Verification & Validation

Credibility in Stockpile Modeling and Simulation

Why:

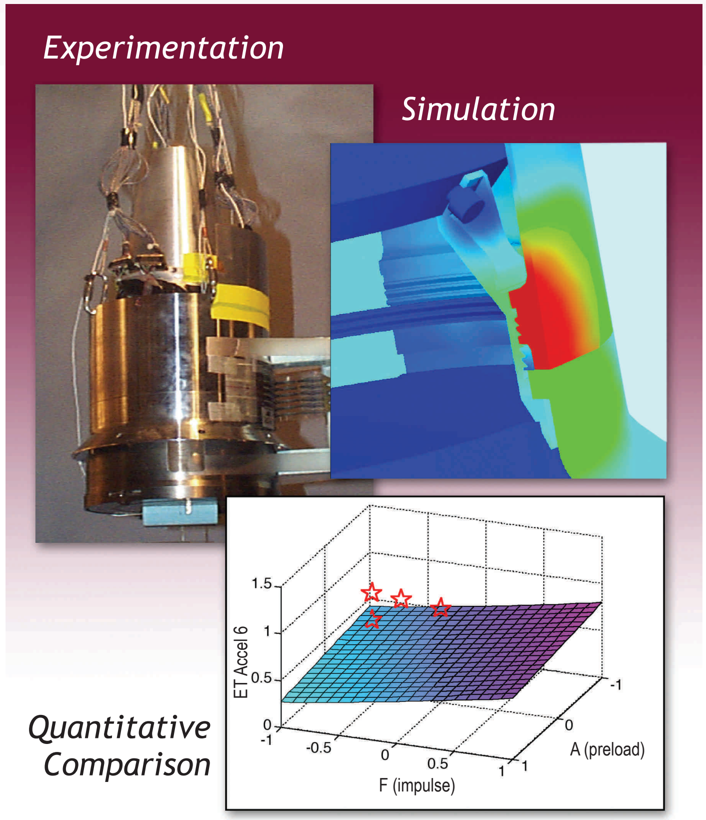
The Advanced Simulation and Computing (ASC) Verification & Validation (V&V) program exists to establish a technically rigorous foundation of credibility for the computational science and engineering calculations required by the NNSA Stockpile Stewardship Program. This program emphasizes the development and implementation of science-based verification and validation methods for the support of high-consequence decisions regarding the management of the U.S. nuclear stockpile. The V&V process reduces the risk of incorrect stockpile decisions by establishing that the calculations provide the right answers for the right reasons.

What:

V&V is the multi-disciplinary process of demonstrating credibility in simulation results. Credibility is built by collecting evidence that (1) the numerical model is being solved correctly and (2) the simulation model adequately represents the appropriate physics. The former activity is called Verification and requires intimate knowledge of the mathematical model representing the physics, the numerical approximation derived from that model, software quality engineering (SQE) practices, and numerical error estimation methods. The latter, termed Validation is accomplished by comparing simulation output with experimental data and quantifying the uncertainties in both. Broad knowledge of modeling and experimentation, augmented with a deep understanding of statistical methods, are necessary for Validation.

Impact:

Computer simulations are used for analysis of all aspects of weapon systems, as well as the analysis and interpretation of experiments. The credibility of our simulation capability is central to the credibility of the certification of the nuclear stockpile and is established through rigorous and quantitative V&V analyses. Regardless of whether or not we return to nuclear testing, V&V establishes credibility by providing evidence to support questions such as, "Why should we trust the simulation's results?" Insufficient confidence or credibility in our simulations, will lead us to an incorrect decision pertaining to the reliability, performance and safety of the nuclear weapons.



The Verification and Validation process ties together simulation and experiments using quantitative comparisons.

Delivery:

The V&V process delivers traceable, reproducible, and formally reviewed conclusions supporting confidence in stockpile simulations, to include, but not limited to:

- Documented analysis and conclusion of the confidence level of the models as a result of the V&V activities.
- Repository of test results associated with unit/regression/system tests, verification and validation tests and/or list of test data used.
- Documented code (feature) and solution (model) verification.
- Documented V&V environment (constraints, assumptions, and tools).
- Repository of code versions, fixes, and other patches used during the V&V phase.

Integration:

The ASC V&V process provides the most quantified evidence available to the programs laid out in the Nuclear Posture Review:

- Validated stockpile simulations as certification evidence for the Annual Assessment Review (integrate with AAR);
- Validated simulations to assess and help quantify the benefit or impact of changes in SLEP content and timing (integrate with SLEP);
- Quantitative Validation of pit performance simulations, as inputs to the high risk assessment of the need and timing for a Modern Pit Facility (integrate with MPF);
- Methods and assessment of predictive adequacy, as we face challenges of certification of Advanced Concept Initiative weapon system certification under CTBT (integrate with ACI);
- Quantify the model assessment benefit of a return to nuclear testing using V&V methods and quantitative model validation (integrate with Test Readiness).

V&V enables credibility in simulation capabilities via these steps:

1. Planning

- *Identify* and document the programmatic and weapons systems needs that drive the detail and accuracy requirements of the physics and engineering calculations.
- *Ensure* that planned activities are sufficient to meet requirements; document the gaps.
- *Review* archived data, and plan small-scale experiments and tests needed to meet the V&V requirements.
- *Ensure* integration with other ASC program elements, experimental campaigns, and directed stockpile work.

2. Verification

- *Confirm* the implementation of sound software quality practices to ensure that the codes are sufficiently free of defects and errors.
- *Conduct* Code/Algorithm Verification to ensure the code is correctly solving the mathematical equations.
- *Perform* solution verification to provide evidence that the time and space discretization of the mathematical model is adequate for the intended application.

3. Validation

- *Align* planned validation experiments with the needs of the mathematical model and the application.
- *Assess* model accuracy with respect to experimental data to provide evidence that:
    - The correct physical equations are being solved, and,
    - The important time-dependent geometric, material, and thermodynamic features of the weapon and its components are adequately represented.
- *Quantify* the predictive capabilities and limitations of the models within their database and in the application parameter space.

4. Predictive Adequacy Estimation

- *Present* evidence of an adequate understanding (through expert judgment and quantitative rigor) to make defensible risk-informed stockpile decisions.
- *Provide* adequate understanding of variabilities and/or uncertainties and quantify their integral impact on design margins.
- *Validate* sensitivities to identify which physical phenomena most influence weapon safety and performance.

For more information contact:

NNSA National Nuclear Security Administration
Jamileh Soudah, NNSA
Ph: (202) 586-2104
jamileh.soudah@nnsa.doe.gov

Sandia National Laboratories
Martin Pilch, SNL
Ph: (505) 845-3047
mpilch@sandia.gov

Los Alamos NATIONAL LABORATORY
Scott W. Doebling, LANL
Ph: (505) 667-6950
doebling@lanl.gov

Lawerence Livermore National Laboratory
Cynthia Nitta, LLNL
Ph: (925) 423-3792
nitta1@llnl.gov

Produced by Sandia National Laboratories for NNSA's Office of Advanced Simulation & Computing, NA-114.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. *SAND2004-0867P Rev. 1*