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Title: Stockpile Stewardship at Los Alamos(U)

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Stockpile Stewardship at Los Alamos(U)

With emphasis on the scientific needs…

Robert Webster, Associate Director for Weapons Physics

presented to

CSIS Project on Nuclear Issues – Summer Workshop

June 27, 2012

With thanks to M. Haertling, J. Kindel and J. Vandenkieboom for many slides

What is Stockpile Stewardship?

- **Retention of nuclear weapons in the stockpile beyond their original design life. These older weapons have potential changes inconsistent with the original design intent and military specifications.**
- **The Stockpile Stewardship Program requires us to develop high-fidelity, physics-based capabilities to predict, assess, certify and design nuclear weapons without conducting a nuclear test.**
- **Each year, the Lab Directors are required to provide an assessment of the safety, security, and reliability our stockpile to the President of the United States.**

  (This includes assessing whether a need to return to testing exists.)

LANL is the design laboratory for the majority of the Nation's deterrent

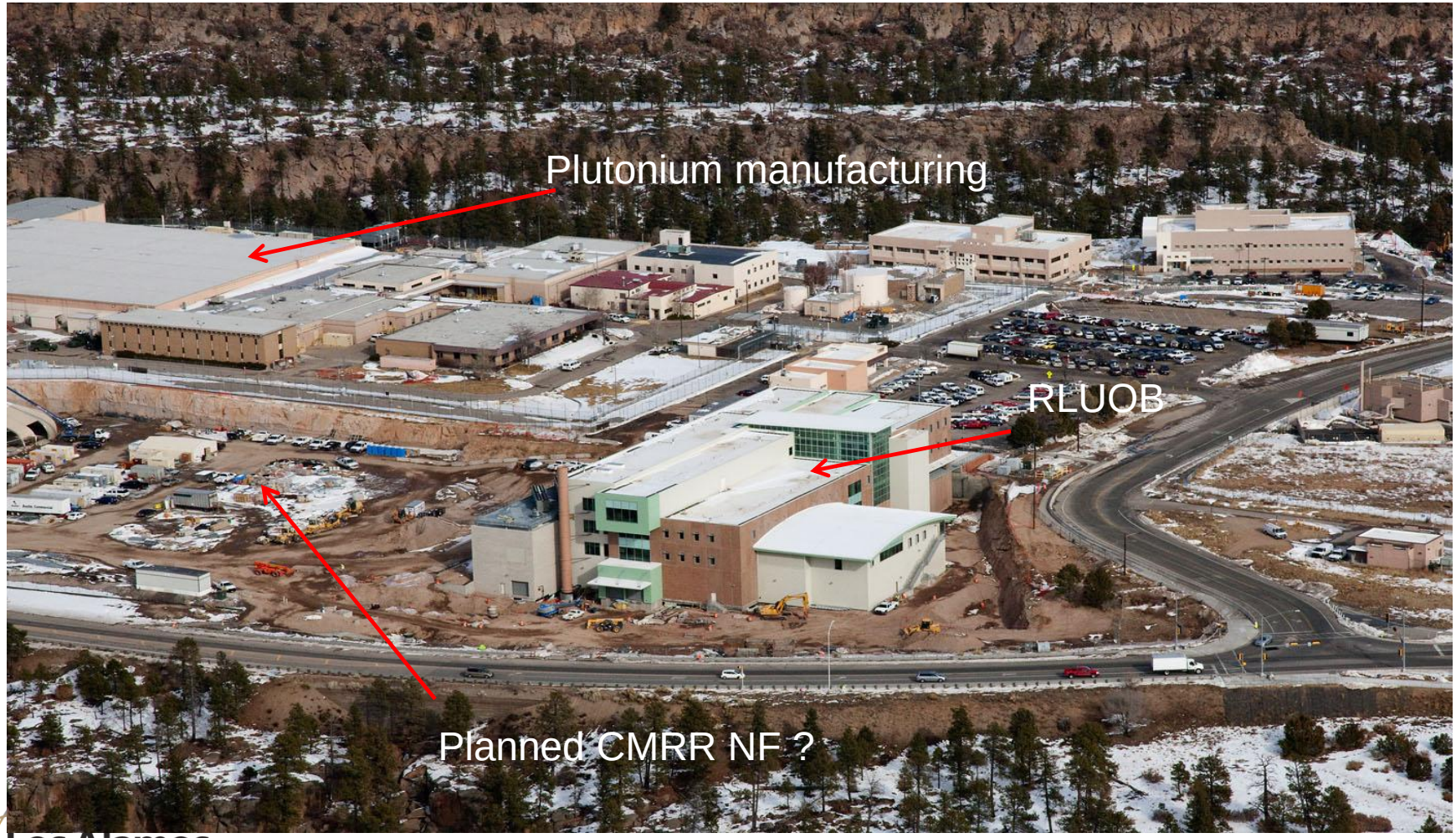
- **LANL is the design laboratory for:**
  - W76 SLBM
  - W88 SLBM
  - B61Gravity bomb
  - W78 ICBM

- **Each Triad leg offers complimentary and reinforcing benefits**

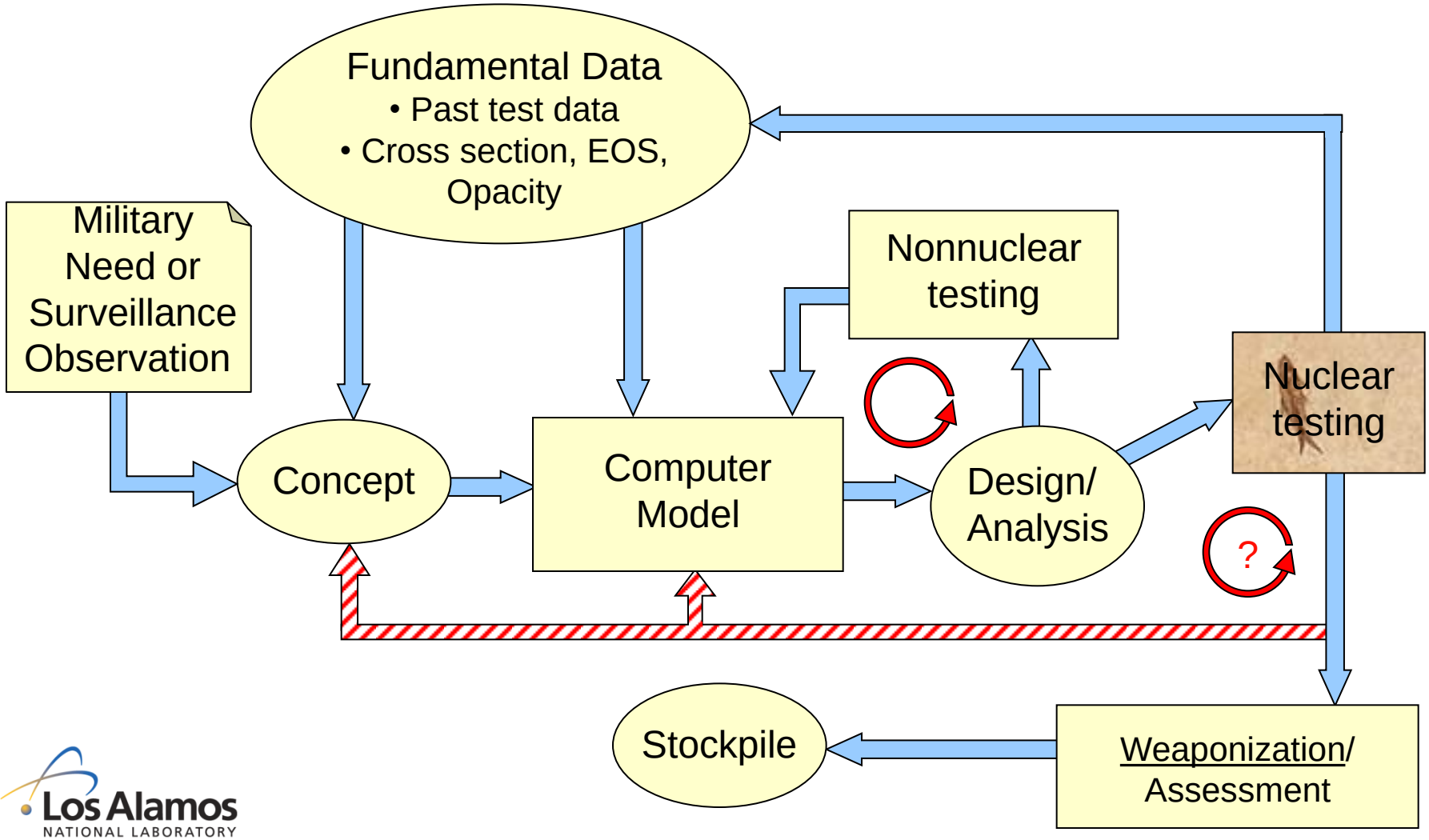
LANL's carefully balanced weapons program strategy is sustaining the Nation's deterrent

- **Stockpile management**
  - B61 Life Extension Program (LEP)
  - Support to plants on W76 LEP
  - Complete build of W88 pits
- **Science, technology and engineering investments**
  - Use science tools to generate data to support assessment
- **Infrastructure investments**
  - Create modern, state of the art facilities to sustain laboratory capabilities
  - Hire and train next generation

Plutonium science and manufacturing infrastructure



Scientifically informed design and analysis for stockpile stewardship, has been adapted from the testing era.



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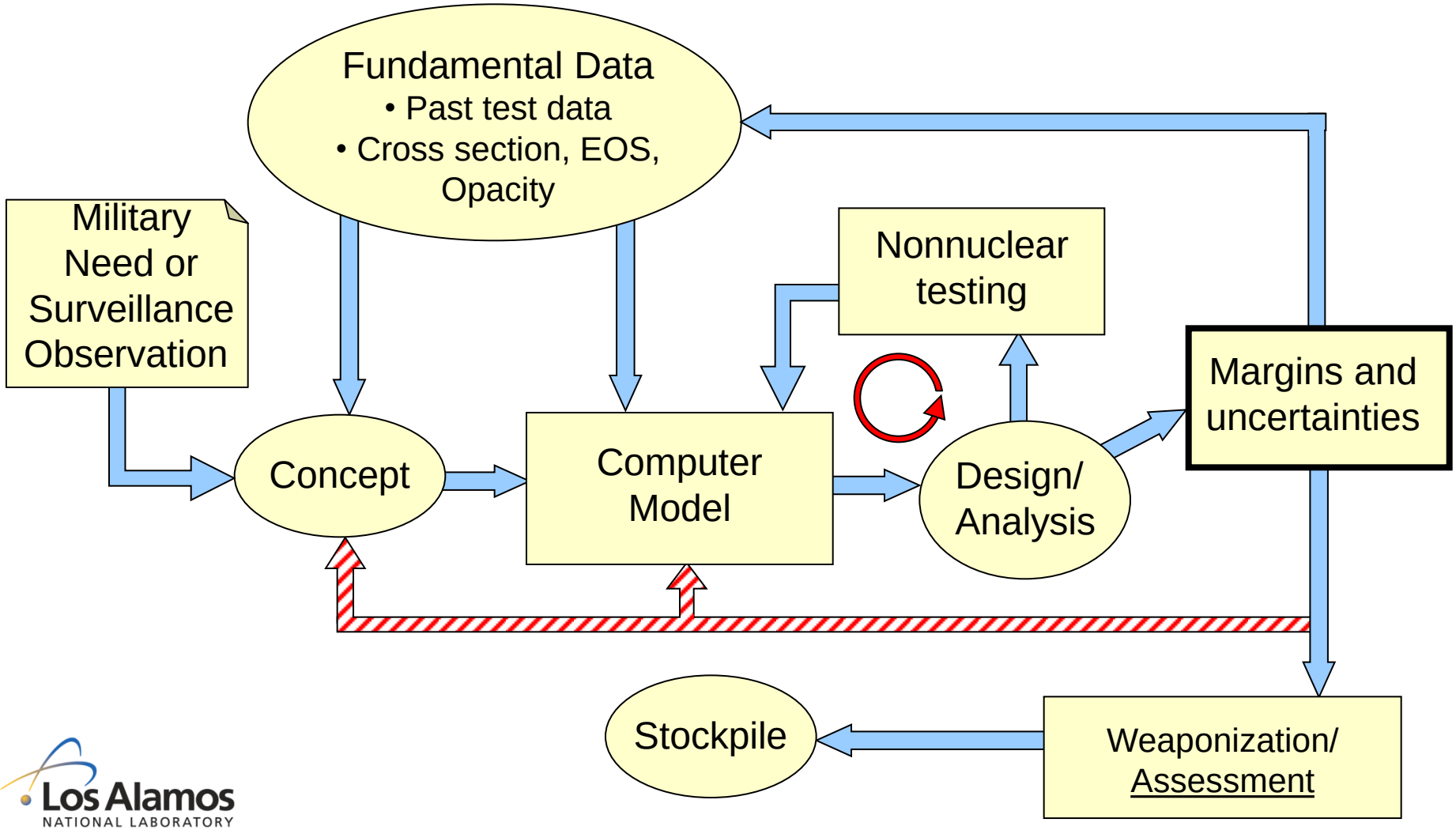
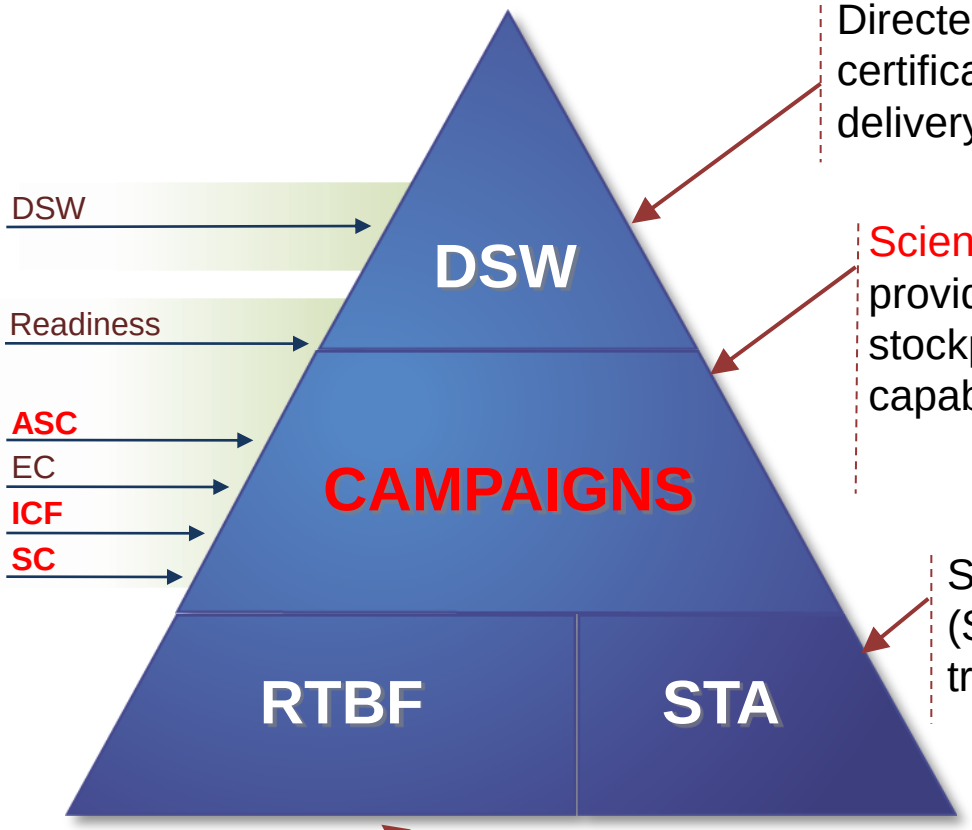


Defense Programs
Programmatic Foundation



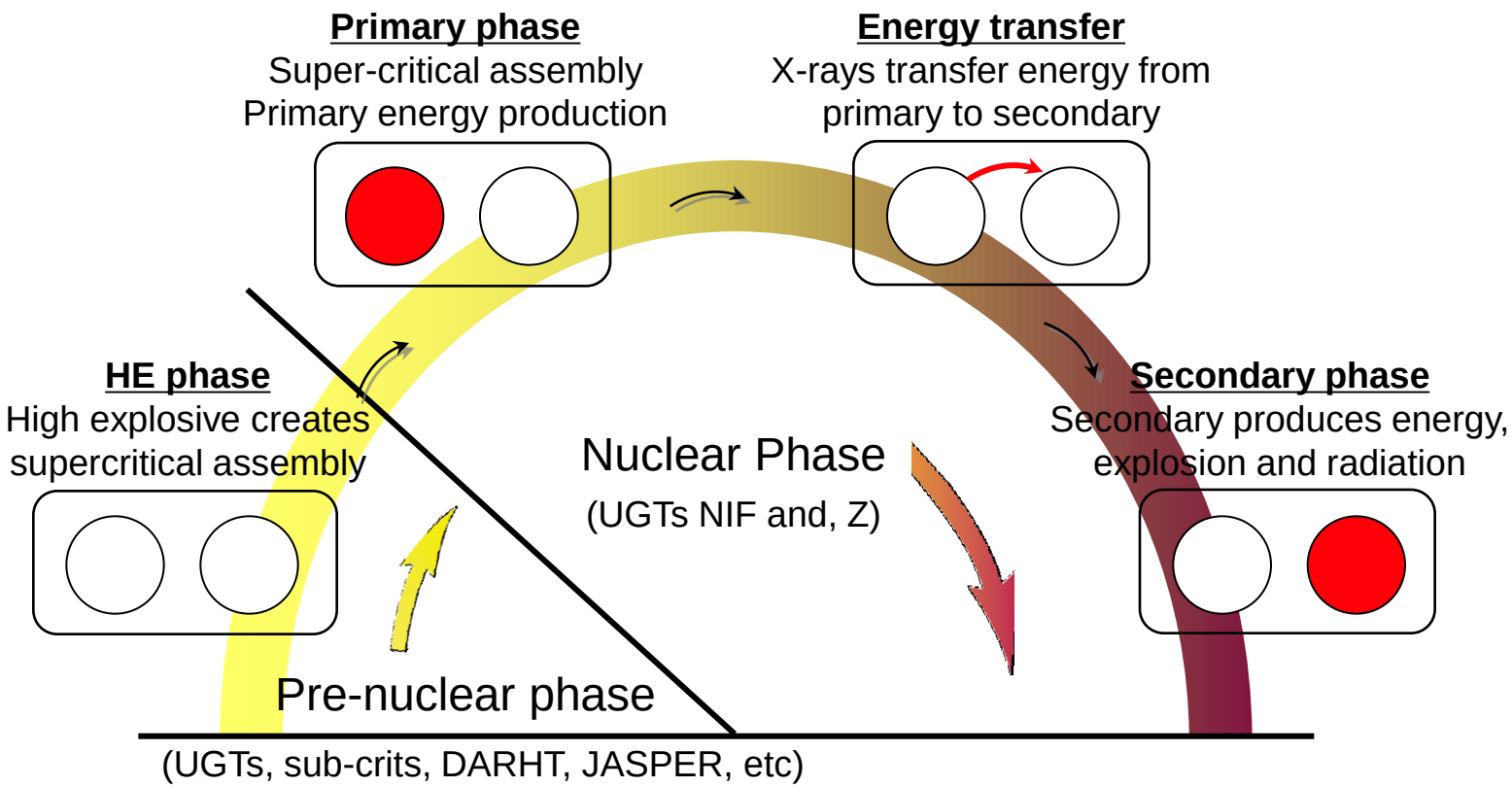
Directed Stockpile Work (DSW) provides the certification and production of stockpile for DoD delivery

Science, Technology and Engineering (ST&E) provides the tools and capabilities for the stockpile stewardship, including predictive capability and technology maturation

Secure Transportation Asset (STA) provides safe and secure transport of nuclear materials

Readiness in Technical Base & Facilities (RTBF) provides operations and facilities

Nuclear Weapon Function Overview



The Stockpile Stewardship Program develops and deploys experimental tools to accurately understand and predict the physics and materials properties at each phase of the nuclear explosives package (NEP)

Nuclear Testing

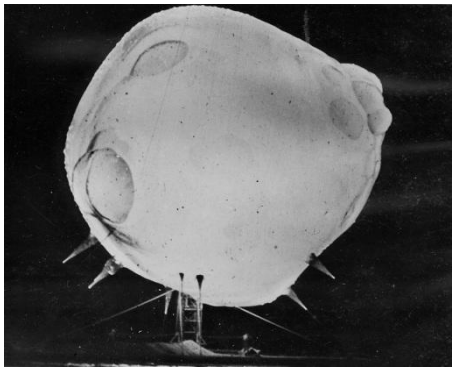
1030 US and 24 Joint US/UK tests

- 839 Underground
- 210 Atmospheric
- 5 Underwater

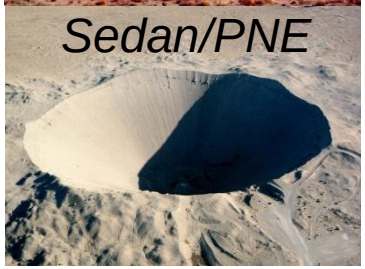

Underwater


Air-launched

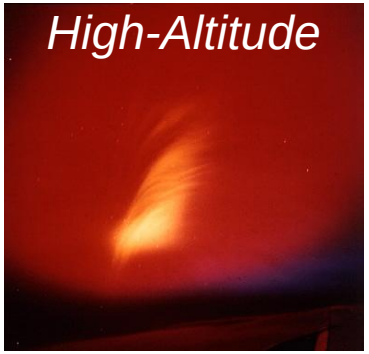

Air-dropped

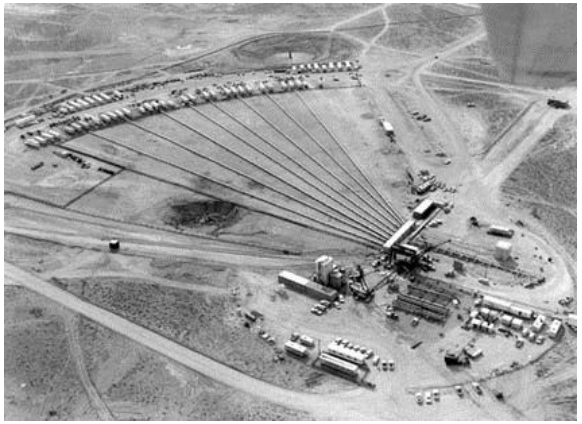

Tower


Sedan/PNE




Artillery


High-Altitude


Underground

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Confidence during the Nuclear Testing Era (1945-1992)

Nuclear Testing

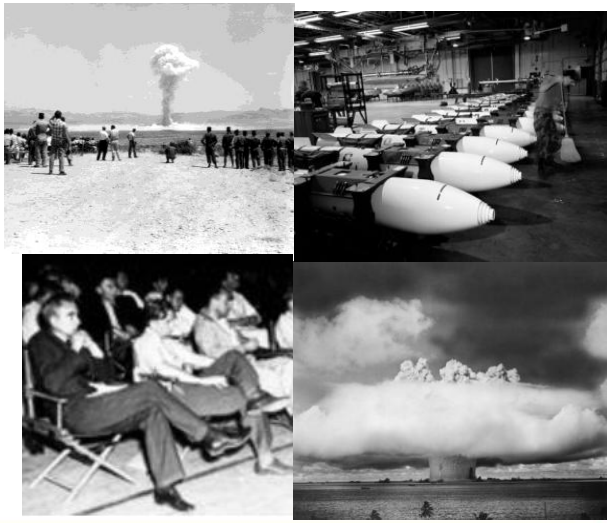
- We tuned modeling tools to match test results
- This allowed predictive capability for similar weapons
- If we needed to look at different conditions (such as weapon type), additional tests were required to predict weapons performance

Based on new weapon development cycle and empirical codes underwritten by nuclear tests, partly to compensate for incomplete scientific knowledge

- Engineering practice codes

New Weapon Development and Replacement Cycle

- Continuous design, development, production and surveillance cycle for new weapons
- Weapons were replaced within their design lifetime (typically 10-15 years)
- Aging was not an issue and was not studied
- Confidence was also bolstered by the size of the stockpile

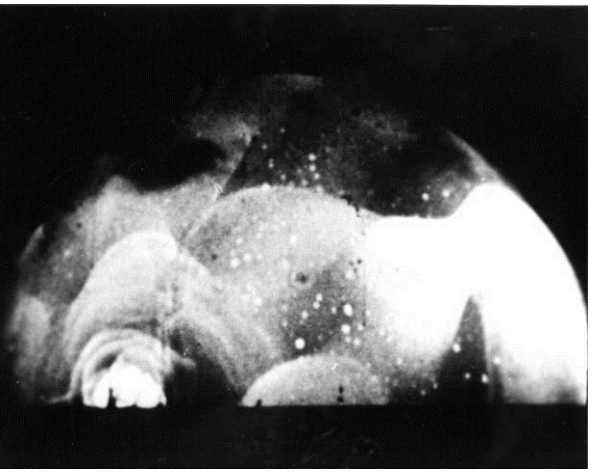


Time Period	Yield					
	Zero or Near-Zero	> 0 to 150 kt	Possible > 150 kt	> 150 to 500 kt	> 500 kt to 1 MT	> 1 MT
1945 - 1948	0	6	0	0	0	0
1951 - 1958	17	137	0	13	1	20
1961 - 11/04/62 *	0	79	0	4	8	9
11/9/62 - 03/17/76 **	5	391	79	9	14	4
May 76 - 1992	1	257	0	0	0	0
Total:	23	870	79	26	23	33

* Last U.S. above-ground or surface detonation.
** Last U.S. detonation above 150 kt.

Grand Total: 1,054 Nuclear Tests

Past Nuclear Tests May Not Answer Many of Our Questions Today



Post-Moratorium (1961-1992):

- 860 tests, mostly conducted in either vertical shafts or horizontal tunnels
- Extensive diagnostic data taken
- NTS data quality improved as weapons physics code capabilities improved
- ***Today legacy data is reanalyzed and used extensively for annual assessment***

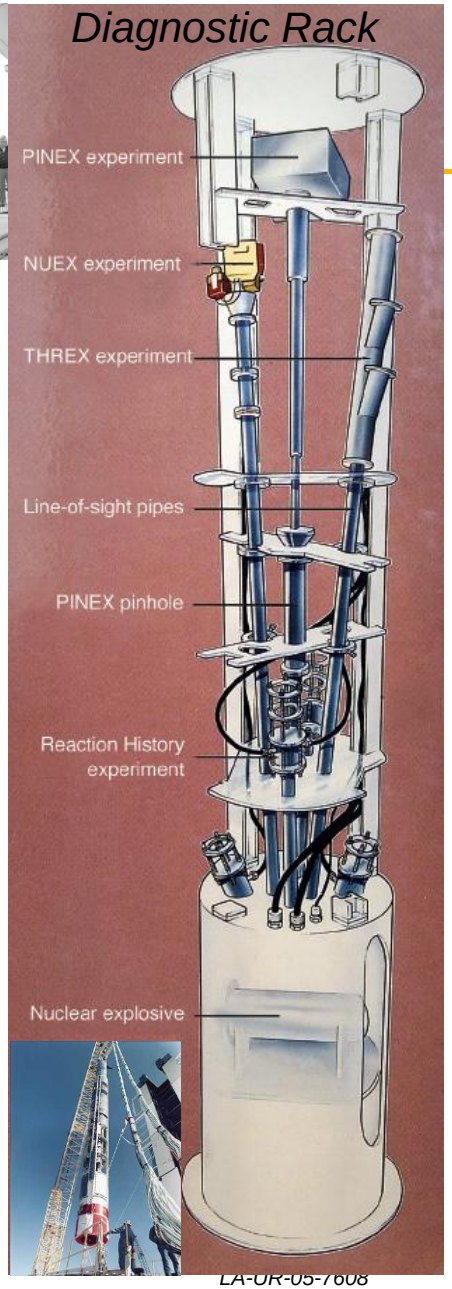
Pre-Moratorium (1945-58):

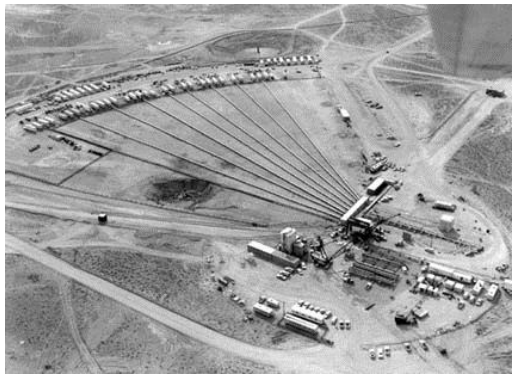
- 194 tests
- Data included fireball photos, seismic, radchem, reaction history

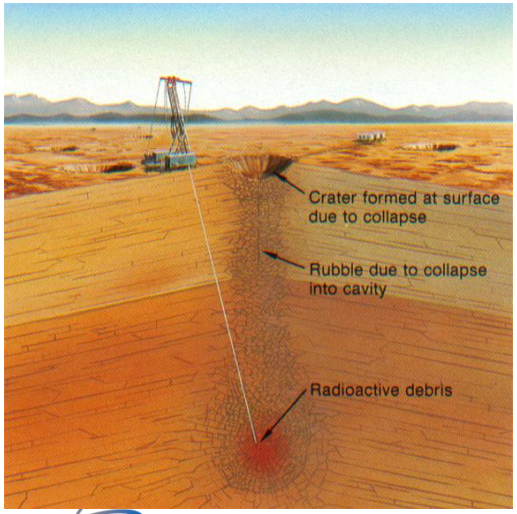
Today:

- Subcritical tests
- Data include velocity, ejecta, radiography
- Explore hypotheses not tested during UGT era; data are used to improve modern modeling capabilities

Underground Test Diagnostics







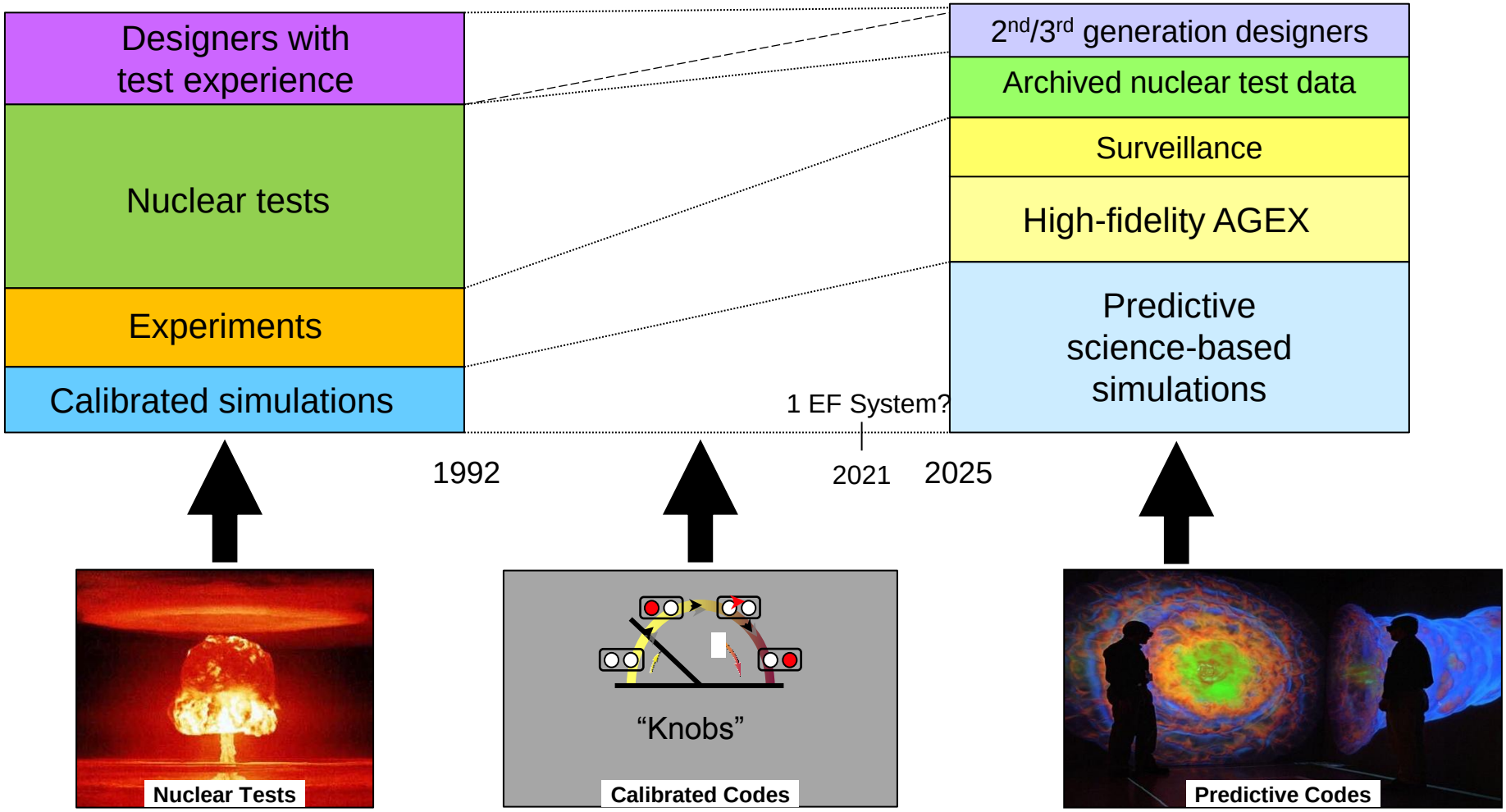
- Rack (with device) lowered to bottom of hole (4-12 ft dia., 650-2300 ft deep)
- Hole is filled with various materials (stemming) to preclude venting

- Nuclear device emits radiation (neutrons gamma rays, and x-rays)
- Measured by various experiments (consist of line-of-sight pipes, detectors, cables, signal processing and data recording hardware)

- Radiochemistry provides another diagnostic technique
- Small quantities of material placed at various locations in the device
- Transformed via neutron interactions
- Drillback recovers samples that are analyzed to assess performance

Confidence in Today's Era of Refurbish, Reuse & Replace (1992 – Today)

Based on a complex, physics and science-based understanding and predictive capability that is validated by simulations with *quantified uncertainties*



Need for Applied Stockpile Stewardship Science is Clear

Science supports & enables informed policy and program decisions by:

- **Evaluating options for stockpile size and composition**
- **Providing assessment ability of foreign weapon programs**
- **Enabling nuclear forensics**
- **Addressing technological surprise**
- **Underpinning safety and surety options**

Policy drives science

- **Annual assessment process**
- **National Security Presidential Directive 28 (NSPD-28)**
- **New START – reduced stockpile size drives increased importance of surety, safety, and reliability**

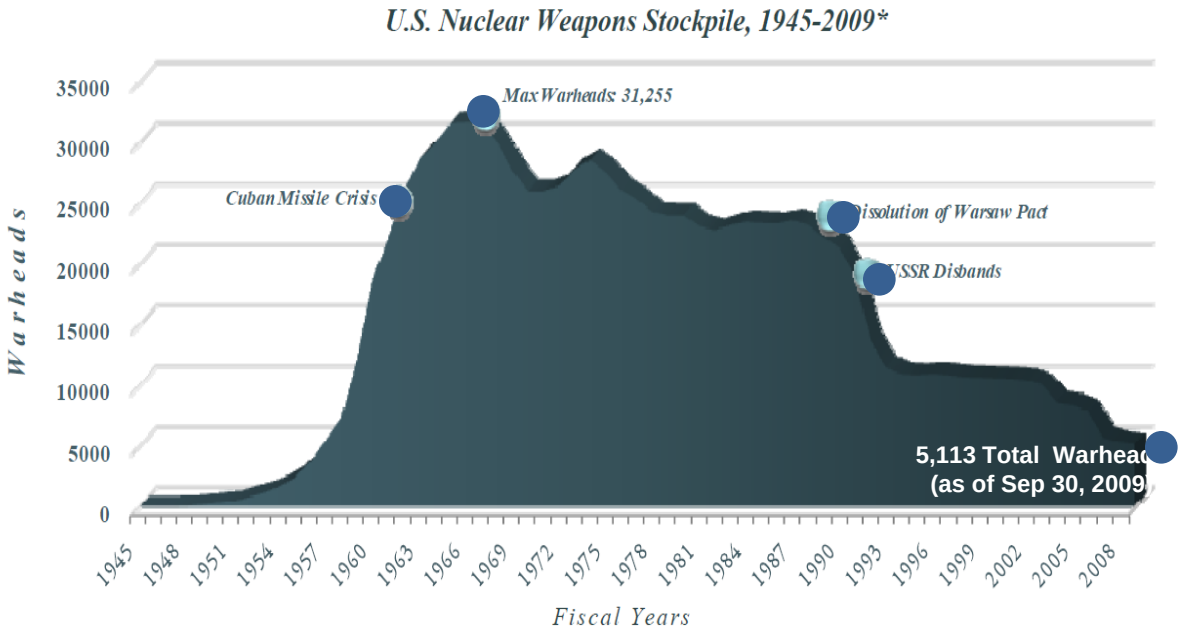
Science and people are essential for the deterrent

- **Science is an essential component of the U.S. nuclear deterrent**
- **Modern physical infrastructure driven by a highly capable workforce**
- **The external world sees our science as proof of our abilities**

Today's stockpile is old and getting older, and NNSA is expected to sustain it beyond its original design lifetime requirement

Issues that can degrade stockpile confidence to unacceptable levels continue to be detected.

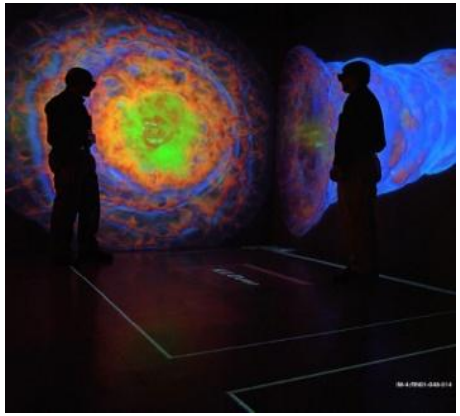
- Aging – Must understand aging trends beyond original manufacturing design lifetime
- Safety – The age of the stockpile requires future safety options
- Surety – Multi-point safety, use-control features, insensitive high-explosives, and R&D future surety options for LEP options
- Birth Defects – We now require greater fidelity in surveillance data



*Includes active and inactive warheads. Several thousand additional nuclear warheads are retired and awaiting dismantlement.

The age of today's stockpile demands a complex, physics/science-based predictive capability and understanding of the weapons

Weapons Materials Aging & Replacement Material Qualification



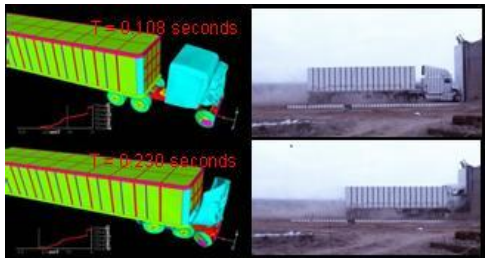
- Increasing need to consider alternative materials in stewardship
- Increasing need for more sophisticated prediction of materials behavior
- Increasing need for first principles models

The Stockpile Stewardship Program is developing advanced material models that will enable prediction of material response of the most important materials given a product rather than process based specification.

The Stockpile Stewardship Program resolves empirically-set knobs in the legacy codes of the stockpile and the main stockpile issues that are expected for the next 20 years. Results will transition solutions from empirically-based to predictive physics.

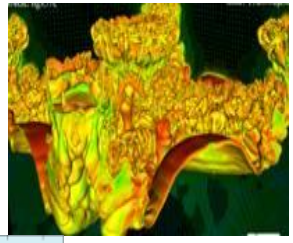
Prediction of weapons performance requires use of advanced computing power

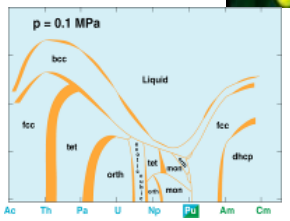
- Increasing emphasis and reliance on 3D simulations and validation experiments
- Increasing requirements for precision and accuracy
- Complex experiments will be needed to obtain this validation, but the payback will be a significantly improved simulation uncertainties



The Stockpile Stewardship Program develops modeling and software tools to take advantage of emerging, advanced computational power

- The experimental validation of these new tools will require new experimental approaches related to measuring complex materials behavior and investigating extreme conditions such as reacting plasmas

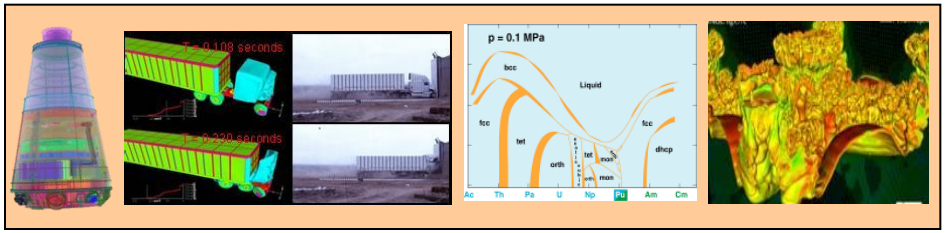




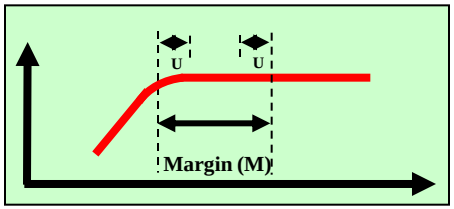
The Advanced Simulation and Computing Campaign provides the integrated prediction tools for Stewardship.

Contributions to the Stockpile

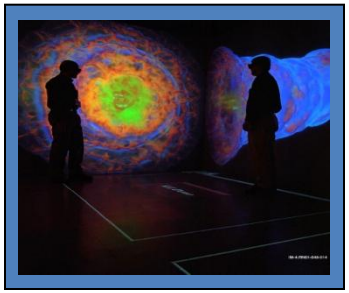
- Support **Assessments, B61 Study**, Certification, SFIs and Stockpile Systems and Services workload
- Upgrade design codes with **improved physics models**
- Perform **Verification** and **Validation** to support stockpile assessments and predictive capability with **Quantification of Margins & Uncertainties**



Code and Model Development



Uncertainty Quantification



Computer Science and Visualization

Platforms

Computing Centers

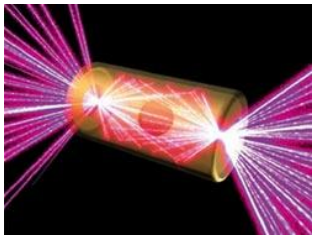
The Science Campaigns provide the validation basis for those predictive tools.

Exceptionally complex mission

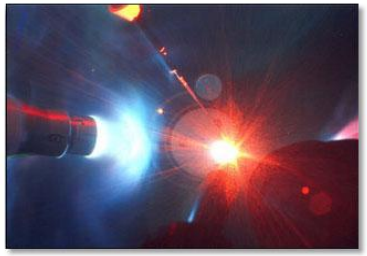
- Requires extreme measures in size, cost
- *The difficulty of simulating nuclear weapons conditions in the laboratory and predicting weapons performance is a grand challenge*
- High energy density (HED) physics – like understanding the physics of the sun
- Unique diagnostics which need to be designed and tested, and cover the whole range of neutral particles, charged particles, and visible light to x-ray measurements

Today's Stockpile Stewardship mission is inherently different than during the Cold War

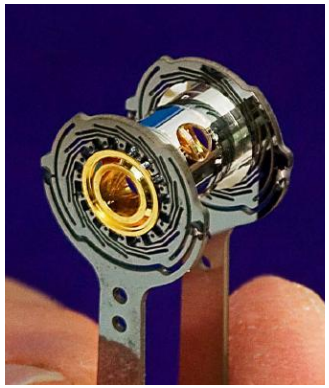
- Cold War: Continuous design, development, production and surveillance of new weapons using "empirical" codes and nuclear tests
- Today: New era of life extension informed by laboratory tools to simulate and predicted weapons performance



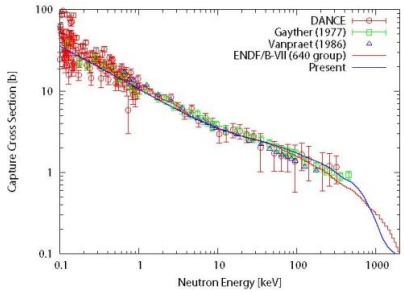
Advanced Radiographic Technologies



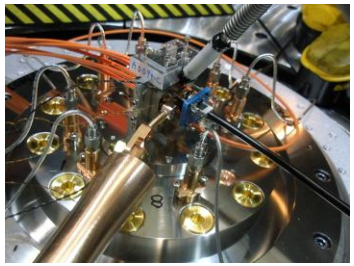
Thermonuclear Burn



High Energy Density (HED) Experiments



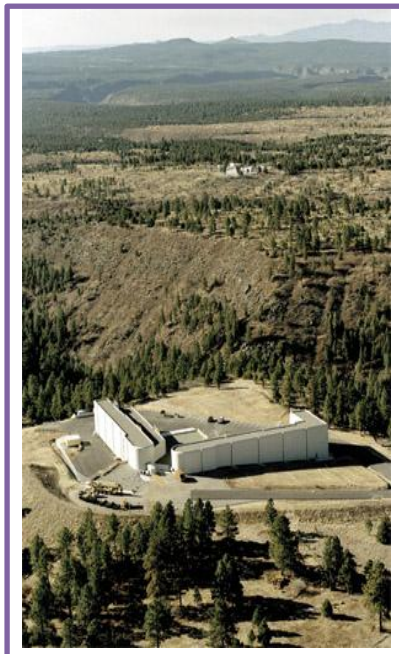
Nuclear Measurements



Dynamic Material Properties

Stewardship requires exploring fundamental material properties and integrated performance

Stockpile Stewardship requires Large Scale, Integrated, Hydrodynamic Experiments

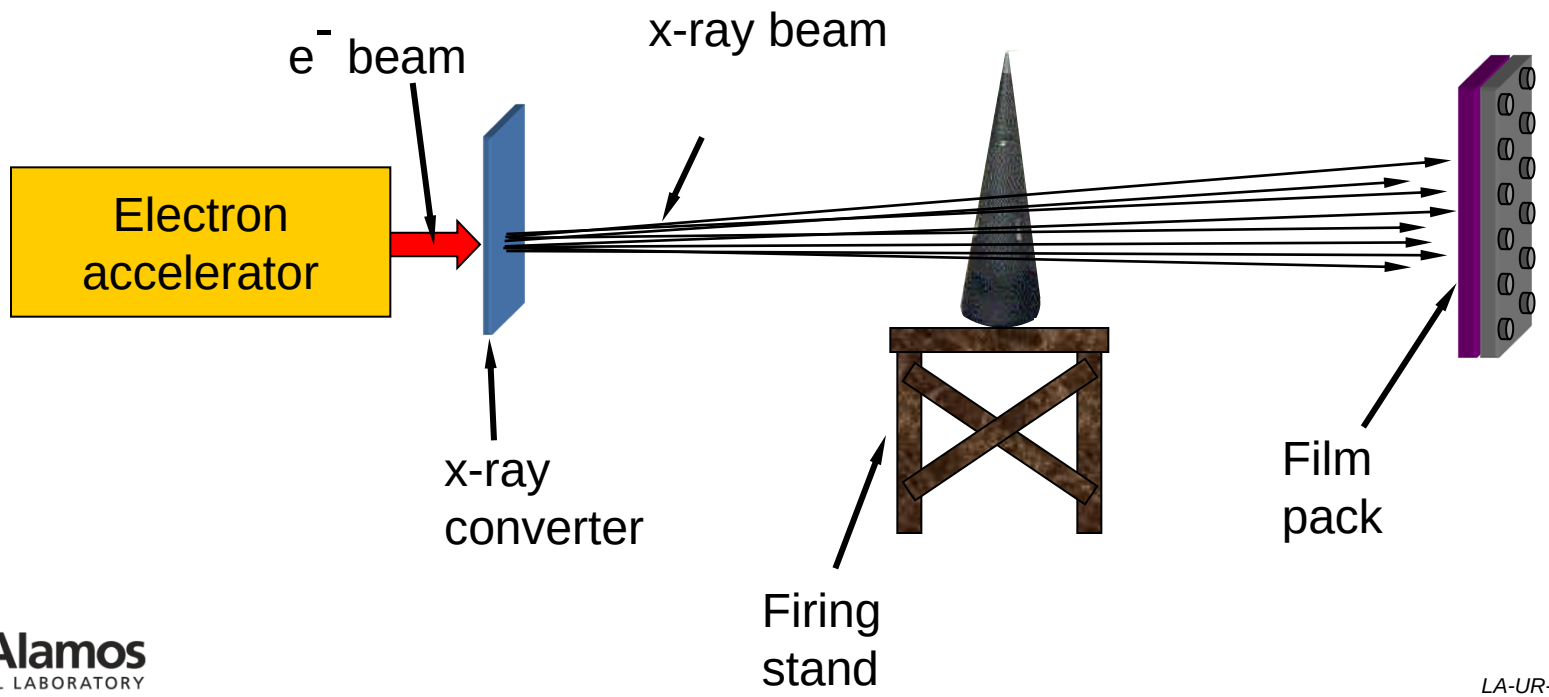


- Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility and Contained Firing Facility perform these experiments to test aspects of the early phase of weapons operation
- Essential to simulation code validation, Significant Finding Investigation (SFI) resolution, annual stockpile assessment and certification, and component performance assessments
- Necessary to establish confidence in stockpile modernization options
- Experiments that include special nuclear material will become more important as aging continues and modernization design options become more complex

The Stockpile Stewardship Program contributes a key element of the current effort involving subcritical experiments for scaling and surrogacy will be an assessment of the need for more sophisticated experiments

Flash Radiography at DARHT, LANSCE/pRad, and CYGNUS is a key diagnostic for non-nuclear evaluation

- Snapshot of fast-moving system
- *Flash x-ray machine*: must be capable of producing extremely intense and short x-ray pulses



Traditional "Pin" diagnostics captured other aspects of the pre-nuclear implosion.

- Measure implosion velocity and symmetry
- Pins produce signals when struck by moving material
  - » Electrical
  - » Optical
  - » ~500 pins typical
- Oscilloscopes capture timing of signals

Pin dome

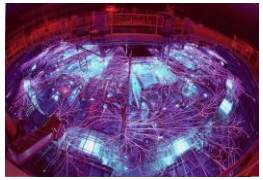
Oscilloscope

Experimental validation and discovery requires large facility and equipment investments

- Dual Axis Radiographic Hydrodynamic Test (DARHT)
- High Explosive Application Facility (HEAF)
- National Ignition Facility (NIF)
- OMEGA
- Z Machine
- Los Alamos Neutron Science Center (LANSCE)
- Enormous increase in computational power

NIF

OMEGA



Z

LANSCE

DARHT

Mini-G Explosion (Nevada)

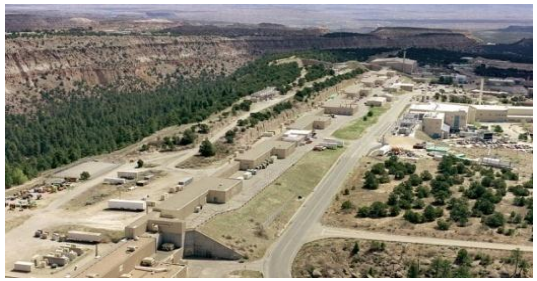
Computing Centers and Platforms

Stockpile Stewardship develops state of the art experimental platforms necessary to conduct world-class research that replicates weapons conditions in the laboratory and predicts weapons performance without testing

LANL's unique science and engineering infrastructure is a critical component of U.S. deterrent

Metropolis Center for Modeling & Simulation

High Explosive laboratories



Los Alamos Neutron Science Center

Plutonium Processing Facility

Chemistry and Metallurgy Building

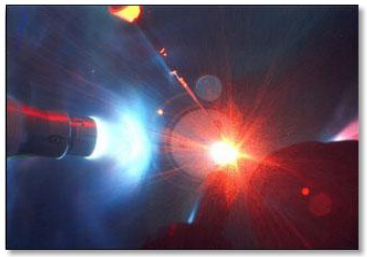
Dual Axis Radiographic Hydrotest Facility

SIGMA Building

Chemistry & Metallurgy Research Replacement (RLUOB)

Accurate prediction of the "Boost Phase" of primary Performance remains a scientific challenge.

- National Boost Initiative will produce valuable results by 2020 that will greatly enhance predictive capability for certification
- Unlikely to settle all issues related to the complex phenomena of boost.



The Stockpile Stewardship is performing a thorough investigation of burning plasma conditions at the National Ignition Facility

- A huge challenge in the application of such data is scaling from the small size of the NIF capsule to an actual weapon configuration.
  - Such scaling requires scale invariant physical models
  - Such scaling will require complex integrated computation.

Stewardship requires continued Human Capital investments

- **By 2025 personnel with actual underground nuclear test design and operation expertise should be retired.**

- **Sustaining the deterrent requires a work force at the cutting edge of weapons physics:**
  - Engineering teams to operate the facilities
  - Theorists and experimentalists to discover the underlying physics
  - Large unique computers and a cadre of people to refine the predictive capability

Stewardship Science Academic Alliance (SSAA) trains students in key areas for stewardship not supported by other agencies

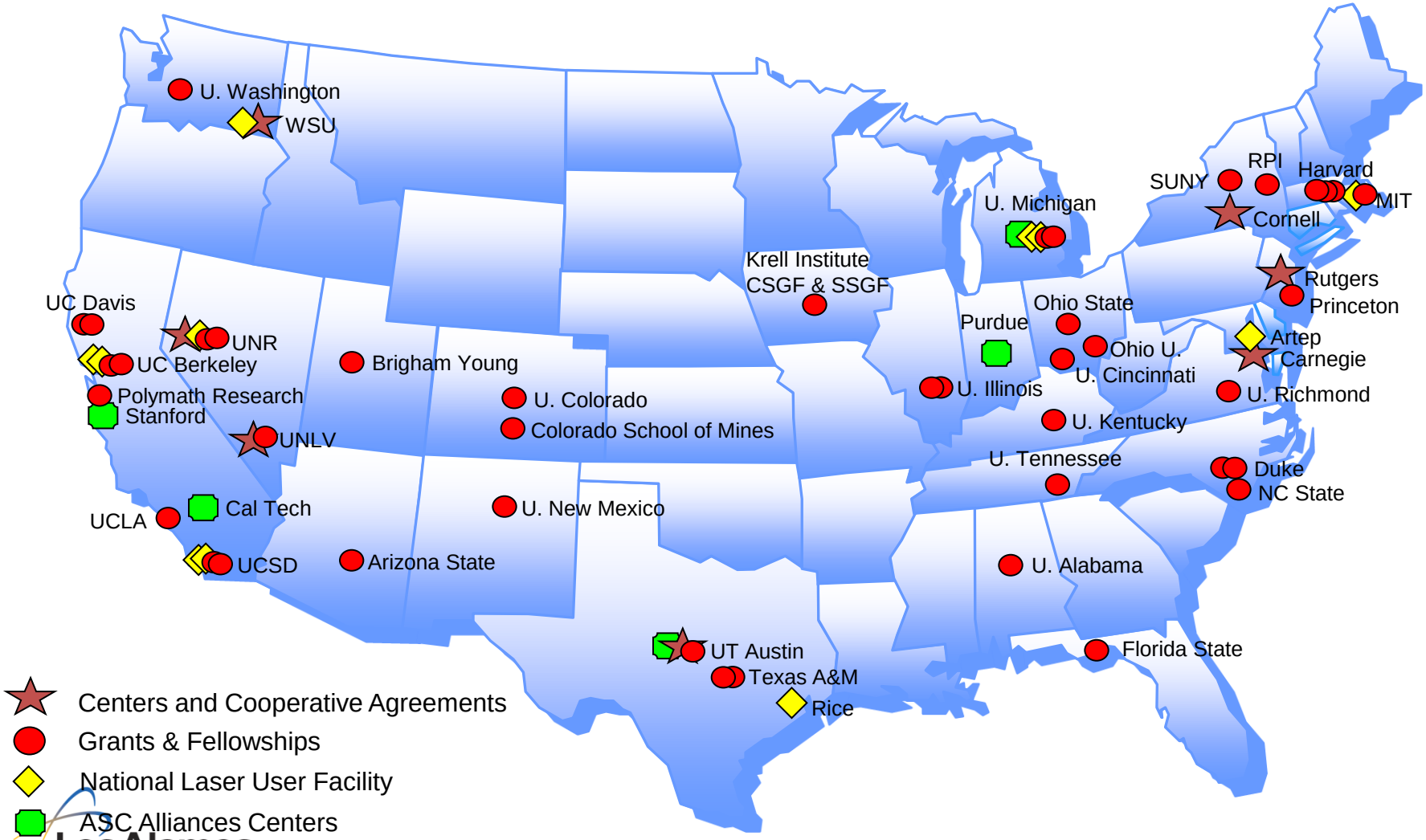
- Offers the highest caliber of education and hands-on training and experience to the next generation of scientist and physicists
- Supports SSAA Grants Program, High Energy Density Lab Plasmas (HEDLP) , and National Laser Users' Facility (NLUF) grant programs
- Recruiting for NNSA Labs
  - More than 70 SSAA-supported students have taken positions at the NNSA labs since 2002
- Publications Awards
  - Over 1,300 peer reviewed articles published since 2005
- Many external reviewers come from our academic program

Stewardship Science Academic Alliances (SSAA)

Future workforce and international visibility

We must maintain weapons design, engineering, and key manufacturing capabilities yet also create modern era nuclear scientists to support the U.S. nuclear posture for decades beyond the last nuclear test

Stockpile Stewardship sustains scientific expertise of the next generation through support of academic research



Stockpile Stewardship Delivers

- **Confidence in the nation's nuclear deterrence**
- **Credible alternatives to UGTs to resolve performance questions**
- **Confidence to reduce the stockpile and fulfill New START obligations**
- **Confidence in broader national security missions**
- **Smarter LEP decisions**
  - Determine lifetime for components more accurately
- **Future cost savings**
  - Resolve SFIs faster with science and advanced computing

"… <u>The entire nuclear deterrence posture is inherently rooted in and inseparable from scientific and technical excellence</u>. Critical decisions ranging from annual assessment of specific systems to changes in manufacturing methods, testing, and deployment are inevitably derived from highly technological methodologies. In order to deal with the changing face of deterrence, including more widely dispersed nuclear knowledge, the U.S. must continue to maintain excellence in nuclear-based science and technology that is second to none."

Conclusion

- **We are undergoing a transition**
  - Calibration → Prediction
    - Avoid technological surprise (own stockpile and foreign programs)
  - Weapons Life → Weapons Life Extension
  - Test Experience → Code Experience
  - Nuclear Weapons Designers → Nuclear Weapons Designer- Scientists

Abstract (U)

- **(U) a talk to provide an overview of Stockpile Stewardship's scientific requirements and how stewardship has changed in the absence of nuclear testing. The talk is adapted from an HQ talk to the War college, and historical unclassified talks on weapon's physics.**

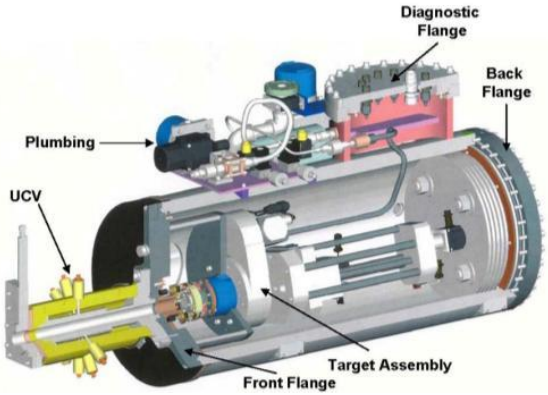
Large scale, integrated experiments contribute to the Stockpile Stewardship scientific base

High Explosive Pulsed Power Experiment (Full Function Test) as part of PHOENIX series at BEEF

Full Toss multi-agency experiment

Barolo experiment Vessel - measure the effects of a shock on a plutonium surface.

Cygnus dual-beam radiographic source enables X-ray imaging of Subcritical Experiments



Containment chamber of JASPER Gas Gun for shocked Pu experiments

Large bore powder gun – measure differences in performance of weapon materials of interest