

The Challenges and Rewards of Stockpile Stewardship

Charles W. Nakhleh

Division Leader X-Theoretical Design

Los Alamos National Laboratory

LA-UR-16-24488

**Stewardship Science Graduate Fellowship Annual Program
Review**

29 June 2016

Abstract

- **(U) This talk provides an overview of the Stockpile Stewardship Program (SSP) and discusses how stewardship has changed in the absence of nuclear testing. The talk is adapted from previous unclassified talks, especially LA-UR-15-24601.**

Why Stockpile Stewardship?

- **The United States is retaining nuclear weapons in the stockpile beyond their original design life.**
- **The objective of the Stockpile Stewardship Program is to maintain the certification of those weapons without conducting additional nuclear tests.**
- **This requires us to develop and utilize high-fidelity, physics-based capabilities to predict, assess, and certify nuclear weapons performance.**
- **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.***



**Secretary of Energy
Ernest Moniz**

The NNSA design laboratories and production complex are essential to maintaining a healthy US deterrent

- **The US maintains a diverse array of weapons**
 - W76, W88 SLBM
 - B61 bomb
 - W78, W87 ICBM
 - W80 cruise missile
 - B83 bomb
- **Each leg of the Triad offers complementary and reinforcing benefits**



The weapons program strategy balances multiple aspects of the US deterrent

■ Stockpile management

- B61 Life Extension Program (LEP)
- Support to plants on W76 LEP
- Selected production facilities

■ Science, technology and engineering investments

- Use science tools to generate data to support assessments

■ Infrastructure investments

- Create modern, state of the art facilities to sustain laboratory capabilities
- Hire and develop the next generation workforce



Nuclear Testing

1030 US and 24 Joint US/UK tests

- 839 Underground
- 210 Atmospheric
- 5 Underwater



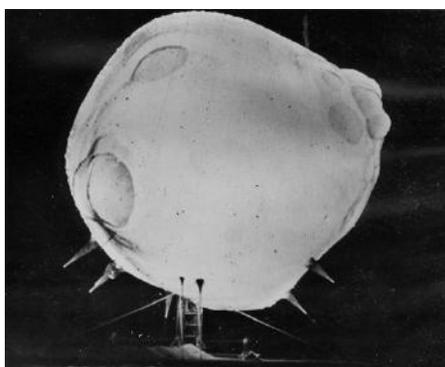
Underwater



Air-launched



Air-dropped



Tower



Sedan/PNE



Artillery



High-Altitude



Underground



During the testing era (1945-92), nuclear tests underwrote system performance assessments

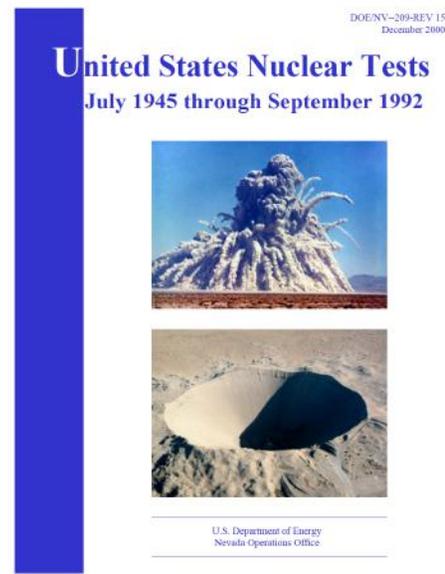
Nuclear Testing

- 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

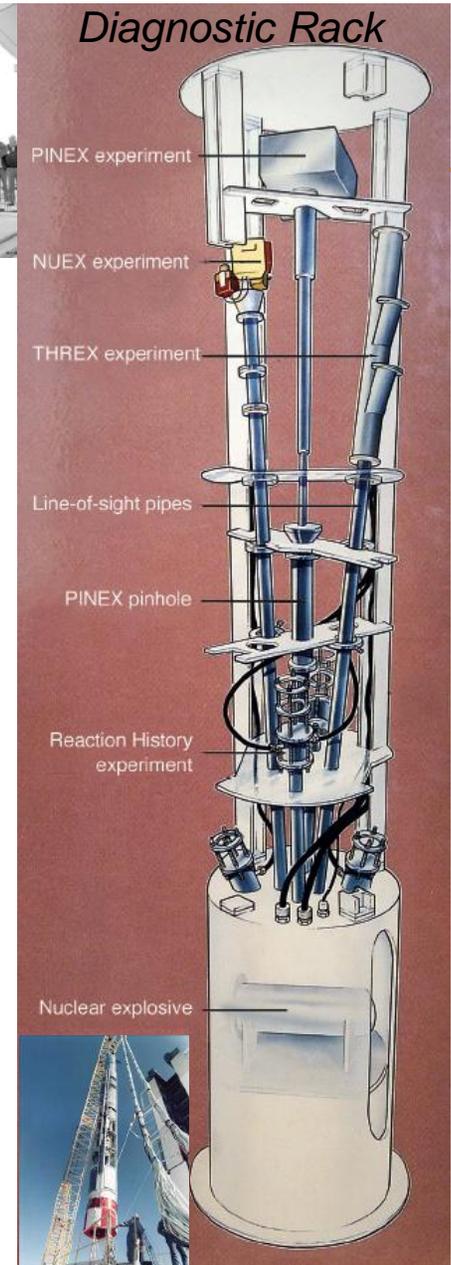
Based on the weapon development cycle and empirical codes underwritten by nuclear tests, partly to compensate for incomplete scientific knowledge

Historical Weapon Development and Replacement Cycle

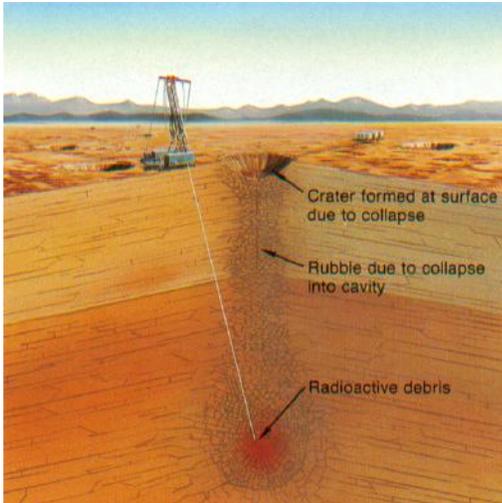
- Continuous design, development, production and surveillance cycle for new weapons
- Weapons were replaced within their design lifetime (typically 10-15 years)
- Aging was not an issue and was not studied
- Confidence bolstered by the size of the stockpile



Underground test diagnostics during nuclear testing era



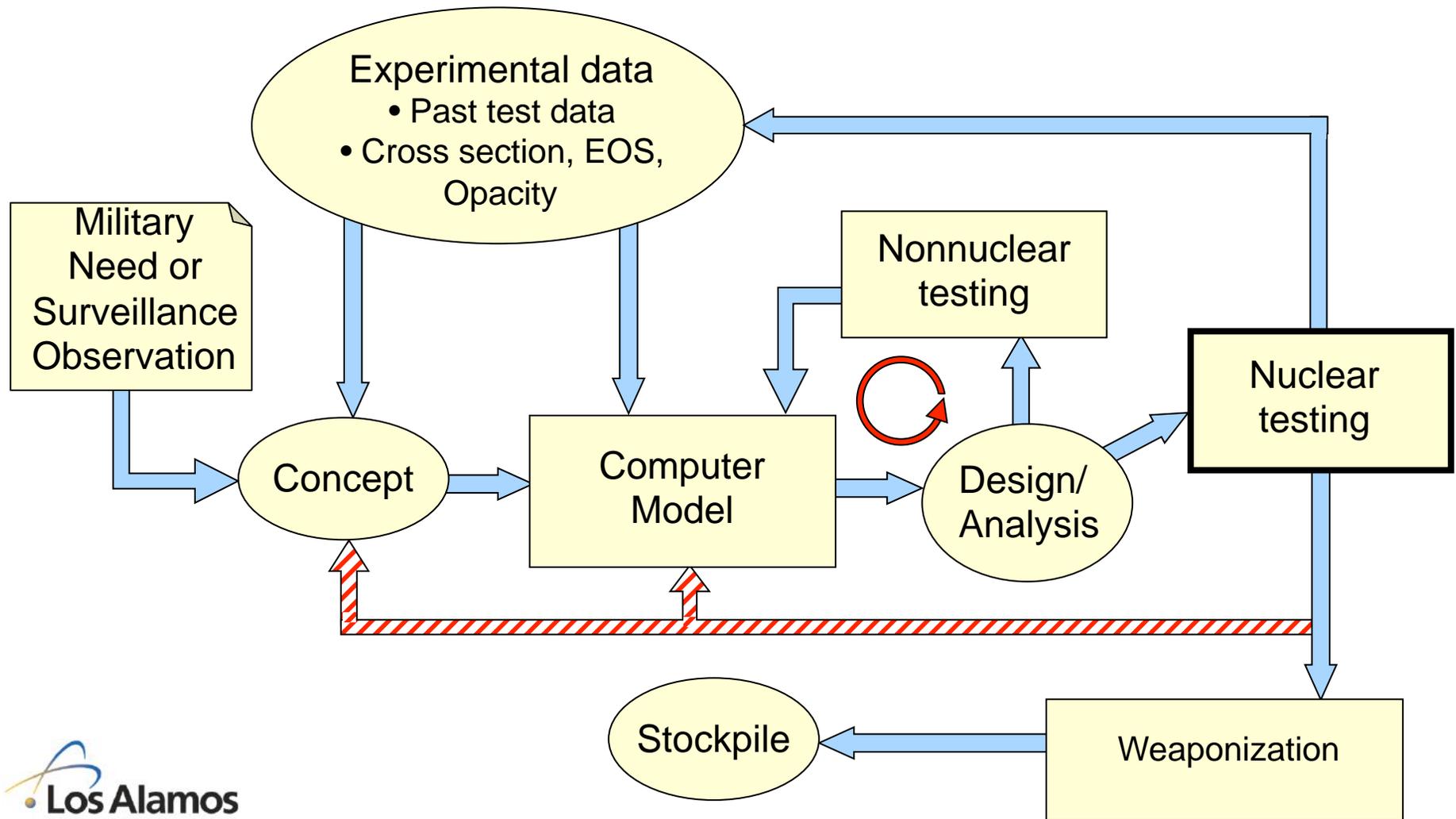
- Rack (with device) lowered to bottom of hole (4-12 ft dia., 650-2300 ft deep)
- Hole is filled with various materials (stemming) to preclude venting



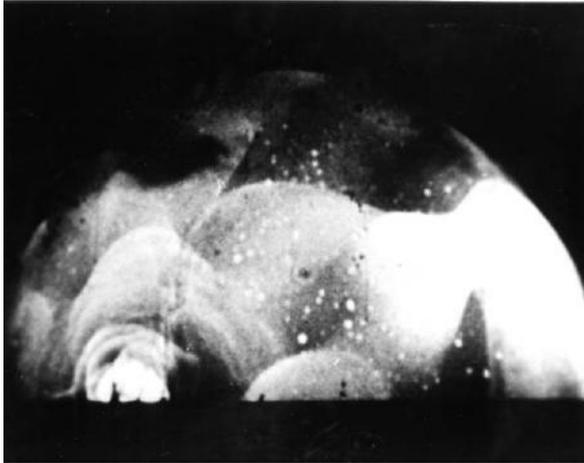
- Nuclear device emits radiation (neutrons, gamma rays, and x-rays)
- Measured by various experiments (consist of line-of-sight pipes, detectors, cables, signal processing and data recording hardware)

- 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

During testing, a nuclear test ensured that the complex product of the design process functioned as intended



Past nuclear tests cannot 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):

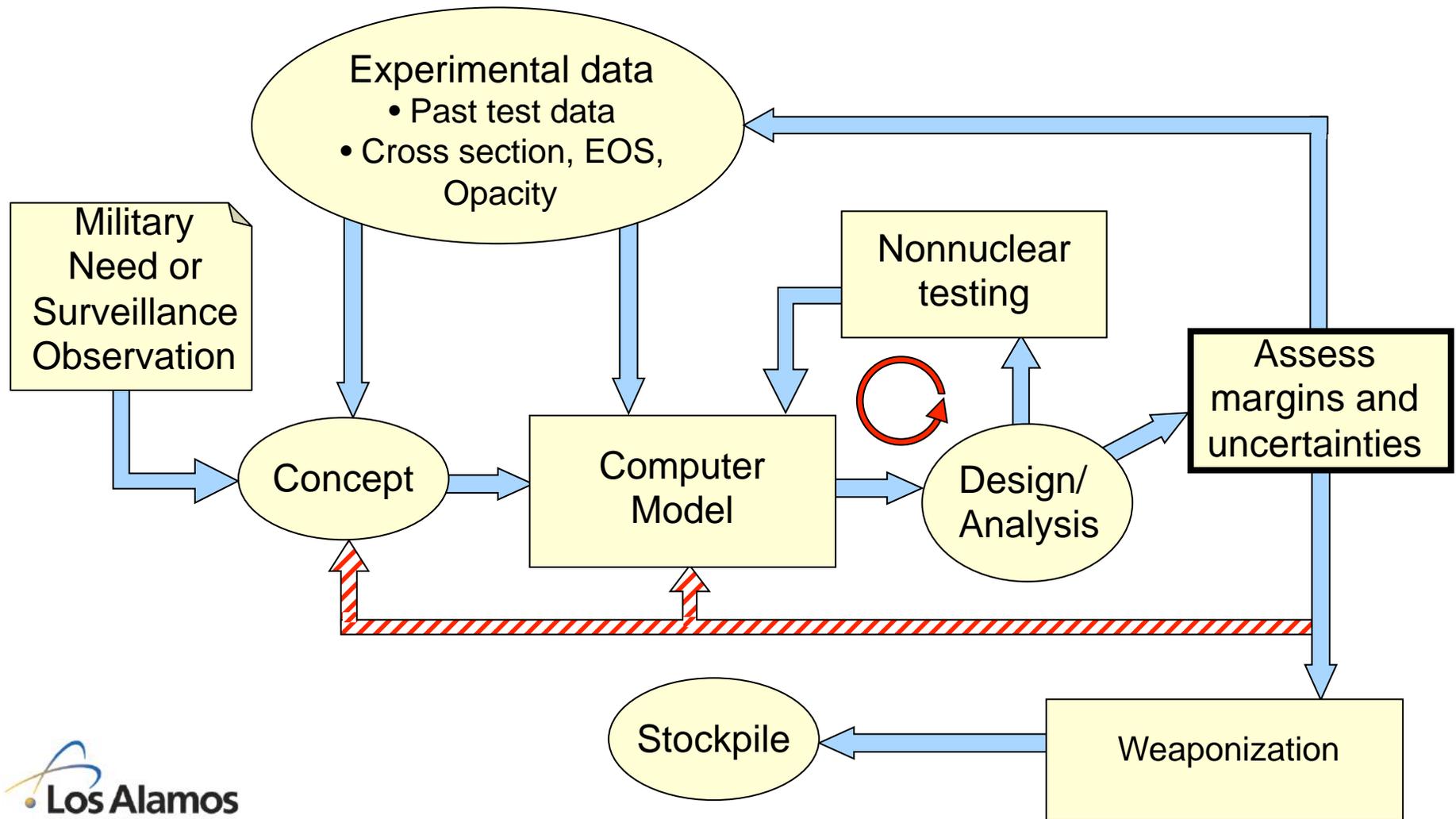
- 194 tests
- Data included fireball photos, seismic, radchem, reaction history



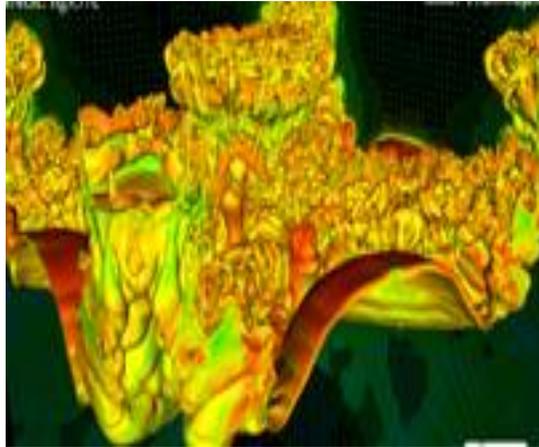
Today:

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

Absent system-level tests, we use detailed computer models to integrate disparate information sources into an assessment of system performance, margins, and uncertainties

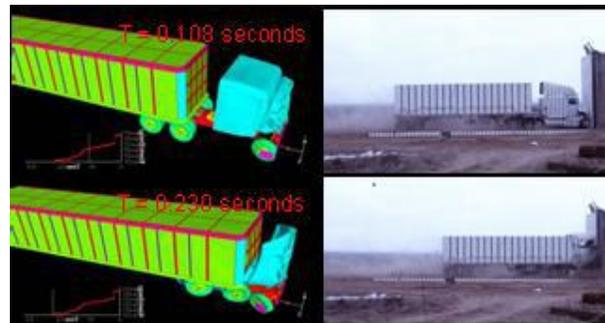


Prediction of weapons performance requires advanced computing power



SSP develops modeling and software tools to exploit emerging, advanced computational power

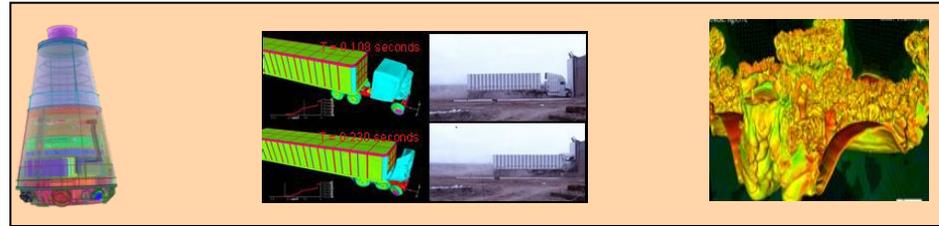
- Increasing emphasis and reliance on 3D simulations
- Experimental validation of these new tools requires new experimental approaches to measuring complex materials behavior and investigating extreme conditions such as reacting plasmas



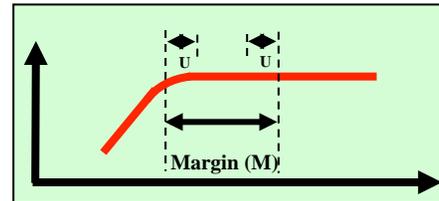
The Advanced Simulation and Computing (ASC) program provides the integrated prediction tools for stewardship

Contributions to the Stockpile

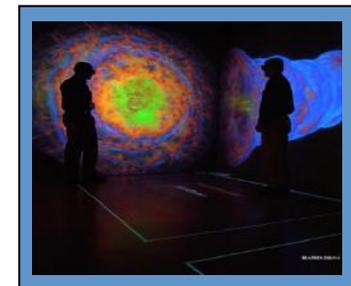
- Support **Assessments, B61 Study**, Certification, SFIs and Stockpile Systems and Services workload
- Upgrade design codes with **improved physics models**
- Perform **Verification and Validation** to support stockpile assessments and predictive capability with **Quantification of Margins & Uncertainties**



Code and Model Development



Uncertainty Quantification



Computer Science and Visualization



Platforms



Computing Centers

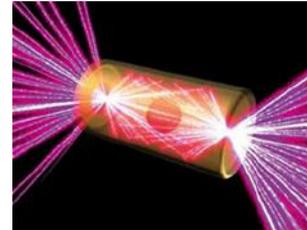
The Science Campaigns provide the validation basis for those predictive tools

Predicting nuclear weapons performance by extrapolation from laboratory experiments is a grand challenge:

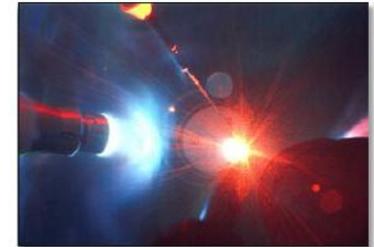
- Requires extreme measures in size, cost
- High energy density (HED) physics – like understanding the physics of the sun
- Unique diagnostics which need to be designed and tested, and cover the whole range of neutral particles, charged particles, and visible light to x-ray measurements

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

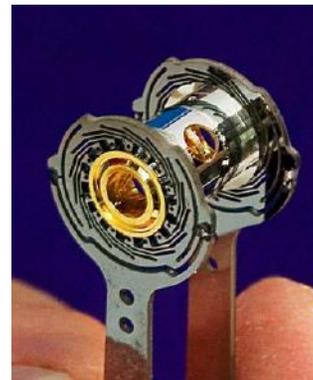
- Cold War: Continuous design, development, production and surveillance of new weapons using “empirical” codes and nuclear tests
- Today: New era of life extension informed by laboratory tools to simulate and predict weapons performance



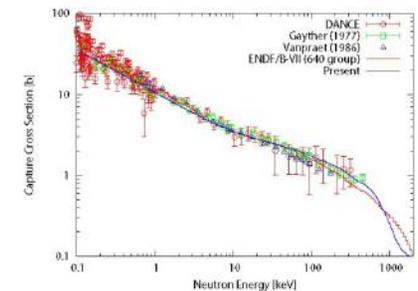
Advanced Radiographic Technologies



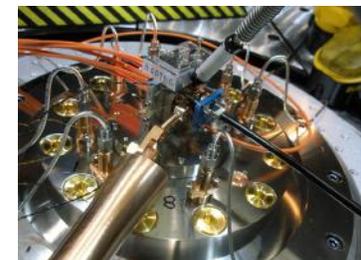
Thermonuclear Burn



High Energy Density (HED) Experiments

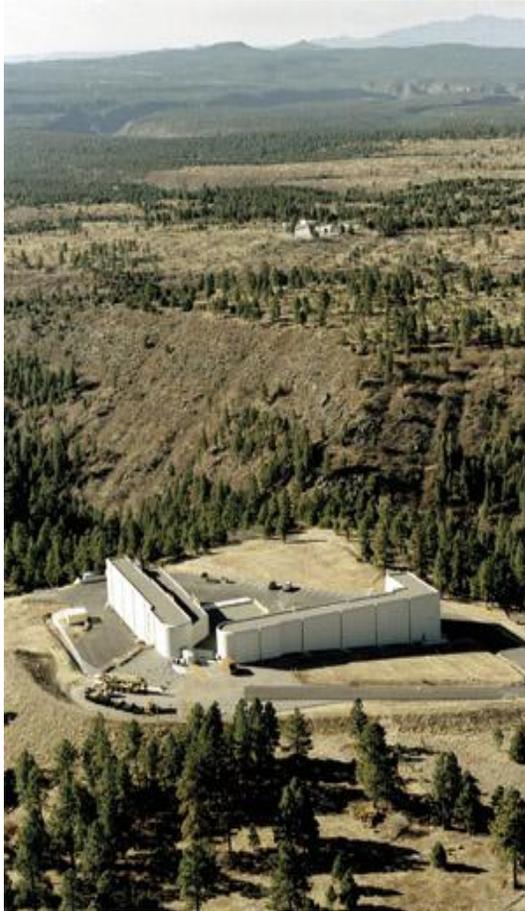


Nuclear Measurements



Dynamic Material Properties

Stockpile stewardship requires large scale, integrated, hydrodynamic experiments



- Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility and Contained Firing Facility (CFF) 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

Traditional “pin” diagnostics captured some aspects of the pre-nuclear implosion



Pin dome



Oscilloscope

- Measure implosion velocity and symmetry
- Pins produce electrical signals when struck by moving material
 - ~500 pins typical
- Oscilloscopes capture the timing of the signals
- Optical velocimetry techniques are rapidly becoming the norm

Experimental validation and discovery requires large facility and equipment investments now and into the future



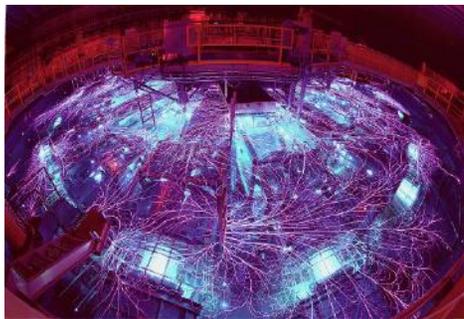
NIF



DARHT



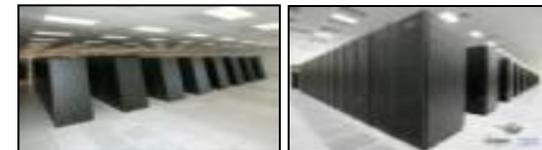
OMEGA



Z



LANSCE



Computing Centers and Platforms

Stewardship requires sustained investments in people

- 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



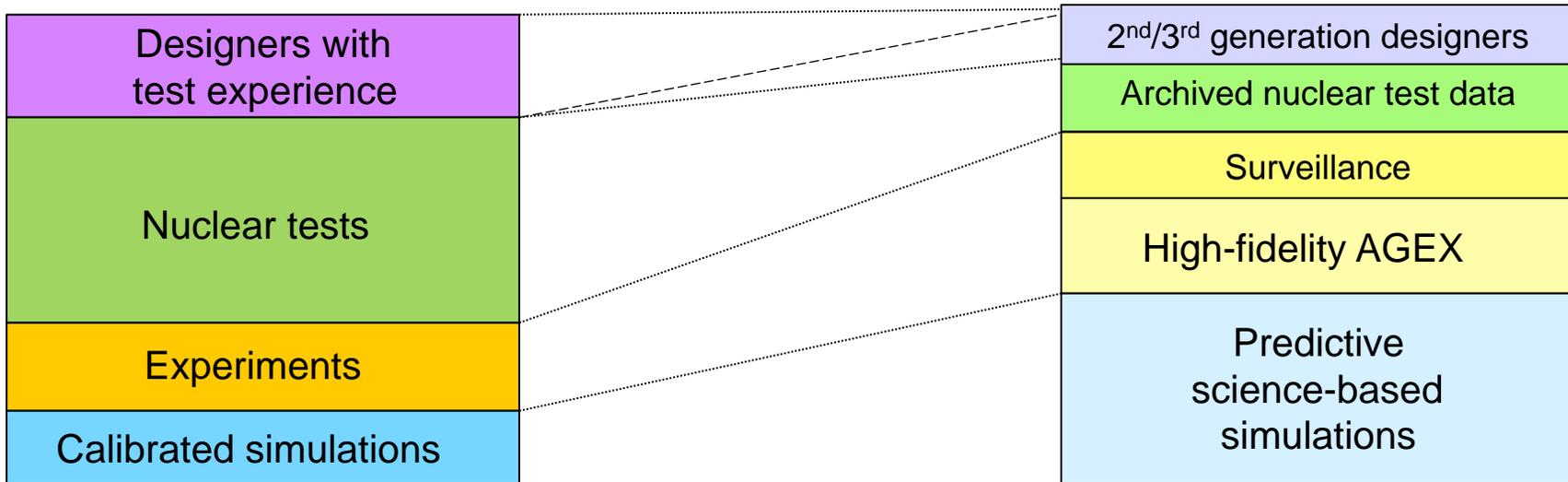
Stewardship Science Academic Alliances (SSAA)



Future workforce and international visibility



How confidence in the stockpile is underwritten has changed since 1992



SSP is delivering on its commitments, and we want you to be part of that

- Confidence in the nation's nuclear deterrence
- Credible alternatives to UGTs to resolve performance questions
- Confidence in enabling technologies for broader national security missions
- Smarter LEP decisions
 - Determine lifetime for components more accurately
- Faster resolution of stockpile issues with utilization of science and advanced computing

“... The entire nuclear deterrence posture is inherently rooted in and inseparable from scientific and technical excellence. 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.” *