threat-based to capabilities-based military planning and a focus on linking political aims to the application of military power has had important consequences for the S&T themes in defense modernization over the past decade.

C4ISR

- C4ISR system inherited from the Cold War is ill suited to 21st century needs.

Targets

- Achieving the desired political outcome in a military campaign involves a transition from an exclusive focus on the attrition of adversary military forces and infrastructure targets as characterized during the Cold War.

Weapons effects

- Modern weapon systems emphasize unique effects to produce a desired contribution to the political purposes of the military campaign.
  - In conventional military operations these effects can be both kinetic and non-kinetic with the importance of the latter now growing rapidly.
  - For nuclear weapons, there are three important unique effects:
    - ionizing radiation
    - extraordinary energy density
    - high thermal output.
  - Application of nuclear weapons to targets requiring high energy density has diminished.

Emerging Science and Technology Requirements

Three "technology vectors" are creating decisive new military capabilities:

- **Speed**
- **Stealth**
- **Precision**

To meet the needs of 21st century deterrence, the Defense Science Board has identified four additional inter-related and mutually reinforcing capabilities.

Twelve Key Technology Area Enablers

Critical Capability	Technology Area
Human Terrain Preparation	• Human, Social, Cultural, Behavioral Modeling • Automated Language Processing • Rapid Training and Learning Methods and Aids
Ubiquitous Observation And Recording	• Day/Night All-Weather Wide Area Persistent Surveillance • Close-in Sensing and Tagging • Soldier-as-Collector
Contextual Exploitation	• Mega-scale Data Management • Situation Dependent Data Exploitation • Human/System Collaboration
Rapidly Tailored Effects	• Time-critical focused conventional strike • Influence Operations • WMD Protection and Mitigation

Constructive Choices for US Leadership in 4 Nuclear Areas

1. Nuclear Policy.
2. High-level challenges for management of the stockpile stewardship program.
3. Science-based challenges for stockpile stewardship.

And finally an “outside-the-box” issue:

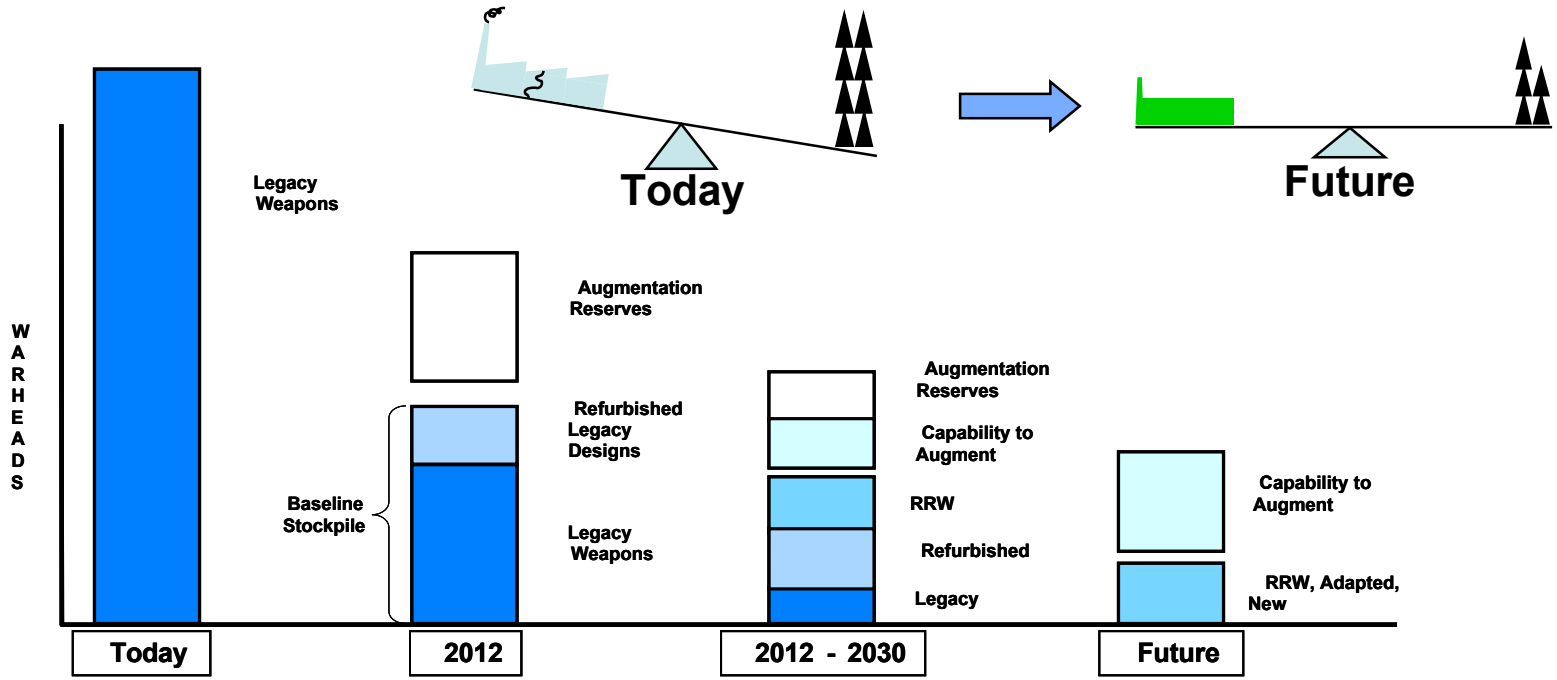
4. Nuclear Energy / Nonproliferation / Nuclear Terrorism issues in the 21st Century.

Constructive Issues for Implementing Capability-Based Deterrence - Nuclear Policy

- RRW (a key building block):
  - Enabling stockpile and infrastructure transformation.
  - maintaining / exercising the capability for new design.
  - utilizing the science derived from the stockpile stewardship program.
- Applying nuclear deterrence concepts such as effects-based targeting which are accepted parts of non-nuclear deterrence.

Constructive Issues for Implementing Capability-Based Deterrence - Nuclear Policy

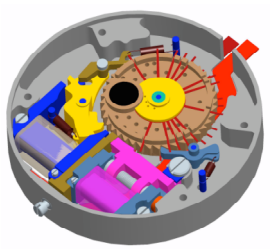
In partnership with DoD, transform the nuclear stockpile

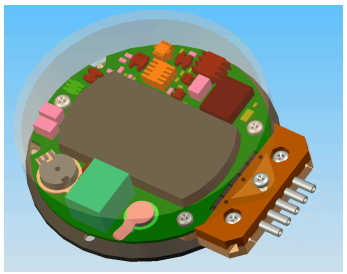


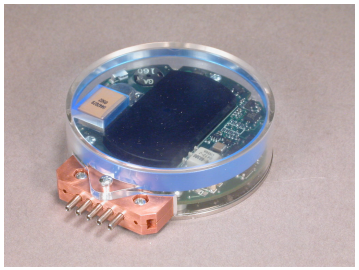
Increased confidence in warhead designs and demonstration of a responsive infrastructure will enable a reduction in total stockpile size

Sustaining Stockpile Stewardship for Another Generation - high level challenges and choices

- Shall the US nourish best-in-the-world, peer-reviewed weapons science and engineering needed for capability-based deterrence?
- How to best consolidate and modernize manufacturing, including Category I/II Plutonium at a single site.
- Sustaining a diversity of designs in the stockpile.
- Enhanced security and safety.
- Arming-fuzing-firing (AFF) technology and interoperability.
- Demonstrating program success in the near term.

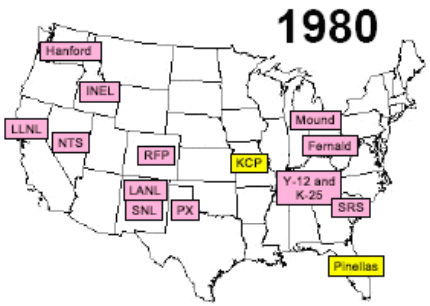




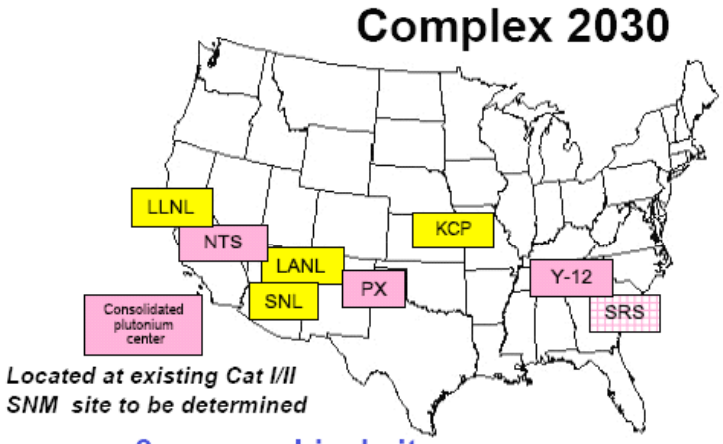


Enhancing Security and Safety: Improving components using modern technology.

Sustaining Stockpile Stewardship for Another Generation - high level challenges and choices



14 independent sites
12 Cat I/II SNM sites

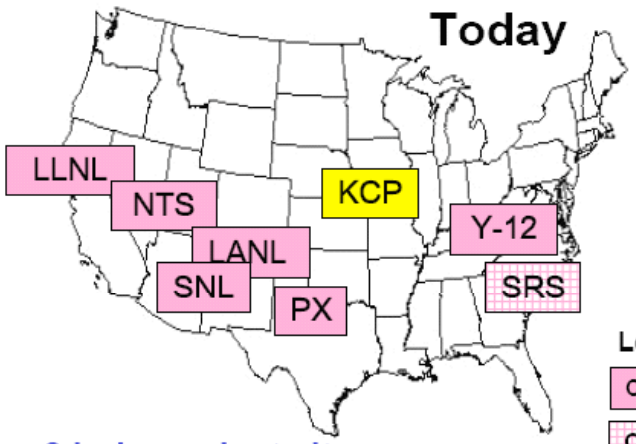


Located at existing Cat I/II SNM site to be determined

8 geographical sites
- modernized
- reduced footprints

1 integrated network
- contracts consolidated
- centralized acquisition
- shared facilities

3-4 Cat I/II SNM sites



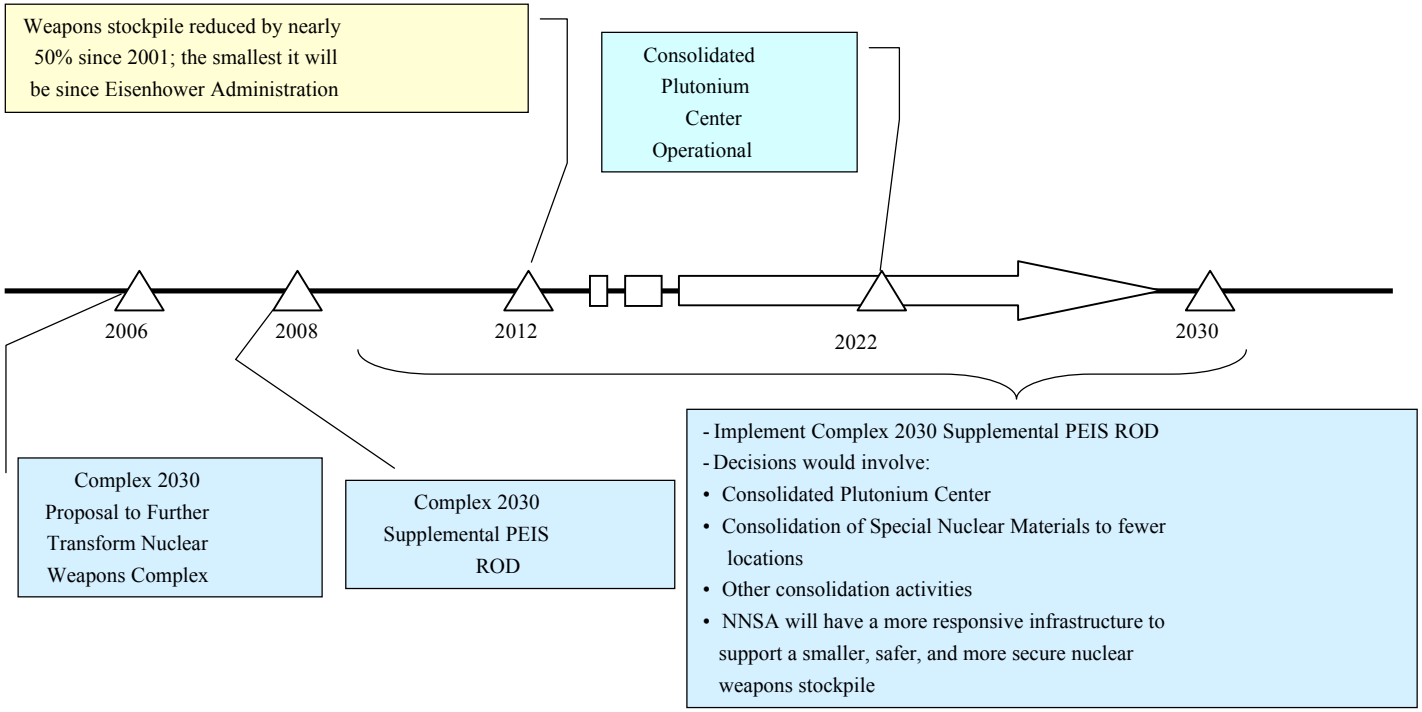
8 independent sites
6-7 Cat I/II SNM sites

Legend:
- Cat I/II SNM
- Other DOE Cat I/II SNM
- No Cat I/II SNM

Stockpile size ↓
Dismantlements ↑
Complex square footage ↓

Sustaining Stockpile Stewardship for Another Generation - high level challenges and choices

Complex 2030 Implementation



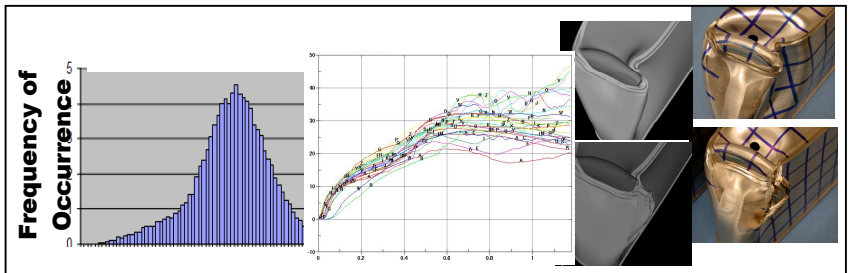
Sustaining Stockpile Stewardship for Another Generation - high level challenges and choices

A successful RRW program enables transformation

	Legacy Warheads	RRWs
Optimized for	High yield -to-weight	Assured long -term reliability
Certification	Increasingly difficult over time	Feasible under test moratorium
Manufacturing	Hazardous/exotic materials Tight tolerances Difficult contours	Reduced hazardous materials Relaxed tolerances Reduced process steps Easier to manufacture
Safety	Legacy safety Some conventional high explosive	Enhanced safety All insensitive high explosives
Security	Limited	Modern, integrated systems

Best-in-the-world, peer-reviewed weapons Science and Engineering needed for capability-based deterrence, anticipating and responding to new threats, certification and annual assessment, stockpile surveillance - what does it look like?

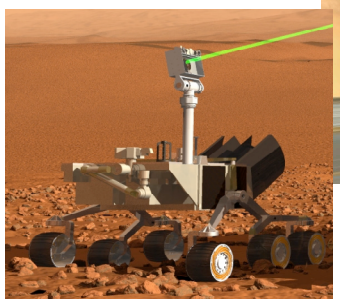
- Assessment and Certification without nuclear testing
- Grand challenges such as full-physics performance of a boosted primary continue to require advances in:
  - Computing
  - Radiography and Hydro Testing
  - Science-Based Stewardship
  - High-Energy Density Physics
- Materials Science
- Explore new technologies to ensure that they sufficiently mature to support LEP/RRW programs
- Transforming Nuclear Test Readiness
- Conduct high-risk and long-term research to ensure US weapons scientists are at the leading edge and able to respond to an uncertain future
- Support non-defense Program requirements for Non-Proliferation, Nuclear Intelligence, Counter Terrorism/Emergency Response



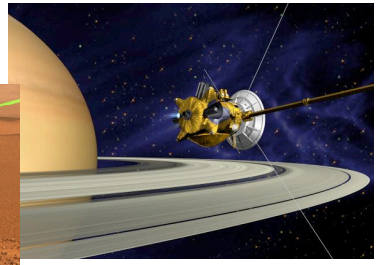
Predictive Capabilities and Measured Responses for Testing

Surprises/challenges - Spread of nuclear power production expertise/ technology in the 21st Century. Nuclear fuel cycles must (and Global Nuclear Energy Partnership does):

- **Reduce proliferation concerns**
- **Intrinsic resistance to terrorism**
- **Technology challenges**



ChemCam on Mars Science Laboratory rover 2009



Cassini exploring Saturn's moons 2005

Pathomics, highly multiplexed sensors, epidemiological modeling, advanced recognition and reporting.