Stockpile Stewardship and Beyond: Why Science is Important to the US Nuclear Deterrent

Matt Cowan

IET Project Engineer
Defense Technologies Engineering Division
Lawrence Livermore National Laboratory

PONI Fall Conference
September 8, 2011

LLNL-PRES-497721

Prior to 1992, large scale nuclear testing was key to establishing technical confidence in the national deterrent

- We conducted nuclear tests to:
  - Reveal physical processes that make nuclear warheads work
  - Measure warhead effects
  - Validate acceptability of weaponized configurations and assure the DoD of efficacy
  - Support government deterrence and assurance policies
  - Identify set points or keystones for calibrating analysis and calculations

The analytical keystones were typically test dependent rather than constrained by systematic understanding of the fundamental governing physics.

The US policy decision to stop nuclear testing fundamentally changed our approach to maintaining technical confidence

- The technical adequacy of each existing warhead type is certified during the Annual Assessment Process. The technical basis is derived from:
  - Conducting surveillance on a limited number of existing warheads and components for a snapshot of the physical condition of the stockpile
  - Predicting the future physical condition with Enhanced Surveillance to understand details of material aging and compatibility
  - Conducting focused Above-Ground Experiments (hydrodynamic experiments, high energy density exp., etc) and subcritical experiments to gather material property data and test predictive modeling capability
  - Conducting flight tests, component tests, hostile and abnormal environment tests
  - Reassessing the historical production and nuclear test databases
  - Investigating fundamental science, and new research & development
- The results are integrated with predictive high performance computing to evaluate what is important and establish our confidence level

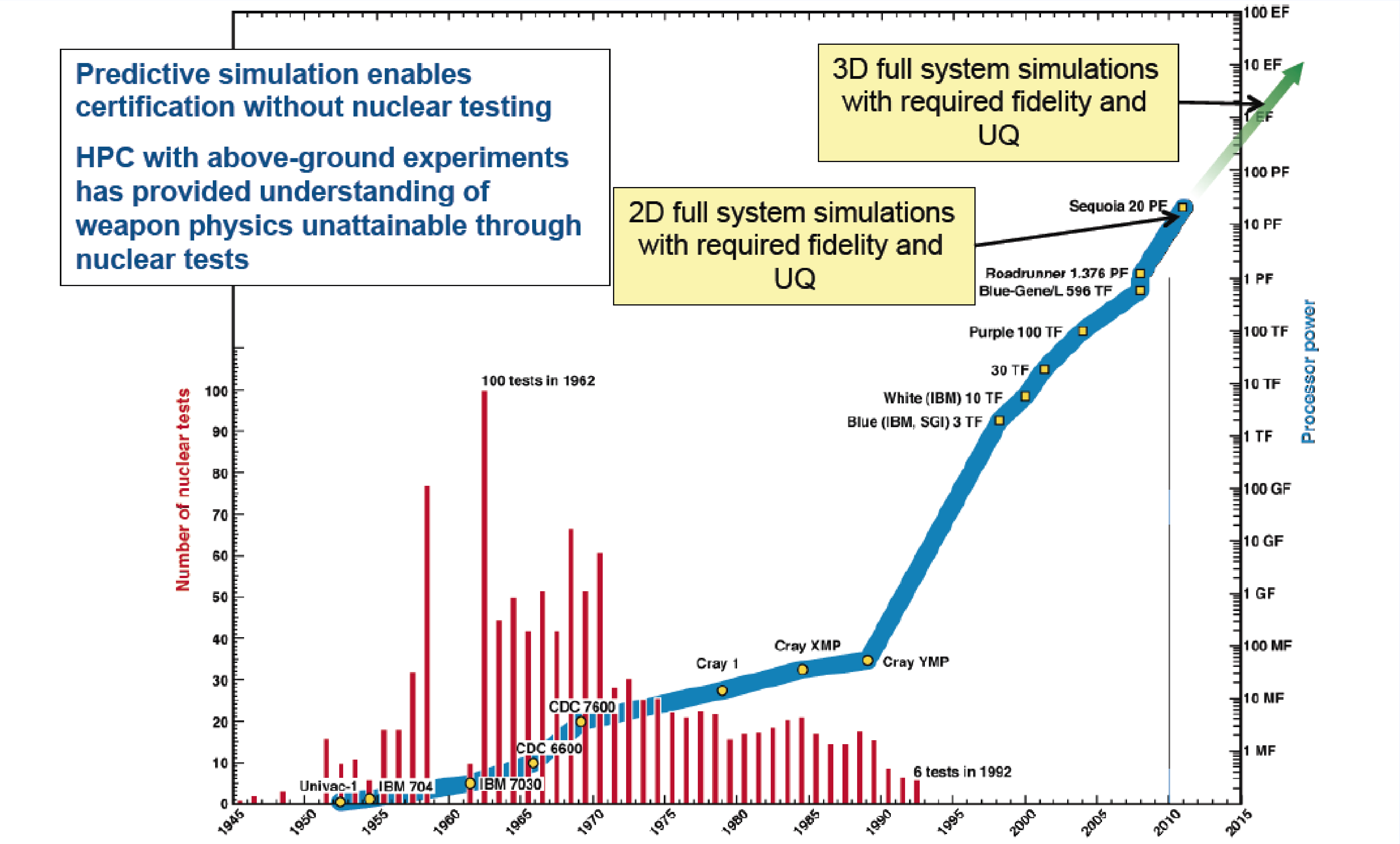
Predictive computing is a powerful tool provided the simulation uncertainties are known and understood.

Uncertainty quantification is a major scientific challenge for understanding numerical simulations

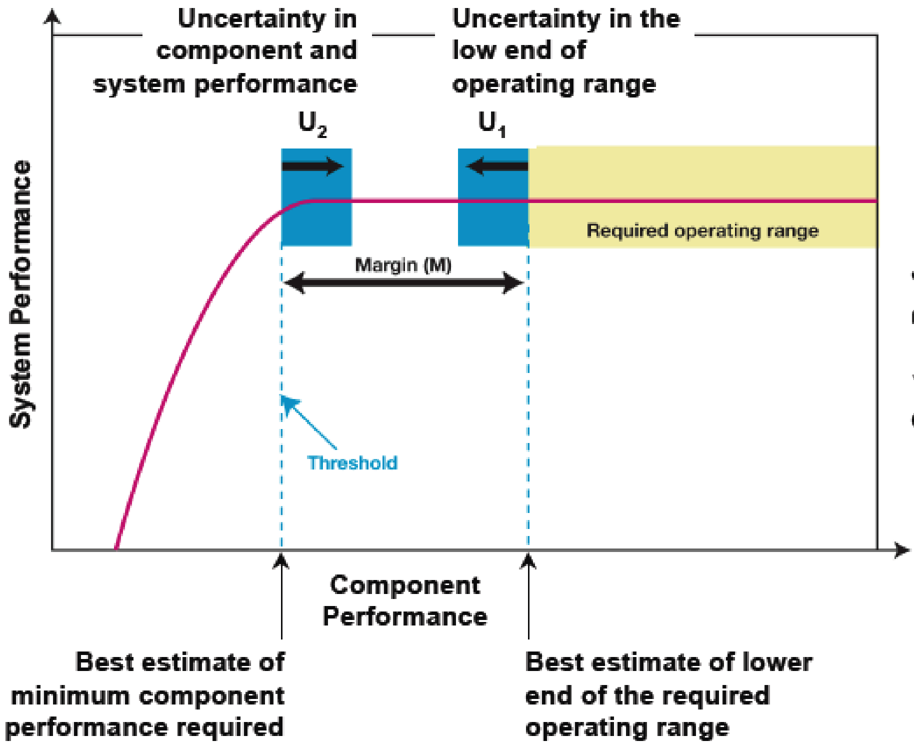
- Uncertainty sources include:
  - Numerical modeling methods
  - Database measurement techniques and quality
  - Data resolution details
  - Knowledge of material properties and physical processes
- Our challenge is to understand how these uncertainties combine, interact, and propagate throughout the predicted stockpile lifetime

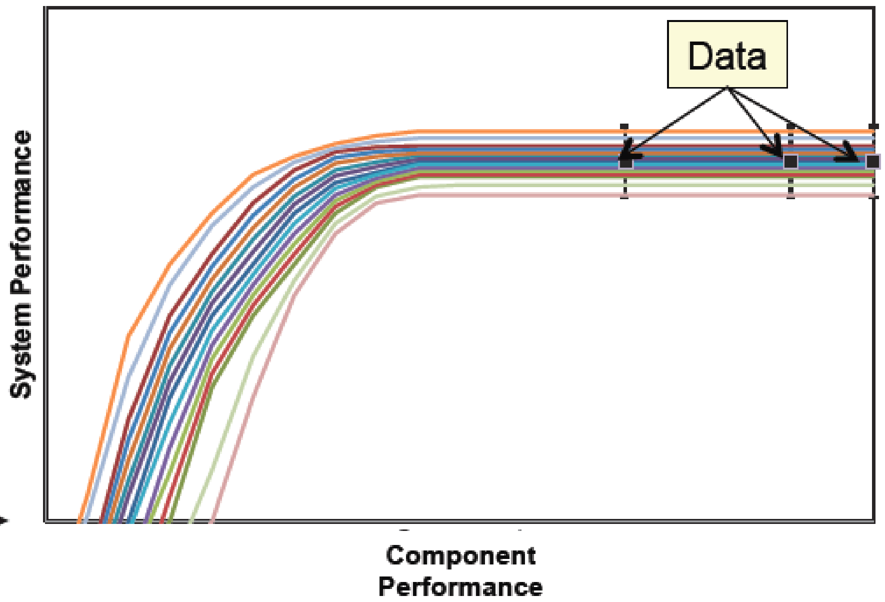
Resolving uncertainties drives the need for demanding computational and experimental capabilities.

The Advanced Simulation Capability (ASC) partnership between NNSA-LLNL-IBM provide a million-fold increase in capability



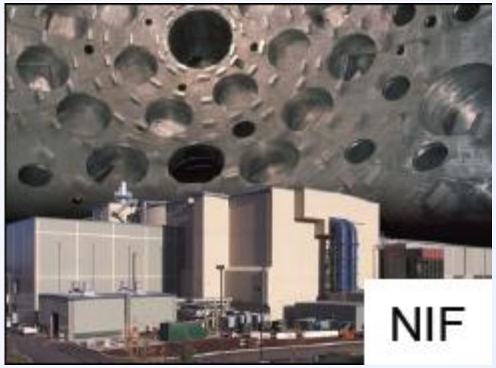
Systematic 3D application of uncertain quantification requires an additional 1000-fold increase in computational capability



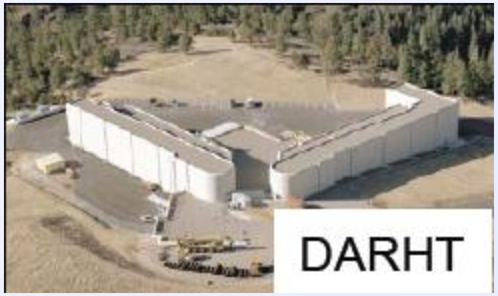


High performance computing must be coupled with experimental programs to keep in touch with reality

- Focused physics experiments provide analytical constraints and previously unavailable material data

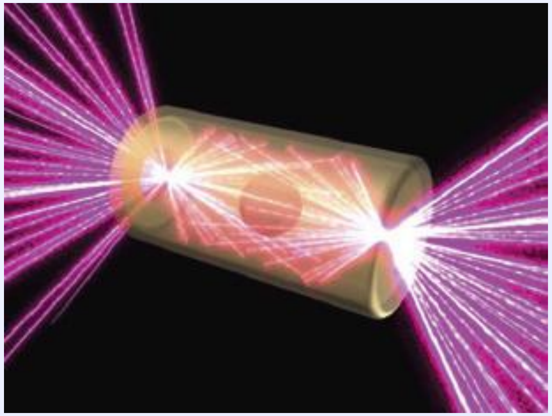


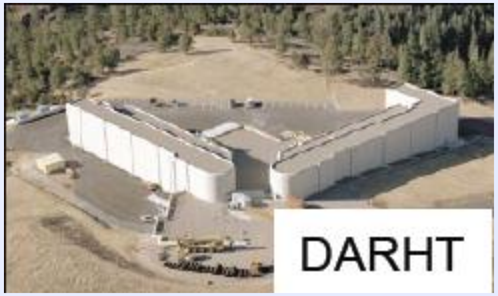
- Integrated experiments couple materials data and analytical methods to test against reality



New advanced scientific tools are online and providing essential data

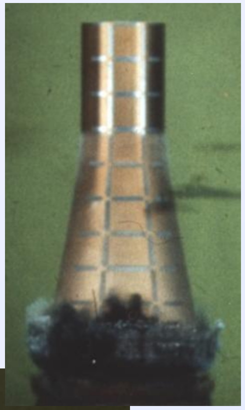
- National Ignition Facility (NIF)
  - Allows access to physical regimes relevant to thermonuclear warheads
  - Only place to study the nuclear phase and fusion in the laboratory
- DARHT provides advanced radiography for integrated tests
  - Improved images with multiple views
- Joint Actinide Shock Performance Experimental Research (JASPER) Facility and U1a allow fundamental measurements of SNM under shock conditions

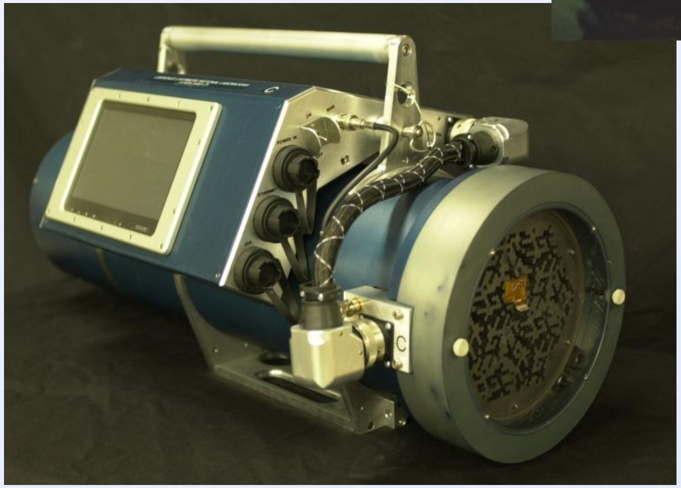




Unique coupling of computational and experimental programs allows ongoing development of critical skills

- High explosives
- Chemistry and material science for exotic materials (including special nuclear materials)
- Computation and simulation
- Integrated testing and diagnostics
- Weaponization, production, flight testing, and life cycle surveillance





Sustaining a skilled and experienced workforce is critical to continued technical confidence in our nuclear deterrent.

Stockpile developed capabilities technically enable the Nuclear Counterterrorism and Non-Proliferation missions

- Although each national security mission has inherently different program goals, they rely on the same critical skill sets and facilities:
  - Access to state-of-the-art analytical modeling codes
  - High performance computation
  - High explosive synthesis, assembly, testing, and analysis
  - Special nuclear material characterization and detection
  - Nuclear weapon design, fabrication, testing, and production experts

Substantial scientific challenges remain

- Understand and analytically constrain the nuclear test keystones tied to fundamental physics data
- Enable full system 3D assessments with uncertainty quantification
- Provide process and age aware material modeling capabilities
- Provide the technically appropriate basis for future stockpile decisions (refurbish, reuse, or rebuild) as we lose the statistics of larger numbers