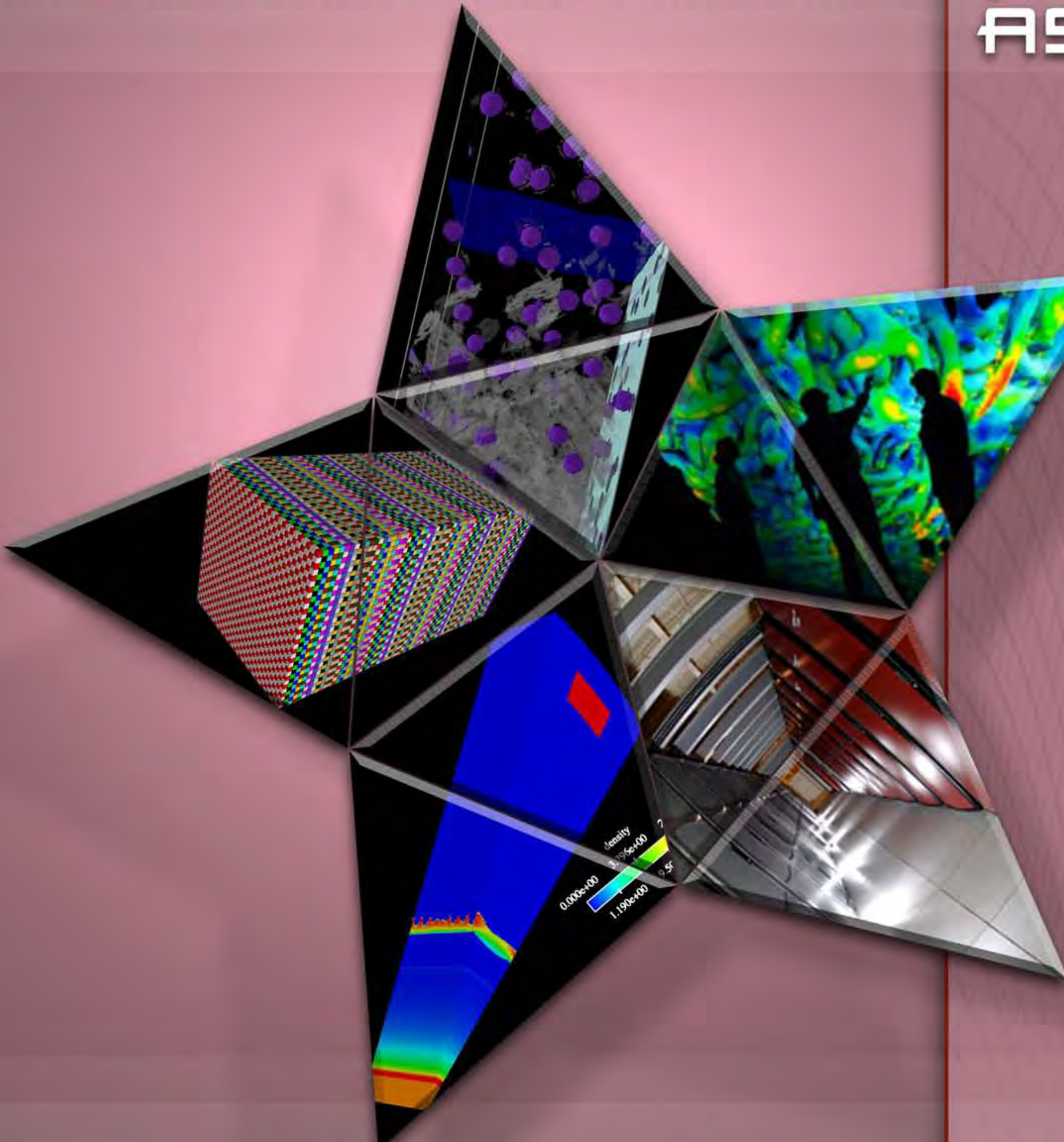
NA-ASC-111R-06-VOL.1-REV.0

PROGRAM PLAN FY07/08

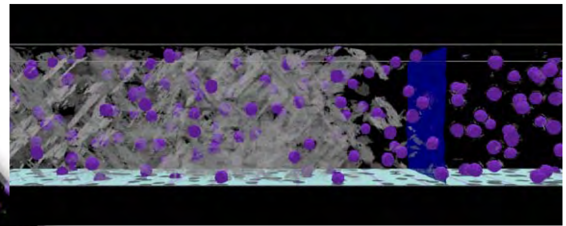


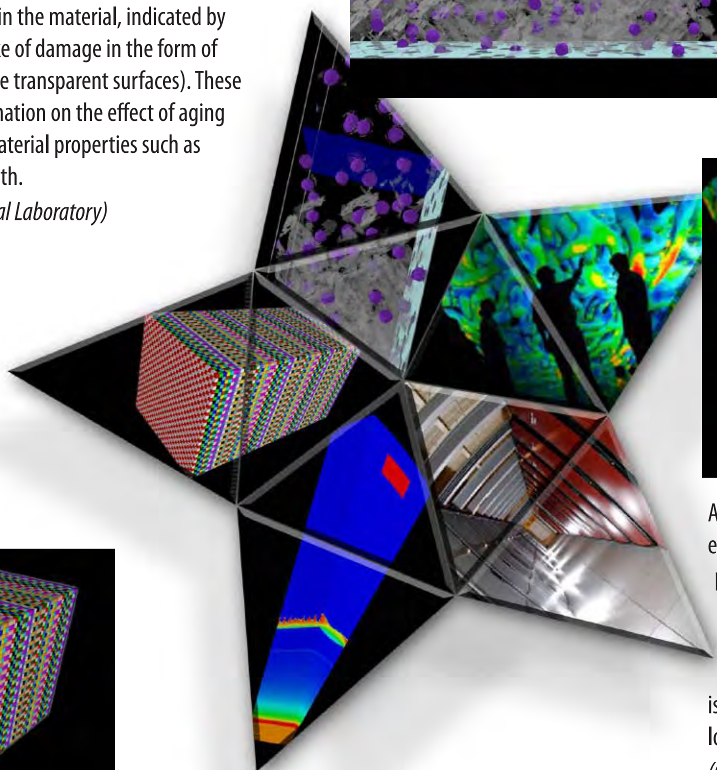
National Nuclear Security Administration

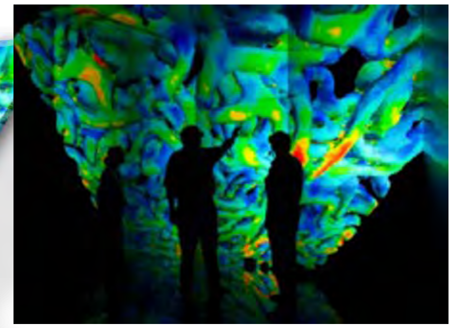
ON THE COVER:

Right: This snapshot shows a 32-million atom molecular dynamics simulation performed on ASC Purple—a shockwave traveling through aluminum that contains 3-nanometer helium bubbles (agglomeration of helium atoms shown as purple spheres; aluminum atoms are not shown). The shockwave traveling to the right in the material, indicated by the blue surface, leaves behind a wake of damage in the form of dislocations and stacking faults (white transparent surfaces). These simulations provide important information on the effect of aging and helium bubbles on changes to material properties such as equation of state and dynamic strength.

(Courtesy: Lawrence Livermore National Laboratory)

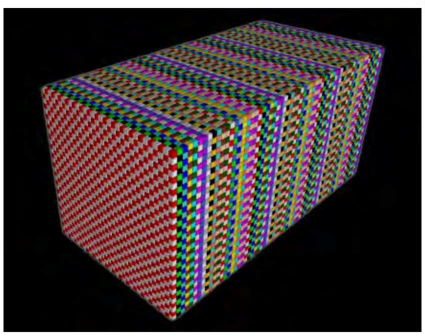






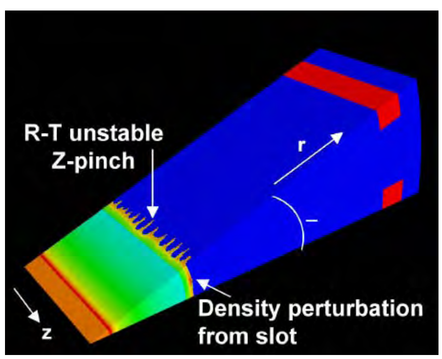
Above: LANL researchers use the CAVE facility to examine the stress state of a compressed foam. The picture shows a CAVE projection of the compression of an experimentally obtained low-density foam microstructure (obtained using x-ray micro-tomography). The image is a triangulated mass isosurface colored by stress, indicating regions of localized bending as the foam is crushed.

(Courtesy: Los Alamos National Laboratory)



Above: This illustration shows the results from porting QBox–a first principles molecular dynamics code developed at LLNL—to the BG/L supercomputer. The visual illustrates an improved node mapping for the 1000-atom molybdenum system on the supercomputer's 65, 536 nodes. This mapping resulted in a peak performance of 64 teraFLOPS, an improvement of over 60% from the default mapping.

(Courtesy: Lawrence Livermore National Laboratory)



Above: In a key V&V test of ALEGRA-HEDP, numerical noise triggered spurious magnetic Rayleigh-Taylor instabilities in the overall solution of a liner implosion problem. Algorithmic breakthroughs in the use and solution of singular and ill-conditioned H(curl) matrices resulted in simulations that ran through the peak of the main power pulse without exhibiting these instabilities, with current and inductance histories in agreement with experiment. These simulations will enable a Sandia FY06 Level-II NNSA milestone to be met on 3-D effects on z-pinch power from dynamic hohlraums.

(Courtesy Sandia National Laboratories)

Above: Sandia's Red Storm supercomputer can scale from a single cabinet to hundreds of cabinets—ranging up to tens of thousands of processors. Red Storm has a peak performance of 124.42 teraFLOPS.

(Courtesy Sandia National Laboratories)

Advanced Simulation and Computing

PROGRAM PLAN FY07/08

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Executive Summary

The Stockpile Stewardship Program (SSP) is a single, highly integrated technical program for maintaining the safety and reliability of the U.S. nuclear stockpile. The SSP uses past nuclear test data along with current and future nonnuclear test data, computational modeling and simulation, and experimental facilities to advance understanding of nuclear weapons and to resolve urgent problems of national interest related to the stockpile. The results of stockpile surveillance and experimental research, combined with modeling and simulation to meet stockpile requirements, support the development of engineering programs and an appropriately scaled production capability. This integrated national program will require the continued use of some current facilities and programs along with new experimental facilities and computational enhancements to achieve its goal.

The Advanced Simulation and Computing (ASC)[1] Program is a cornerstone of the SSP. It provides simulation capabilities and computational resources to (a) support the annual stockpile assessment and certification, (b) study advanced nuclear-weapons design and manufacturing processes, (c) analyze accident scenarios and weapons aging, and (d) support Stockpile Life Extension Programs (SLEPs) and the resolution of Significant Finding Investigations (SFIs). This requires a balanced program, including technical staff, hardware, simulation software, and computer science solutions.

In its first decade, the ASC strategy focused on developing and demonstrating simulation capabilities of unprecedented scale in three spatial dimensions. Now in its second decade, ASC is focused on increasing its predictive capabilities in a three-dimensional simulation environment for the SSP. The program continues to improve its unique tools for solving progressively more difficult stockpile problems (focused on sufficient resolution, dimensionality, and scientific details); to quantify critical margins and uncertainties (QMU); and to resolve increasingly difficult analyses needed for the SSP. ASC platforms such as BlueGene/L, Red Storm, and Purple continue to support the SSP. Moreover, ASC has restructured its business model from one that was very successful in delivering an initial capability to one that is integrated and focused on requirements-driven products that provide predictive capability in the simulation tools.

This Program Plan describes the ASC strategy and deliverables for the FY 2007–FY 2010 planning horizon; defines program goals; describes the national work breakdown structure; and details the subprograms, strategies, and associated performance indicators. The plan also includes ASC's proposed Level 1 milestones and the top ten risks. To ensure synchronization with SSP needs, the Program Plan will be reviewed and updated annually.

[1] In FY02 the Advanced Simulation and Computing (ASC) Program evolved from the Accelerated Strategic Computing Initiative (ASCI).

I. Introduction

An unprecedented level of computational capability was needed to serve as the integrating force to make effective use of the collective scientific understanding.

On October 2, 1992, a moratorium on U.S. nuclear testing was established. This decision ushered in a new era by which the U.S. ensures confidence in the safety, performance, and reliability of its nuclear stockpile by means other than nuclear testing. The U.S. also decided to halt new nuclear weapons production. This decision meant that the nation's stockpile of nuclear weapons would need to be maintained far beyond its original design lifetime. To implement these pivotal policy decisions, the Stockpile Stewardship Program (SSP) was established. The goal of this program is to provide scientists and engineers with the technical capabilities to maintain a credible nuclear deterrent without the use of the two key tools used to do that job over the past 50 years: (1) underground nuclear testing and (2) modernization through development of new weapon systems. The National Nuclear Security Administration (NNSA) was established to carry out these national security responsibilities. To meet this challenge, a new set of above-ground, non-nuclear experimental capabilities was required, environmentally benign fabrication capabilities were needed, and archived data from decades of nuclear tests had to be made available to weapon scientists and engineers. An unprecedented level of computational capability was needed to serve as the integrating force to make effective use of the collective scientific understanding. This reality meant that a new and powerful role for modeling and simulation was required. The Advanced Simulation and Computing Program (formerly known as the Accelerated Strategic Computing Initiative, or ASCI) was established to create this capability.

To realize its vision, ASC is creating simulation capabilities using advanced weapon codes and high-performance computing that incorporate more complete scientific models based on experimental results from the Campaigns, past tests, and theory.

Realizing the Vision—Established in 1995 as a critical element of the SSP, ASC is developing the computational capabilities to allow a smooth transition from nuclear test-based certification to science- and simulation-based certification. ASC is a focused and balanced program that is accelerating the development of simulation capabilities needed to analyze and predict the performance, safety, and reliability of nuclear weapons and certify their functionality—far exceeding what might have been achieved in the absence of a focused initiative. To realize its vision, ASC is creating simulation capabilities using advanced weapon codes and high-performance computing that incorporate more complete scientific models based on experimental results from the Campaigns, past tests, and theory. The expected outcomes will be predictive simulations that enable assessment and certification of the safety, performance, and reliability of nuclear weapon systems. These simulation capabilities will also help scientists understand weapons aging, predict when components will have to be replaced, and evaluate the implications of changes in materials and fabrication processes to the design life of the aging weapon systems. This science-based understanding is essential to ensure that changes brought about through aging or remanufacturing will not adversely affect the enduring stockpile.

The Future of the Nuclear Weapons Complex—The Complex today is at a crossroads: on the one hand, its nuclear weapons stockpile stewardship mission, while an enduring one, will be diminishing; on the other hand, threats to national security have evolved from relatively well-defined scenarios to unpredictable, possibly non-centralized sources scattered around the globe with no well-defined national boundary. Today's Complex needs to be able to meet current stockpile stewardship requirements and respond to new national security needs. In this spirit, the NNSA has embarked on a Complex transformation process that will make the post-cold war Complex more nimble and agile to respond to possible surprises. This transformation will reduce the footprint of the Complex, consolidate capabilities, eliminate redundancies that the country can no longer afford, and reduce reliance on hazardous materials.

The NNSA has embarked on a Complex transformation process that will make the post-cold war Complex more nimble and agile to respond to possible surprises.

For this transformation, it is not unreasonable for each office in Defense Programs (DP), including ASC, to ask itself: what are the *core competencies* at each laboratory that are essential to the Stockpile Stewardship mission? What are the *redundancies* that do not add value? What *new capabilities* will the laboratories need to develop to support the stockpile stewardship mission and respond to future changes? What *intellectual capital* will need to reside at the laboratories so that the Complex sustains its ability to carry out its evolving mission?

ASC Driver: Predictive Capability—As the last of the weapons designers, physicists, and engineers with actual underground nuclear testing experience retire, NNSA needs to move from depending on a mostly "expert judgment" based certification process to more reliance on a science-based methodology that will allow defensible stockpile decisions to be made without returning to underground nuclear testing. Recently, "Quantification of Margins and Uncertainties (QMU)" has become the methodology employed by DP for nuclear weapons assessment. In QMU, "margins" and "uncertainties" need to be quantified based on a scientific understanding of the stockpile system. The Complex plans to take an integrated approach that combines the use of experimental tools, analytical and numerical models, integrated codes, and high-performance computing tools, to develop an increasingly mature *predictive capability* that will form the basis for the QMU methodology. Simulation science is at center stage of this predictive capability.

The ASC Program is charged to provide, for the Complex, capacity and capability computing power, software and integrated multi-scale, multi-physics codes that run on these platforms, development and implementation of detailed physics and engineering models, and verification and validation of simulation tools.

Before the advent of ASC, predictive capability was out of reach. The pre-ASC computing power only allowed for what would be considered coarse-mesh weapons physics and engineering simulations by today's standards. Arbitrary parameters, or *knobs*, were used in lieu of detailed physics modeling. Slow processors, small memory, and poor communication bandwidth were some of the obstacles faced by the computational scientists. The lack of computing power also meant that resources could not be spent on verification and validation; subjective judgments were made in the determination of the correctness of the simulations.

The ASC Program is charged to provide, for the Complex, capacity and capability computing power, software and integrated multi-scale, multi-physics codes that run on these platforms, development and implementation of detailed physics and engineering models, and verification and validation of simulation tools. In the last ten years, ASC has fostered innovations and provided leadership-class computing power to the nuclear weapons simulations community, enabling the scientists and engineers to finally begin to explore long-standing physics, engineering, and algorithmic issues and bring scientific rigor to simulation science. It is in this modern environment that one can finally consider the possibility of removing historical knobs and replacing *ad hoc* models with those grounded in physical reality.

Major ASC Objectives—The program has at its core the following overarching mission, vision, and goal to meet the science and simulation requirements and drivers of the SSP.

Mission: Provide leading-edge, high-end simulation capabilities needed to meet weapons assessment and certification requirements.

Vision: Predict, with confidence, the behavior of nuclear weapons, through comprehensive, science-based simulations.

Goal: Deliver accurate simulation and modeling tools, supported by necessary computing resources, to maintain nuclear deterrence.

Development and implementation of comprehensive methods and tools for certification, including simulations, are top DP priorities that will meet the SSP vision of an integrated nuclear security enterprise consisting of *"research and development (R&D), tests and production facilities that operates a responsive, efficient, secure, and safe, nuclear weapons complex and that is recognized as preeminent in personnel, technical leadership, planning, and program management."*[2]

To ensure its ability to respond to stockpile needs and deliver accurate simulation and modeling tools, ASC's strategic goals for the next ten years are focused on:[3]

- Improving the confidence in prediction through simulations;
- Integrating the ASC Program with certification methodologies;
- Developing the ability to quantify uncertainty and confidence bounds for simulation results;
- Increasing predictive capability through tighter integration of simulation and experimental activities;
- Providing the necessary computing capability to code users, in collaboration with industrial partners, academia, and government agencies.

The products of ASC serve as the integrators for all aspects of the nuclear weapons enterprise, from assisting the manufacturing plants to the full stockpile life cycle. The ASC tools also provide capabilities for studies and assessments of crude terrorist devices and their effects in Homeland Security applications or advanced weapon concepts that could respond to any new strategic threat.

Strategy—For the next decade, ASC has adopted a new strategy that emphasizes providing a science basis for *ad hoc* phenomenological models in the weapons simulation codes and a deeper understanding, in quantitative terms, of their predictive capabilities and uncertainties in order to enable risk-informed decisions about the performance, safety, and reliability of the stockpile.

The ASC Program and the other science campaigns will be integrated with structured certification methodologies, including as an inherent element the ability to assess and quantify the confidence in the use of ASC tools for making predictions and informed stockpile-related decisions. Developing the tools to address new concepts and options is another goal that leads to this new strategy, guiding the transition from a successful initiative toward a more powerful and demonstrably predictive capability.

The ASC strategy has, and will continue to have, both short- and long-term components. These elements are not separable, but complementary and interdependent. The goal of the short-term component is to meet the continuing and time-constrained needs of stockpile stewardship, in particular, Significant Finding Investigations (SFIs) and stockpile life-extension activities. Addressing these needs as the properties of the materials and devices in the stockpile change will force a transition to the modern codes with their increased dimensionality and enhanced modeling capabilities. The fidelity and performance of these codes will continue to be improved so that they become increasingly responsive to any potential stockpile problems that might be uncovered in the surveillance process.

[2]Source: DP Program Planning and Resource Call Guidance

[3]Source: *ASC Strategy*, NA-ASC-100R-04-Vol.1-Rev.0, August 2004

The long-term component of the strategy is to ensure movement toward science-based, predictive capability that will enhance confidence in the simulation results. It has been understood since the inception of computing in the weapons program that codes cannot be built and then accepted "on faith." To ensure that they are grounded in physical reality and provide a foundation for scientifically based decisions, the representation of weapons behavior must be supported by an increased focus on both verification and validation. As new models are incorporated into the codes, they can be rigorously tested against appropriate experiments to validate that they conform to physical reality. This strategy emphasizes a strengthened program of validation and peer review to quantify and then expand the parameter space currently spanned by older codes.

The success of ASC was demonstrated through a series of pioneering proof-of-principle milestone calculations. A brief list of accomplishments and future contributions to the Complex is given below.

ASC Contributions to the SSP

- **In FY 1996,** ASCI Red was delivered. Red, the world's first teraFLOPS supercomputer, has since been upgraded to more than 3 teraFLOPS.
- **In FY 1998,** ASCI Blue Pacific and ASCI Blue Mountain were delivered. These platforms were the first 3-teraFLOPS systems in the world.
- **In FY 2000,** ASCI successfully demonstrated the first-ever three-dimensional (3-D) simulation of a nuclear weapon primary explosion and the visualization capability to analyze the results; ASCI successfully demonstrated the first-ever 3-D hostile-environment simulation; and ASCI accepted delivery of ASCI White, a 12.3-teraFLOPS supercomputer.
- **In FY 2001,** ASCI successfully demonstrated simulation of a 3-D nuclear weapon secondary explosion; ASCI delivered a fully functional problem solving environment for ASCI White; ASCI demonstrated high-bandwidth distance computing among the three national laboratories; and ASCI demonstrated the initial validation methodology for early primary behavior. Lastly, ASCI completed the 3-D analysis for a stockpile-to-target sequence (STS) for normal environments.
- **In FY 2002,** ASCI demonstrated 3-D system simulation of a full-system (primary and secondary) thermonuclear weapon explosion, and ASCI completed the 3-D analysis for an STS abnormal-environment crash-and-burn accident involving a nuclear weapon.
- **In FY 2003,** ASC delivered a nuclear safety simulation of a complex, abnormal, explosive initiation scenario; ASCI demonstrated the capability of computing electrical responses of a weapons system in a hostile (nuclear) environment;[4] and ASCI delivered an operational 20-teraFLOPS platform on the ASCI Q machine.
- **In FY 2004,** ASC provided simulation codes with focused model validation to support the annual certification of the stockpile life-extension refurbishments, including W88 pit certification.
- **In FY 2005,** ASC documented SSP requirements to move beyond a 100-teraFLOPS computing platform to a petaFLOPS-class system and delivered a metallurgical structural model for aging to support pit-lifetime estimations.
- **By FY 2006,** ASC delivered the capability to perform nuclear performance simulations and engineering simulations related to the W76/W80 Life Extension Programs (LEPs) to assess performance over relevant operational ranges, with assessments of uncertainty levels for selected sets of simulations.
- **By FY 2007,** ASC supported the completion of the W76-1 and W88 warhead certification, using quantified design margins and uncertainties; ASC also provided two robust 100-teraFLOPS-platform production environments by IBM and CRAY, supporting DSW and Campaign simulation requirements, respectively. One of the original ASCI Program Level 1 milestones was completed when the ASC Purple system was formally declared "general available." This was augmented by the 360-teraFLOPS ASC BlueGene/L system, which provided additional capability for science campaigns.
- **By FY 2008,** ASC will deliver the codes for experiment and diagnostic design to support the CD-4 approval on the National Ignition Facility (NIF). An advanced architecture platform capable of sustaining a 1-petaFLOPS benchmark will be sited at LANL.

[4]Level 1 milestone (NN-3.1), "Stockpile-to-target sequence hostile environment simulation for cable SGEMP and electrical response to x-rays."

ASC Level 1 Milestones—ASC will deliver its next major contributions to the Complex in the form of a proposed set of eight Level 1 milestones. Level 1 milestones track ASC's progress toward accomplishing its strategic goals, meeting its performance measures, and providing the predictive capabilities and computing power necessary to meet SSP's needs and to facilitate the transition toward Complex transformation. Table 1 identifies ASC's interfaces with other DP components needed to accomplish its Level 1 milestones. Appendix A lists all Defense Programs, NA-10 Level 1 milestones, including those of ASC, which must be accomplished to meet the SSP mission.

Table 1. ASC Level 1 Proposed Milestones and Interfaces with DP Components Ending from FYs 2009–2020

ASC Milestone # and Title	Responsibility	End Date	Program Stakeholders
1. Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of the initial conditions for secondary performance.	HQ, LLNL, LANL	FY09 Q4	C11, C4
2. Develop, implement, and validate a suite of physics-based models and high-fidelity databases in support of Full Operational Capability in DTRA's National Technical Nuclear Forensics program.	HQ, LLNL, LANL	FY09 Q4	C11, C1, C4, NA-22, DTRA
3. Baseline demonstration of UQ aggregation methodology for full-system weapon performance prediction.	HQ, LLNL, LANL, SNL	FY10 Q4	C11, C1, C4, DSW
4. Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of the initial conditions for primary boost.	HQ, LLNL, LANL	FY12 Q4	C11, C1, C2
5. Capabilities for SFI response improvements.	HQ, LLNL, LANL, SNL	FY13 Q4	C11, DSW
6. Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of primary boost.	HQ, LLNL, LANL	FY15 Q4	C11, C1, C2, C10
7. Develop predictive capability for full-system integrated weapon safety and surety assessment.	HQ, LLNL, LANL, SNL	FY16 Q4	C11, C1, C2, DSW
8. Develop, implement, and apply a suite of physics-based models and high fidelity databases to enable predictive simulation of secondary performance.	HQ, LLNL, LANL	FY20 Q4	C11, C4, C2, C10

Proposed Milestone Descriptions

1. Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of the initial conditions for secondary performance. This milestone is directed toward establishing an initial validated suite of physics-based models for the physical processes that underpin the initial conditions for secondary performance. It will comprise advanced material constitutive property models, enhanced radiation transport capabilities, and improved physical databases for relevant materials and processes and other models required to replace existing *ad hoc* models.

2. Develop, implement, and validate a suite of physics-based models and high-fidelity databases in support of Full Operational Capability in DTRA's National Technical Nuclear Forensics program. This milestone will support the identified needs for physics models, algorithms, and nuclear data to meet the needs of Full Operational Capability (FOC) for DTRA's National Technical Nuclear Forensics program. This milestone also supports nuclear counterterrorism efforts and foreign device assessment based on radiochemical debris. These efforts leverage capabilities developed for our DSW stockpile mission, but expand the code capabilities into new physics regimes that have not been critical to DSW.

3. Baseline demonstration of UQ aggregation methodology for full-system weapon performance prediction. Effort on this milestone builds on identification of major sources of uncertainty; first full-system demonstration of uncertainty aggregation methodology; provides baseline for assessing reductions in uncertainty (improvements in confidence); exercises "Initial" maturity level for predictive capabilities; supports ASC methodology for QMU and identification of major simulation uncertainties.

4. Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of the initial conditions for primary boost. This milestone is directed toward establishing an initial validated suite of physics-based models for the physical processes that underpin the initial conditions for primary boost. It will comprise advanced equations of state, material constitutive property models, nuclear cross-section databases, and other models required to replace existing *ad hoc* models.

5. Capabilities for SFI response improvements. Deliver nuclear safety/performance and weapons engineering analysis codes for highly responsive execution of simulations for SFI resolution. The codes will incorporate advances in predictive capability achieved in the FY2009 to FY2012 time frame and will be supported by optimized setup/analysis tools and responsive computing resources and environment. This capability will be demonstrated in simulations needed to resolve current SFIs in FY2011 to FY2012, depending on their nature, or classes of simulations used in resolving previous SFIs or anticipated SFIs. Demonstration simulations are likely to include nuclear safety/surety and engineering analyses of a stockpile system with perturbed geometry or material properties, or under unusual postulated environmental conditions. Enhanced responsiveness will be demonstrated through a combination of improved fidelity and faster setup-to-solution turnaround compared with previous generation simulation capabilities.

6. Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of primary boost. This milestone is directed toward establishing an initial validated suite of physics-based models for the physical processes that underpin primary boost. It will comprise advanced equations-of-state, plasma property models, nuclear cross-section databases, and other models required to replace existing *ad hoc* models.

7. Develop predictive capability for full-system integrated weapon safety and surety assessment. This will include combined environment accident scenario of impact followed by fire; self-consistent and integrated modeling of all critical weapon component responses and interactions; failure time calculated for weapon system critical inadvertent nuclear detonation (IND) safety components; predictions of time margin and associated UQ for IND avoidance; UQ of main charge response predictions modeled concurrently with IND analysis; exercise of "Extrapolation" maturity level for predictive capabilities; support of the capability to certify safety and surety of un-fielded weapon.

8. Develop, implement, and apply a suite of physics-based models and high-fidelity databases to enable predictive simulation of secondary performance. This milestone is directed toward establishing an initial validated suite of physics-based models for the physical processes that underpin secondary performance. It will comprise advanced equations-of-state, opacity models, nuclear cross-section databases, and other models required to replace existing *ad hoc* models. This supports the establishment of a predictive capability for key physical phenomena.

II. ASC Program Structure

In response to the drivers and to achieve its objectives, ASC is comprised of five major sub-programs, each with its individual strategies. As the program has matured, the original program elements have been restructured to reflect the changes in the challenges we face. The result is the following list of integrated sub-programs:[5]

- Integrated Codes
- Physics and Engineering Models
- Verification and Validation (V&V)
- Computational Systems and Software Environment
- Facility Operations and User Support.

Below is a brief description of these sub-programs, their respective strategies, and performance indicators.

Integrated Codes (IC)

This sub-program produces the weapons simulation codes, particularly the new weapons codes created over the last decade; has responsibility for the engineering codes, emerging codes, and specialized codes, and maintains selected legacy codes. It also fosters interactions with the larger scientific and academic community. Codes produced by this sub-program are used by all elements of the SSP. It is these codes that serve as the integrating elements of the ASC Program, incorporating the products of the ASC Physics and Engineering Models sub-program, and serving as the objects to be examined and assessed in the ASC Verification and Validation (V&V) sub-program and as essential tools for implementing QMU methods. The IC sub-program sets requirements for, and serves as, the principal consumer of products from the Computational Systems and Software Environment and the Facility Operations and User Support sub-programs.

The enhanced predictive capability envisioned in the 10-year *ASC Strategy* will be accomplished through advances realized in these codes. The tangible steps and "stretch"[6] goals enumerated in the *ASC Roadmap*,[7] which "defines a path that focuses on the NNSA investment in modeling and simulation for stockpile stewardship and related national security missions," will reach fruition in these codes. These codes are the tools for supporting the stockpile and the transformation of the Complex.

The DSW program element is an immediate customer of the IC sub-program, using the codes directly for the full range of stockpile assessment and certification objectives. In turn, DSW requirements drive near-term code activities and longer-term development of new capabilities. The National Ignition Campaign uses the codes on ASC computing resources to meet mission goals, including National Ignition Facility (NIF). The Science and Engineering Campaigns are both customers and suppliers for the IC sub-program, as they use these codes to design and analyze stockpile-relevant experiments, to advance fundamental understanding of weapons physics and engineering, and then to provide scientific discovery, physical data, and certification methodologies that are used to improve the codes and guide their use.

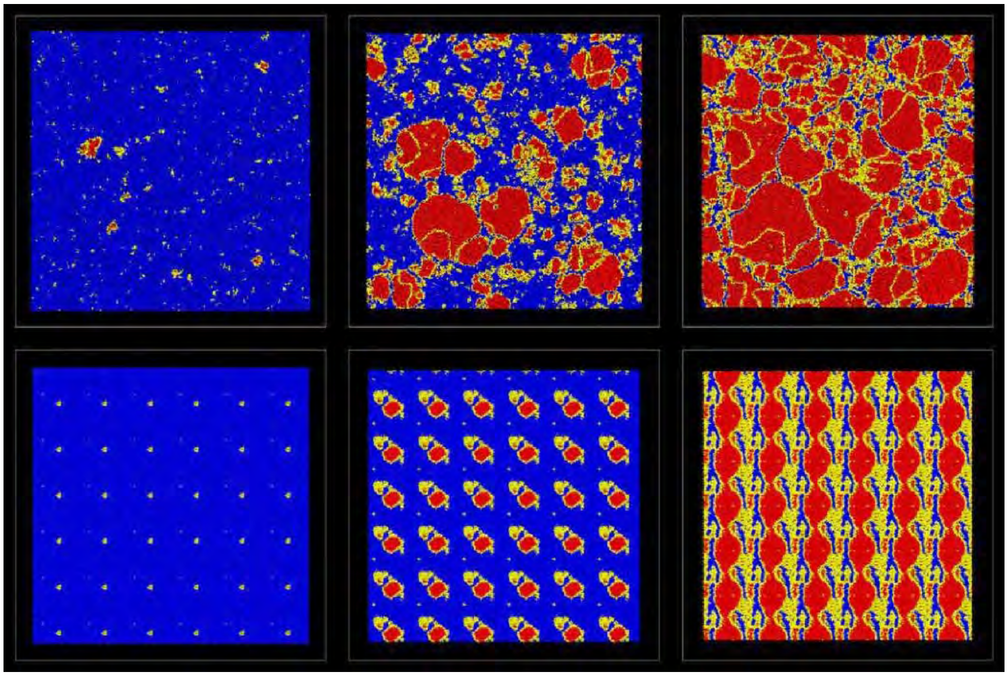
The IC sub-program has five major product areas. A prominent one is the set of **Modern Multi-Physics Codes**, which are the newest, most capable simulation tools for simulations of all aspects of nuclear weapon safety, performance, and reliability. These codes provide advanced capability for the stockpile stewardship mission and continue to undergo concerted development for this role. While the multi-physics codes are

[5]*The ASC Business Model* (NA-ASC-104R-05-Vol.1-Rev.0, July 2005) contains detailed descriptions of each sub-program element.

[6]The goals are designed to inspire longer term innovations aimed at making challenging, or "stretch," outcomes achievable at some future time.

[7]*The ASC Roadmap*, NA-ASC-105R-6-Vol.1-Rev. 0

1. Cross sections of simulations using (top row) 16 million atoms and (bottom row) 64,000 atoms taken at equivalent times during solidification.



rapidly superseding previous generation codes, the second product area, **Legacy Codes**, is also important. A selection of legacy codes must still be maintained during this transition to the newer codes, since some legacy codes still have unique capabilities. Legacy codes also serve as references for verifying the new codes and for providing residual links back to the era of nuclear testing. **Engineering Codes** are the third product area of this sub-program, providing comparable advanced simulation capability for addressing the most challenging engineering-related stockpile issues.

This sub-program also includes two other supporting products areas. One is **Focused Research, Innovation, and Collaboration**, which targets needed future technologies, algorithms, and computational methods, and draws from expertise at the laboratories and in the larger scientific and academic community. Interactions with the academic community include university contracts and activities such as the ASC Alliances and Computational Science Graduate Fellowships that encourage laboratory-university collaboration. The other supporting product area is **Emerging and Specialized Codes**, which provides developmental products built on promising, emerging technologies. It also provides specialty codes that simulate complex processes in unique environments or provide unique capabilities closely tied to user applications for problem setup and analysis.

IC has the following high-level goals:

- A national code strategy;
- Modular physics and engineering packages for national weapons codes;
- A tested capability to address emerging threats, effects, and attribution;
- Measurable improvement in setup-to-solution time for SFI simulations;
- Full-system engineering and physics simulation capability.

Associated strategic steps include:

- Releasing improved versions of modern multi-physics codes and supporting the users who apply these codes to stockpile issues, implement models to meet user requirements, and enhancing the codes for increased predictive capability;

- Maintaining ability to run selected legacy codes using legacy input files to serve as a reference for modern multi-physics and engineering codes;
- Releasing improved versions of engineering codes and supporting the users who apply these codes to stockpile issues, implementing models to meet user requirements, and enhancing the codes for increased predictive capability and applications breadth;
- Researching, developing, and maintaining algorithmic capabilities for codes and leverage advances of the external scientific community for programmatic code activities;
- Delivering capabilities and prototype applications for classes of experiments or phenomena requiring specialized physics and engineering models. Implementing promising approaches in special-purpose codes for development and evaluation for broader use in integrated codes.

Associated Performance Measures include:

- Adoption of ASC Codes: The cumulative percentage of simulation runs that utilize modern ASC-developed codes on ASC computing platforms, as measured against the total of legacy and ASC codes used for stockpile stewardship activities.
- Reduced Reliance on Calibration: The cumulative percentage reduction in the use of calibration "knobs" to successfully simulate nuclear weapons performance.
- ASC Impact on SFI Closure: The cumulative percentage of nuclear weapon SFIs resolved through the use of modern (non-legacy) ASC codes, measured against all codes used for SFI resolution.

Physics and Engineering Models (PEM)

This sub-program develops microscopic and macroscopic models of physics and material properties, as well as improved numerical approximations to the simulation of transport for particles and x-rays and other critical phenomena. PEM also develops special-purpose physics codes required to investigate specific physical phenomena in detail and, in some cases, to provide numerical data (e.g., from direct numerical simulation) for model validation. Finally, this sub-program is responsible for the development, the initial validation, and the incorporation of new models into the IC; therefore, it is essential that both sub-programs be interdependent.

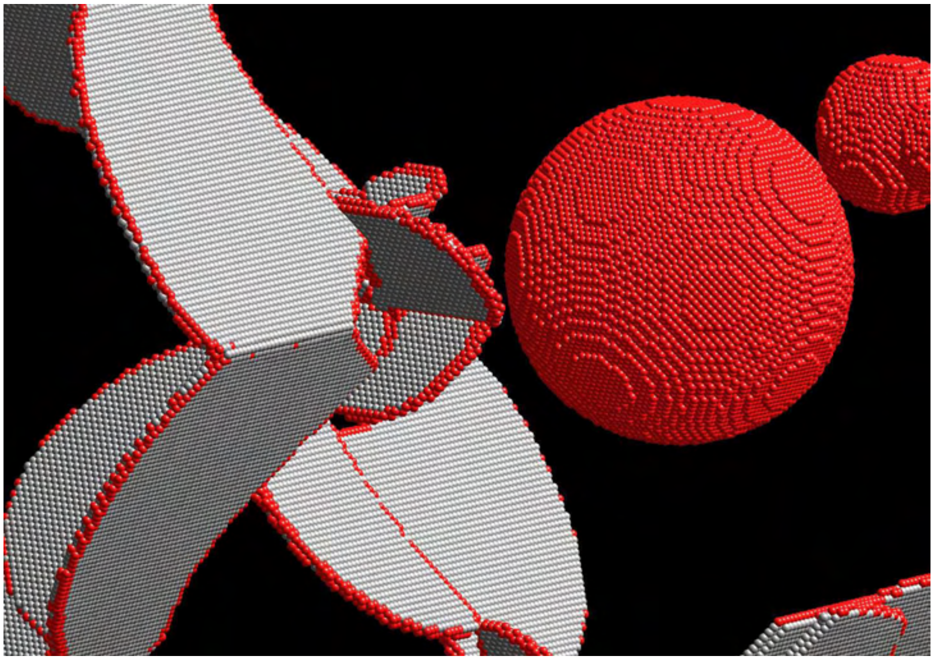
There is also extensive integration between the model development program and the SSP experimental programs executed by the Science Campaigns, such as Dynamic Materials Properties, the ICF Campaign, and the Engineering Campaign. Functional requirements for this sub-program are established by assessment of known uncertainties and prioritized via a QMU analysis.

The PEM sub-program has the following high-level goals:

- Development of special-purpose physics codes and direct numerical simulation capabilities to investigate complex physical phenomena including plutonium aging;
- Science-based replacements for "knobs" (*ad hoc* models) in performance codes;
- Implementation of models to support simulations required for design and assessment activities, including SFI resolution;
- Science-based models for neutron tube simulations.

Associated strategic steps include:

- Developing and implementing validated models for use in the ASC simulation codes;
- Developing fundamental understanding of underlying physical phenomena to support development of high-fidelity models;



2. Dynamic void collapse in single crystal copper by dislocation emission. Shown is a small section of a 2.13-billion atom molecular dynamics simulation of a shock-compressed copper single crystal with a 0.41% preexisting void density. The simulation was performed using the SPaSM application running on BlueGene/L. Atoms in pristine fcc lattice sites are not shown, atoms in hcp stacking faults are grey, and other atoms (including surfaces and dislocation cores) are red. Untouched voids ahead of the shock front are visible in the upper right, while the complete collapse of voids leads to an array of planar stacking faults (gray) bounded by partial dislocation loops (red) behind the shock front.

- Developing and deploying improved material data libraries (equation of state, nuclear data, opacities, etc.) and demonstrated improvement in ASC simulations utilizing these libraries.

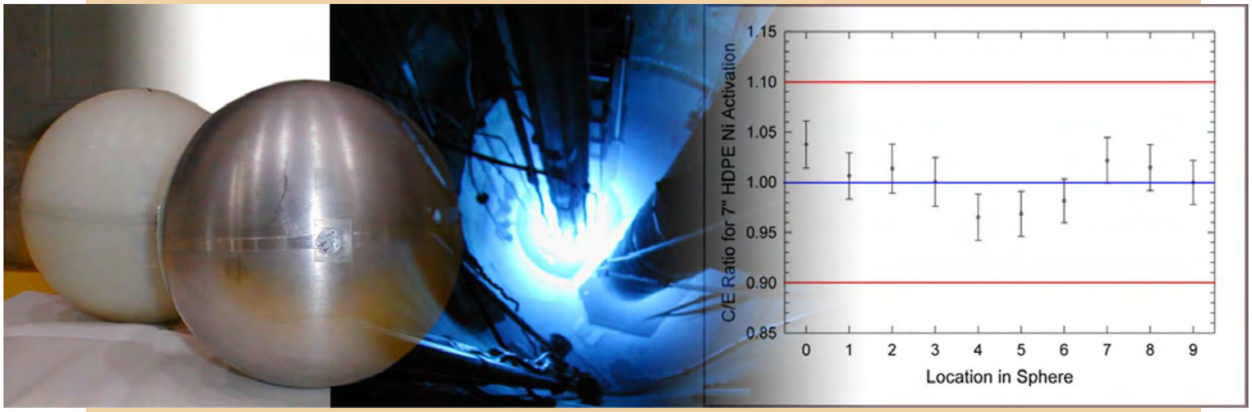
Associated performance measures include:

- ASC Modern Codes: The cumulative percentage of simulation runs that utilize modern ASC-developed codes on ASC computing platforms, as measured against the total of legacy and ASC codes used for stockpile stewardship activities.
- Reduced Reliance on Calibration: The cumulative percentage reduction in the use of calibration "knobs" to successfully simulate nuclear weapons performance.
- ASC Impact of SFI Closure: The cumulative percentage of nuclear weapon SFIs resolved through the use of modern (non-legacy) ASC codes, measured against all codes used for SFI resolution.

Verification and Validation (V&V)

This sub-program element provides a scientifically based measure of confidence in simulation capabilities used for the resolution of high-consequence nuclear stockpile problems. V&V, as a multidisciplinary process, provides a technically rigorous foundation of credibility for computational science and engineering calculations by developing and implementing tools for accessing numerical approximations of physical models, demonstrating model capabilities in various operational and functional regimes, assigning and quantifying uncertainties, and documenting the pedigree of the simulation tools.

As the NWC bases more of its high-consequence nuclear stockpile decisions on simulations, it is imperative that the simulation tools possess demonstrated credibility. Verification activities focus on demonstrating that the weapons codes are solving the equations correctly. These may include development of a Verification Suite, a set of tests for which all codes must demonstrate correct convergent behavior, and verification methods development, where new procedures such as solution verification are developed and studied to assess their utility in verifying a code. Validation activities ensure that the weapons codes are solving the correct equations; that is, the *physics and engineering models* are correct. These may include examining sub-components of the codes to make comparisons to above-ground experiment



3. Various test items are used to validate the calculated radiation environment in reactor test environments. The center image shows the Annular Core Research Reactor (ACRR) at Sandia with the central cavity. The left shows test spheres that contain many internal sensors and are used for validation purposes. The right figure shows the calculated-to-measured agreement for the sensors as a function of their radial position within an aluminum test sphere. The red bounding lines indicate the RAMSES/NuGET acceptance metric, the central blue line indicates the position corresponding to complete agreement, while the ratios for the C/E values are given with associated uncertainty.

(AGEX) data, examining integral calculations to make comparisons to underground test (UGT) data, exploring the regime-of-applicability for specific models, and the development of a Validation Suite against which a code must demonstrate the degree to which a simulation with the code can match available data, with quantified results and error estimates.

In addition to verification and validation, the uncertainty in the simulation output must be quantified. Given that typical nuclear weapons simulations employ numerous fundamental databases, material models, physics models, and numerical algorithms to simulate the wide range of physical phenomena under extreme conditions, the predictions from weapons codes output must be understood in the context of all the uncertainties in these databases and in the various physics and numerical approximations. V&V is developing UQ procedures as a part of the foundation to the QMU methodology of weapons certification. V&V also strives to set the standard for documentation and drive advances in numerical and physics modeling.

The program goal is to deliver a coherent set of assessments and tools necessary to support the risk-informed decision of maintaining the safety and reliability of the U.S. nuclear stockpile:

- Documented assessment of simulation and assurance of quality of ASC software tools;
- Uncertainty quantification analysis methods and tools;
- Measurable progress toward predictive capability.

Associated strategic steps include, but are not limited to:

- Develop a tri-lab verification suite that provides wide coverage of multi-physics;
- Qualify physics models: evaluate/document the (respective) ranges of applicability for physics models and their implementations, reconcile if necessary;
- Identify major contributors of epistemic uncertainties and devise plans to reduce these uncertainties;
- Identify meaningful metrics that form the basis for experiment-simulation comparisons; demonstrate how a suite of metrics may allow analysts and designers to estimate the modeling uncertainties;

- Continue ongoing sensitivity studies to identify and rank parameters; continue knob-removal activities;
- Continue cooperative and collaborative development of tri-lab validation suites.

Associated performance measures include:

- ASC Modern Codes: The cumulative percentage of simulation runs that utilize modern ASC-developed codes on ASC computing platforms, as measured against the total of legacy and ASC codes used for stockpile stewardship activities.
- Reduced Reliance on Calibration: The cumulative percentage reduction in the use of calibration "knobs" to successfully simulate nuclear weapons performance.
- ASC Impact on SFI Closure: The cumulative percentage of nuclear weapon SFIs resolved through the use of modern (non-legacy) ASC codes, measured against all codes used for SFI resolution.

Computational Systems and Software Environment (CSSE)

This sub-program builds integrated, balanced, and scalable computational capabilities to meet the predictive simulation requirements of NNSA. It strives to provide users of ASC computing resources a stable and seamless computing environment for all ASC-deployed platforms, which include capability, capacity, and advanced systems. The Complex and diverse demands of the ASC performance and analysis codes and the scale of the required simulations require ASC to be far in advance of the mainstream high-performance computing community. To achieve its predictive capability goals, ASC must continue to invest in and consequently influence the evolution of computational environments. This will require radical innovation tempered by the understanding that computing environments must be reliable and should not require applications to be substantially rewritten or reinvented without realizing significant returns. In other words, CSSE must provide the stability that ensures productive system use and protects the large ASC investment in its simulation codes.

A balanced and stable computational infrastructure is essential for delivering the required computing capabilities to its customers. Along with the powerful capability, capacity, and advanced systems that ASC will field, the supporting software infrastructure that CSSE is responsible for deploying on these platforms includes many critical components, from system software and tools, to Input/Output (I/O), storage and networking, to pre- and post-processing visualization and data analysis tools. Achieving this deployment objective requires sustained investment in applied research and development activities to create technologies that address ASC's unique mission-driven need for scalability, parallelism, performance, and reliability.

In the next decade, both the enhancement of future predictive capabilities and the achievement of DSW simulation deliverables will demand ever more powerful and sophisticated simulation environments. CSSE will meet these requirements by providing mission-responsive computational environments for UQ analyses, weapons science studies, and enhanced predictive capability. The immediate focus areas include moving toward a more standard user environment and improving its usability, deploying more capacity computing platforms, planning for and developing petascale computing capability, and making overall strategic investments so that ASC can continue to meet the requirements of the program at an acceptable cost. CSSE's longer-term efforts in applied research and development will support the *ASC Roadmap*, which documents computing requirements at exascale levels of performance.

Associated strategic steps include but are not limited to:

- Providing users a stable, secure, integrated tri-lab computing environment for all classified ASC computing resources;
- Investing in development of production hardware and software systems capable of running the largest simulations addressing NNSA requirements;

4. During his visit to Sandia on February 17, 2006, former NNSA Administrator Linton Brooks discussed unique capabilities of Sandia's Red Storm supercomputer. In two of six key benchmark tests, Red Storm measured as the fastest computer in the world. Behind Brooks is a visualization created by Red Storm of how a specific fire event might affect a weapon.

- Developing and implementing problem setup, data management, data analysis, and visualization tools to provide QMU-enabled comparisons of ASC simulation results with validation measurements;
- Developing and implementing a methodology to measure the effectiveness of the CSSE work to increase the productivity of the end-users;
- Establishing standards for measurements of RAS (reliability, accessibility, & serviceability) performance of ASC platforms, which might later be shared with and adopted by the High-Performance Computing (HPC) community at large;
- Actively promoting opportunities for standard open source software solutions on ASC systems at the same time while seeking to partner with industry;
- Collaborating with vendors and other government programs (e.g., DOE Office of Science, Defense Advanced Research Projects Agency [DARPA], HPCS, and National Security Agency [NSA]) with a new focus on Advanced Systems to support the path to exascale computing before 2020.

Associated performance measures include:

- The percentage of total usage by simulations that use 30% or more of the available processors on the General Availability capability platforms.
- The cumulative percentage increase of user productivity (ratio of improvements in problem setup, analysis time, and execution throughput), as measured by a Productivity Indicator (PI).
- ASC Modern Codes: The cumulative percentage of simulation runs that utilize modern ASC-developed codes on ASC computing platforms, as measured against the total of legacy and ASC codes used for stockpile stewardship activities.
- Code Efficiency: cumulative percentage of simulation turnaround time reduced while using modern ASC codes.

Facility Operations and User Support (FOUS)

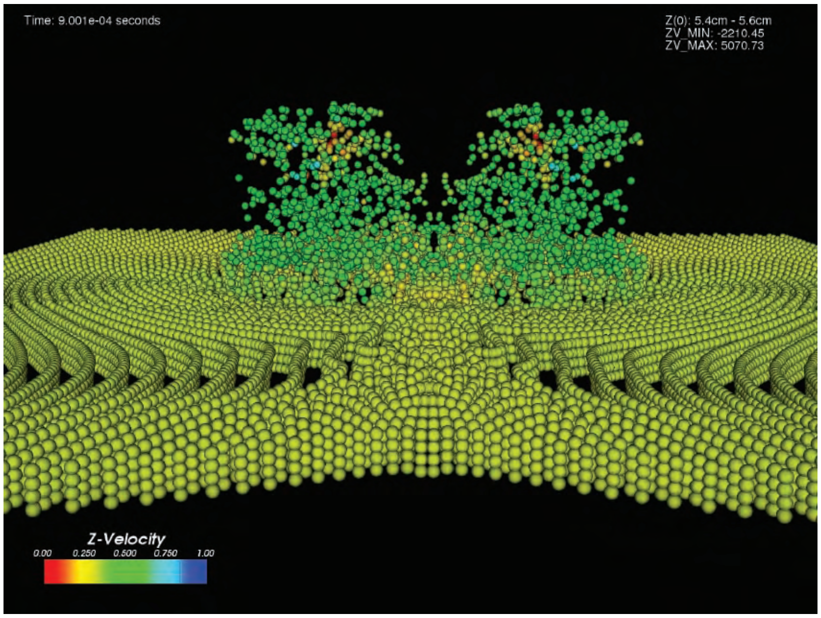
This sub-program provides both necessary physical facility and operational support for reliable production computing and storage environments as well as a suite of user services for effective use of ASC tri-lab computing resources. The designers, analysts, and code developers of the Complex provide functional and operational computational requirements for FOUS.

The scope of the facility operations includes planning, integration, and deployment; continuing product support; software license and maintenance fees; procurement of operational equipment and media; quality and reliability activities; and collaborations. Facility Operations also covers physical space, power and other utility infrastructure, and LAN/WAN networking for local and remote access, as well as requisite system administration, and cyber-security and operations services for ongoing support and addressing system problems. Industrial and academic collaborations are an important part of this sub-program.

The scope of the User Support function includes planning, development, integration and deployment, continuing product support, and quality and reliability activities collaborations. Projects and technologies include computer center hotline and help-desk services, account management, Web-based system documentation, system status information tools, user training, trouble-ticketing systems, and application analyst support.

Associated strategic steps include but are not limited to:

- Providing continuous and reliable operation and support of production computing systems and all required infrastructure to support these systems on a 24 hours a day, 7 days a week basis. The emphasis is on providing efficient production quality support of stable systems.
- Prioritizing capability computing resources under the ASC Capability System Governance Model.
- Ensuring that the physical plant has sufficient resources (such as space, power, cooling) to support future computing systems.
- Providing the authentication and authorization services used by applications for remote access and data movement across ASC sites.
- Developing and maintaining a wide area infrastructure (links and services) that enables distant users to operate on remote computing resources as if they were local (to the extent possible).
- Enabling remote access to ASC applications, data, and computing resources to support computational needs at the plants.
- Operating highly reliable, available, and secure laboratory ASC computers and supporting integration of new systems.
- Providing user services and help desks for laboratory ASC computers.



5. ASC has long-term strategic alliances with five U.S. universities, collaborations that are an important part of the FOUS sub-program. This image is from the University of Chicago's Center for Astrophysical Thermonuclear Flashes. It shows the evolution of a sample of tracer particles embedded in a vortex flow field created after the passage of a Mach 1.2 shockwave through a column of a high-density gas.

III. Integration

Continual collaboration among ASC, Campaigns, and DSW is a major strength of the SSP. Joint efforts in software development, code verification and validation, and tool-suite application are good examples of this collaboration.

Relationship of ASC to Directed Stockpile Work—The DSW Program conducts the surveillance, maintenance, refurbishment, and manufacturing activities for nuclear weapons in the stockpile. This program serves as the principal Defense Programs (DP) interface with the Department of Defense (DoD). DSW is responsible for activities that lead to the continuing assessment of the performance, safety, and reliability of aging nuclear weapons and the certification of weapons that are modified with refurbished components. ASC supports the DSW Program by providing advanced simulation and modeling capabilities and technologies that lead to high-confidence assessments and certification of the nuclear weapon stockpile consistent with the DSW refurbishment schedule and the discovery of surveillance findings.

Relationship of ASC to the Defense Science Programs (Campaigns)—The development of predictive capabilities relies on a strong experimental program to support the assessment of stockpile issues and to provide physics and materials data needed to validate new scientific models and theories incorporated into the simulation codes. Science and Engineering Campaigns provide crucial experimental data needed to support SSP activities. In the previous era of test-based confidence, experimental programs provided direct answers about the safety, security, and reliability of the stockpile. In the current era, the focus has shifted to a simulation-based confidence, which requires a close connection between ASC and the Science Campaigns. The Campaigns provide the understanding in science and the data for improving physics models needed to understand weapon performance. ASC provides the verified and validated codes, supercomputer platforms, and simulation environment that make it possible to simulate the operation and aging of U.S. weapon systems. Using facilities such as the National Ignition Facility at Lawrence Livermore, the Dual Axis Radiographic Hydrodynamic Testing (DARHT) Facility at Los Alamos, and the Microsystems and Engineering Sciences Applications (MESA) Facility at Sandia, the Science Campaigns produce significant quantities of high-quality physics data. Working together with the Science Campaigns, ASC simulation tools are employed in the design of experiments. These experimental programs provide ASC with the data necessary to validate (evaluate and improve) the physics models required to better characterize weapons performance and aging.

Relationship of ASC to the Department of Energy (DOE) Office of Science and other Government Agencies—Certain technical problems that arise in terascale computing are universal to scientific simulation and apply equally well to applications within the NNSA, DOE's Office of Science, and other government agencies such as the NSA, DoD, and DARPA. This includes I/O and archival management of large scientific data sets, the validation and debugging of large-scale parallel applications, the analysis and visualization of petabyte data sets, the operating systems for high-performance computing, and mathematical algorithms and software for solving complex problems.

While there are significant differences in the detailed nature of the scientific problems addressed, there is still much to be gained by exploiting the natural synergy between the high-performance computing goals and objectives of ASC and those of other such governmental programs. Accordingly, ASC is collaborating with these other agencies to identify areas of common interest and to establish appropriate coordination of efforts.

IV. Risk Management

Risk management is a process for identifying and analyzing risks, executing mitigation and contingency planning to minimize potential consequences of identified risks, and monitoring and communicating up-to-date information about risk issues. Risk management is about identifying opportunities and avoiding losses. A "risk" is defined as (1) a future event, action, or condition that might prevent the successful execution of strategies or achievement of technical or business objectives and (2) the risk-exposure level, defined by the likelihood or probability that an event, action, or condition will occur, and the consequences if that event, action, or condition does occur. Table 2 summarizes ASC's top ten risks, which are managed and tracked.

Table 2. ASC Top 10 Risks

No.	Risk Description	Risk Assessment			Mitigation Approach
		Consequence	Likelihood	Risk Exposure	
1.	Our ability to quantify margins and assess uncertainties, the fundamental activities at the heart of the QMU methodology, will not improve significantly, and thus there is a concomitant increase in the risk associated with any certification.	Very High	High	High	Increase investments in UQ methodologies and validation experiments and manage stronger integration between the campaigns to align sufficient resources to address this issue. Sponsor various tri-labs and national UQ workshops and external reviews to assess the fidelity of the UQ and QMU principles and techniques.
2.	Compute resources are insufficient to meet capacity and capability needs of designers, analysts, DSW, or other Campaigns.	High	High	High	Integrate program planning with DSW and other Campaigns to ensure that requirements for computing are understood and appropriately set; maintain emphasis on platform strategy as a central element of the program; pursue plans for additional and cost-effective capacity platforms.
3.	Inability to respond effectively with modeling & simulation (M&S) capability and expertise to support stockpile requirements or respond to emerging threats.	Very High	Low	Medium	Integrate program planning, particularly technical investment priority, with DSW and other Campaign programs to ensure that capability and expertise are developed in most appropriate areas; retain ability to apply legacy tools, codes, and models.
4.	Inability to integrate theoretical, computational, and experimental capabilities will greatly reduce confidence in materials models and consequently performance assessments.	High	Moderate	Medium	Management of weapons physics requirements and resources to meet DSW goals – the physics issues of the nuclear explosives package that must be addressed to assess LEP options, certification, and resolution of SFIs is a major driver of resources. Effective management of these issues to ensure efficient programmatic integration is required.
5.	Inadequate materials models based upon insufficient or inaccurate data will jeopardize our ability to certify aging and remanufactured weapons without nuclear testing.	High	Moderate	Medium	Fundamental science – The balance between smaller-scale, fundamental science experiments and large integrated experimental capabilities and programs must be managed. This will ensure the health of the laboratory scientific enterprise as it continues to develop a fundamental understanding of weapons physics and materials and the validation of simulations supporting certification through larger integrated experiments.
6.	Uncertainties in qualification requirements for refurbished weapons.	High	Moderate	Medium	Ongoing planning between product development, code development, and experimental validation organizations already has provided a basis to define validation requirements for some near-term refurbishment programs. Other critical refurbishment programs that will require extensive code validation remain in the midst of planning, but are expected to define more fully their experimental-validation requirements during upcoming years—in time to more accurately define future sub-program requirements. Therefore, it is critical to maintain an integrated effort with ASC and DSW.

No.	Risk Description	Risk Assessment			Mitigation Approach
		Consequence	Likelihood	Risk Exposure	
7.	Model development or code validation efforts will be insufficient to provide the confidence necessary to certify weapon performance.	High	Moderate	**Medium**	In cases where threat environments can no longer be simulated experimentally, the absence of validated, computationally based qualification tools will undermine our ability to qualify weapons in the future. To mitigate this risk, physical model development, computer code development, experimental code validation, and application of these modeling and simulation tools in stockpile computations will be done within the framework of a formal, comprehensive, and rigorous V&V program.
8.	Base of personnel with requisite skills, knowledge, and abilities to effectively respond to emerging needs of the stockpile and the NWC in 2030 erodes.	High	Low	**Medium**	Ensure mentoring and alliance programs are sufficient to support the technical needs and skills.
9.	Inability to provide timely insertion of predictive materials models into simulation tools will undermine our ability to assess an aging or remanufactured stockpile.	Moderate	Moderate	**Medium**	Integration of validated models of physical properties and processes into simulation codes — Appropriate attention is required to ensure that work on physical models is appropriately prioritized and that the results are incorporated into ASC codes.
10.	Fundamental flaws discovered in numerical algorithms used in advanced applications require major changes to application development.	Moderate	Low	**Medium**	Anticipate or resolve algorithm issues through technical interactions on algorithm research through the Institutes, ASC Centers, and academia and focus on test problem comparisons as part of software development process.

V. Program Funding

ASC funding is allocated to cover people, hardware, and contract costs incurred by the ASC divisions. The budget is reported and analyzed monthly by ASC's laboratory resource analysts and by laboratory management. Funding and costs are tracked and reported at the program element level using DP's Budget and Reporting (B&R) classification codes and Financial Information System. These tracking systems are extended in greater detail down to the level of individual projects.

VI. Revision

This is a revision of the FY06 ASC Program Plan (NA-ASC-106R-05-Vol.1-Rev.0), which was completely rewritten in accordance with the 2003 guidance established by DP's Implementer Team.

Program changes (that affect cost, schedule, and scope) discussed in this year's program plan are managed in accordance with clarified roles of federal and laboratory managers.[8] In general, federal managers prioritize the elements of the national program, allocate the resources at the Level 3 sub-program level and resource-load at the Level 4 products; and monitor and evaluate the scope and execution of the program. Laboratory managers develop and execute technical projects. They are responsible for maintaining the Level 3 sub-program budgets, as allocated by HQ; and manage the scope, schedule, and budget of their individual projects, as described in the *ASC Implementation Plan*.

[8] "Role of the Federal and Laboratory Program Managers," ASC Business Model, NA-ASC-104R-05-Vol. 1-Rev.5

Appendix A

NA-10 Level 1 Milestones

Table A-1 lists NA-10 Level 1 milestones for FY 2007–2014. ASC Level 1 milestones, and those shared with other entities, are highlighted in this table. The second part of this appendix lists all ASC Level 1 milestones prior to FY 2004.

Table A-1. NA-10 Level 1 Milestones

MRT ID	Milestone Title	Campaigns	Organizations	Due Date	Programs
333	Annually, prepare and execute an integrated, comprehensive RTBF/Facilities and Infrastructure Recapitalization Program (FIRP) plan to ensure flexible, responsive, and robust infrastructure.		NA-11	Sep-09	RTBF
334	Annually, assess the safety, security, and reliability of the stockpile and provide the required assessments of certification and reports to the Secretary for submission to the President.		NA-11	Jan-09	DSW
337	DARHT dual-axis multi-pulse radiographic capability available to the National Hydrotest Program.	C3	NA-11	Jun-08	SC
347	Complete certification of a W80-3 warhead with quantified design margins and uncertainties.		NA-11	Jan-09	DSW
350	Provide a 100TF Platform environment supporting to the tri-laboratory DSW & Campaign simulation requirements.	C11	NA-11	Dec-06 (Completed)	ASC
351	Complete the first ZR stewardship experiment.	C10 C2	NA-11 NA-16	Sep-08	SC ICF
352	Complete certification of a W76-1 warhead with quantified design margins and uncertainties.		NA-11	Sep-07	DSW

NA-10 Level 1 Milestones (continued)

MRT ID	Milestone Title	Campaigns	Organizations	Due Date	Programs
353	Issue a Major Assembly Release (MAR) for the W88 system with a LANL-manufactured pit.	C12	NA-11 NA-12	Sep-07	DSW PIT
354	Begin type 126 pit manufacturing capability at ten pits per year.	C12	NA-11	Sep-07	PIT
355	Complete the key requirements for CD4 approval of MESA.		NA-11	Apr-10	RTBF
356	CD4 approval to begin NIF operations.	C10	NA-11	Mar-09	ICF
359	Complete modern baseline of all enduring stockpile systems with ASC codes.	C11	NA-11	Sep-09	ASC
360	Begin first integrated ignition experiments.	C10	NA-16	Sep-10	ICF
1540	Accounting for both simulation and experimental uncertainties, assess ability to reproduce the full UGT data sets for a representative group of nuclear tests (including nominal and marginal performers) with consistent set of models. (Cycle I)	C1 C11 C4	NA-11	Sep-10	SC ASC
1541	Publish documented plan to reduce major source of uncertainty based on FY10 certification capability. (Cycle II)	C1 C11 C4	NA-11	Sep-11	SC ASC
1542	Accounting for both simulation and experimental uncertainties, reassess ability to reproduce the full UGT data sets for a representative group of nuclear tests (including nominal and marginal performers) with consistent set of models. (Cycle II)	C1 C11 C4	NA-11	Sep-14	SC ASC

ASC's Previous Level 1 Milestones

Previous ASC milestones (prior to FY 2004) are identified with an ID label, the quarter in which they were to be completed, and a title. The ID label identifies the milestone, as seen in this example: "NA-0.1" is the first (".1") milestone to be completed in the area of Nuclear Applications ("NA") in the year 2000 ("0").

Nuclear Applications

NA-0.1 FY00 Q1	Three-dimensional primary-burn prototype simulation
NA-0.2 FY00 Q4	Three-dimensional prototype radiation-flow simulation
NA-1.1 FY01 Q1	Three-dimensional secondary-burn prototype simulation
NA-2.1 FY02 Q1	Three-dimensional prototype full-system coupled simulation
NA-3.1 FY03 Q1	Enhanced primary physics initial capability
NA-3.2 FY03 Q1	Focused secondary physics capability at LLNL

Nuclear Safety

NS-2.1 FY02 Q4	Three-dimensional safety simulation of a complex abnormal explosive-initiation scenario
NS-3.1 FY03 Q2	Nuclear safety simulation of a complex abnormal explosive-initiation scenario

Nonnuclear Applications

NN-0.1 FY00 Q2	Three-dimensional prototype hostile-environment simulation
NN-0.2 FY00 Q4	Architecture for coupled mechanics running at all NWC sites
NN-1.1 FY01 Q4	Mechanics for normal environments
NN-2.1 FY02 Q4	STS abnormal environment prototype simulation for crashes and burns events
NN-3.1 FY03 Q4	STS hostile environment simulation for cable SGEMP and electrical response to x-rays

Verification and Validation

VV-1.1 FY01 Q1	Establish and deploy a common set of acceptable software engineering practices applicable to all advanced application-development activities
VV-1.2 FY01 Q2	Demonstrate initial validation methodology on the then-current state of application modeling of early-time primary behavior
VV-2.1 FY02 Q4	Demonstrate initial validation methodology of the then-current state of ASCI code modeling for normal and abnormal STS environments behavior

Physics and Materials Modeling (Predecessor Materials & Physics Modeling)

PM-2.1 FY02 Q2	Microstructure-level shock response of PZT 95/5
PM-2.2 FY02 Q4	Delivery of initial macro-scale reactive flow model for high-explosive detonation derived from grain scale dynamics
PM-3.1 FY03 Q4	Meso-scale model for corrosion of electrical components Simulation and Computer Science
SC-3.1 FY03 Q4	User environment for the Q platform at LANL

Data and Visualization Sciences (DVS) (Predecessor: VIEWS)

VU-0.1 FY00 Q1	Prototype system that allows weapons analysts to see and understand results from three-dimensional prototype primary-burn simulations

PSE

PS-1.1 FY01 Q1	Initial software development environment extended to the 10-teraFLOPS system

DisCom

DC-1.1 FY01 Q2	Distance-computing environment available for use on the 10-teraFLOPS ASCI system

Physical Infrastructure and Platforms

PP-0.1 FY00 Q3	10-teraFLOPS system (White), final delivery and checkout
PP-2.1 FY02 Q3	20-teraFLOPS system (Q), final delivery and checkout

Appendix B

Performance Measures

Table B-1. Advanced Simulation and Computing (ASC) Campaign

Goal: Provide the computational science and computer simulation tools necessary for understanding various behaviors and effects of nuclear weapons for responsive application to a diverse stockpile and scenarios of national security.

INDICATOR	ANNUAL TARGETS								ENDPOINT TARGET DATE
	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	
ADOPTION OF ASC MODERN CODES: The cumulative percentage of simulation runs that utilize modern ASC-developed codes on ASC computing platforms, as measured against the total of legacy and ASC codes used for stockpile stewardship activities.	50%	63%	72%	80%	85%	90%	95%	99%	By 2013, ASC-developed modern codes are used for all simulations on ASC platforms. Adoption of modern ASC Codes will enable a responsive simulation capability for the nuclear weapons complex. This measure is meant to show how quickly ASC codes are being adopted by the user community in place of legacy codes.
REDUCED RELIANCE ON CALIBRATION: The cumulative percentage reduction in the use of calibration "knobs" to successfully simulate nuclear weapons performance.	2%	8%	16%	25%	33%	41%	50%	58%	By 2018, the four major calibration knobs affecting weapons performance simulation have been replaced by science-based, predictive phenomenological models. Reduced reliance on calibration will ensure the development of robust ASC simulation tools. These tools are intended to enable the understanding of the complex behaviors and effects of nuclear weapons, now and into the future, without nuclear testing.
ASC IMPACT ON SFI CLOSURE: The cumulative percentage of nuclear weapon Significant Finding Investigations (SFIs) resolved through the use of modern (non-legacy) ASC codes, measured against all codes used for SFI resolution.	10%	25%	37%	50%	62%	75%	87%	100%	By 2013, ASC codes will be the principal tools for resolution of all Significant Finding Investigations (SFIs). Demonstrates how valuable the ASC tools are for meeting the needs of the weapon designers and analysts by documenting the impact on closing Significant Finding Investigations.
CODE EFFICIENCY: Cumulative percentage of simulation turnaround time reduced while using modern ASC codes.	6%	7%	13%	26%	32%	39%	45%	50%	By 2013, achieve a 50% reduction in turnaround time, as measured by a series of benchmark calculations, for the most heavily used ASC codes. To show code efficiency by demonstrating that simulation time decreases as the ASC codes mature.

Appendix C

ASC Risk Management Process

Risk management is a process for identifying and analyzing risks, encouraging mitigation and contingency planning to minimize potential consequences of identified risks, and monitoring and communicating up-to-date information about risk issues. Risk management is about identifying opportunities and avoiding losses.

A "risk" is defined as (1) a future event, action, or condition that might prevent the successful execution of strategies or achievement of technical or business objectives and (2) the risk-exposure level, defined by the likelihood or probability that an event, action, or condition will occur and the consequences if that event, action, or condition does occur.

ASC risk management consists of three major components: Assessment, Handling/Mitigation, and Tracking.

Risk Assessment

Risk assessment involves identification, analysis, and mitigation/contingency planning. The objective of risk assessment is to prioritize risks so that management may focus efforts on mitigating top risk items (Table C-1 and Table C-2). There are five different ASC risk types: Programmatic, Technical, Cost, Schedule, and Performance.

Risk Handling/Mitigation

Risk handling/mitigation is proactively undertaken to lessen consequence or likelihood and/or to develop contingency actions if risk issues develop (Table C-3). There are four different risk-handling methods: Avoidance, Control, Assumption, and Risk Transfer.

Risk Tracking

Risk tracking involves tracking the progress and status of mitigation actions and of risks. Risk status and evaluations can be found in tri-lab quarterly progress reports, as well as in DP status reports.

Table C-1 on the next page evaluates consequences against cost, performance, and schedule.

- *Cost Risks* – Not enough money at the highest level to do the job required in the time allocated.
- *Performance Risks* – One or more performance requirements may not be met because of technical concerns, or issues of competence, experience, organizational culture, and management team skills.
- *Schedule Risks* – Not enough time exists at the highest level to do the required job with the resources allocated.

Table C-1. Consequence Criteria

Consequence	Criteria
Very Low	**Cost:** Negligible impact on cost. Impact is contained within the strategic unit and results in neither undercosting nor overcosting of spend plan. **Performance:** Negligible impact on function or performance. Requirements are clearly met. **Schedule:** Negligible impact on schedule. Impact is managed within the strategic unit. Results in no impact to critical path and no impact to other strategic units. Milestones are clearly met.
Low	**Cost:** Minor impact on cost. Impact is contained within the strategic unit and results in less than 5% undercosting or less than 5% overcosting of spend plan. **Performance:** Minor impact on function or performance. Requirements are clearly met. **Schedule:** Minor impact on schedule. Impact may be managed within the strategic unit. Results in no impact to critical path and no impact to other strategic units. Milestones are clearly met.
Moderate	**Cost:** Recognizable impact on cost. Impact is not contained within the strategic unit and may result in less than 5% undercosting or greater than 5% overcosting of spend plan. **Performance:** Recognizable impact on function or performance. Requirements may not all be met. **Schedule:** Recognizable impact on schedule. Impact may not be managed within the strategic unit. May result in impact to critical path or may impact other strategic units. Milestones may not be met.
High	**Cost:** Significant impact on cost. Impact is not contained within the strategic unit and may result in less than 10% undercosting or greater than 10% overcosting of spend plan. **Performance:** Significant impact on function or performance. Requirements will not all be met. **Schedule:** Significant impact on schedule. Impact will not be managed within the strategic unit. Will result in impact to critical path or will impact other strategic units. Milestones will not be met.
Very High	**Cost:** Major impact on cost. Impact will not be contained within the strategic unit and will result in less than 10% undercosting or greater than 10% overcosting of spend plan. **Performance:** Major impact on function or performance. Requirements cannot be met. **Schedule:** Major impact on schedule. Impact cannot be managed within the strategic unit. Will result in failure in critical path or will significantly impact other strategic units. Milestones cannot be met.

Table C-2 on the next page evaluates likelihood against programmatic or technical risks.

- *Programmatic Risks* – Refer to tasks that flow from, or have an impact on, program governance, and those risks that impact program performance.
- *Technical Risks* – Refer to performance risks associated with end items.

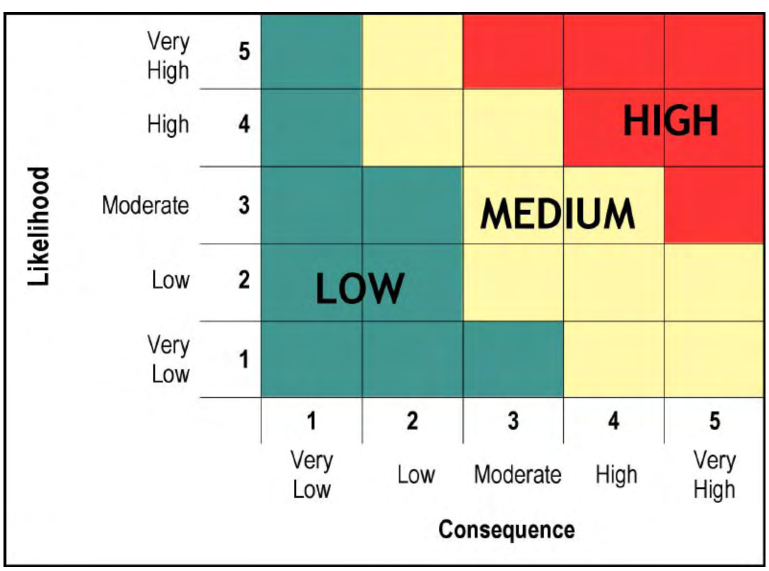
Table C-3 on the next page evaluates risk exposure, based on consequence and likelihood. Different risk-handling methods that relate to this exposure include:

- *Avoidance* – Uses an alternate approach, with no risks, if feasible. This approach can be applied to high and medium risks.
- *Control* – Develops a risk mitigation approach/action and tracks the progress of that risk. This approach is mostly applied to high and medium risks.
- *Assumption* – Accepts the risk and proceeds. This approach is usually applied to low-risk items.
- *Risk Transfer* – Passes the risk to another program element. This approach can be applied to external risks outside the control of the ASC Program.

Table C-2. Likelihood Criteria

Likelihood	Criteria
Very Low	**Programmatic:** No external, environment, safety, and health (ES&H), security, or regulatory issues. Qualified personnel, resources, and facilities are available. **Technical:** Nonchallenging requirements. Simple design or existing design. Few and simple components. Existing technology. Well-developed process.
Low	**Programmatic:** Minor potential for external, ES&H, security, or regulatory issues. Minor redirection of qualified personnel, resources, or facilities modification is necessary. **Technical:** Low requirements challenge. Minor design challenge or minor modification to existing design. Moderate number or complex components. Existing technology with minor modification. Existing process with minor modification.
Moderate	**Programmatic:** Moderate potential for external, ES&H, security, or regulatory issues. Moderate redirection of qualified personnel, resources, or facilities modification is necessary. **Technical:** Moderate requirements challenge with some technical issues. Moderate design challenge or significant modification to existing design. Large number or very complex components. Existing technology with significant modification. Existing process with significant modification.
High	**Programmatic:** Significant potential for external, ES&H, security, or regulatory issues. Significant redirection of qualified personnel, resources, or facilities modification is necessary. **Technical:** Significant requirements challenge with major technical issues. Significant design challenge or major modification to existing design. Large number and very complex components. New technology. New process.
Very High	**Programmatic:** Major potential for external, ES&H, security, or regulatory issues. Major redirection of qualified personnel, resources, or facilities modification is necessary. **Technical:** Major requirements challenge with possibly unsolvable technical issues. Major design challenge or no existing design to modify. Extreme number and extremely complex components. Possibly no technology available. Possibly no process available.

Table C-3. Risk Exposure Level Matrix



The risk-exposure values and the resulting matrix categorize risks as high, medium, or low. When risk exposure is high, a mitigating or contingency plan is required. When risk exposure is medium, a mitigating or contingency plan is recommended. When risk exposure is low, developing a mitigating or contingency plan is optional. Table C-2 details the risk-exposure levels found in Table C-3, describing the risk, its associated risk assessment, and the approach to mitigation.

Appendix D

ASC Management Structure

To ensure successful execution of the ASC strategy, an organizational structure, program-management process, and performance-measurement mechanisms have been instituted within the ASC tri-lab framework.

Organization

ASC's organizational structure is designed to foster a focused, collaborative effort to achieve program objectives. The following elements make up this structure:

- **Executive Committee.** This body consists of a high-level representative from each NNSA laboratory and a senior member in the Advanced Simulation and Computing Office at NNSA Headquarters (HQ). The Executive Committee sets overall policy for ASC, develops programmatic budgets, and oversees the program execution.
- **Sub-Program Management Teams.** These teams are responsible for planning and execution of the implementation plans for each of the ASC sub-programs: Integrated Codes; Physics and Engineering Models; Verification & Validation; Computational Systems and Software Environment; and Facility Operations and User Support. These management teams have a primary and alternate representative from each laboratory, and the corresponding sub-program manager from NNSA-HQ. These teams work through the executive committee. Tasking from NNSA-HQ for these teams originates from the ASC Federal Program Manager and is communicated through the executive committee.
- **ASC's NNSA-HQ Team.** This team consists of NNSA federal employees and contractors, in concert with laboratory and plant representatives. The ASC HQ team is responsible for ensuring that ASC supports the SSP. The team facilitates ASC interactions with other government agencies, the computer industry, and universities. In addition, the team sets programmatic requirements for the laboratories and reviews management and operating contractor performance.

Program Management Planning and Execution Process

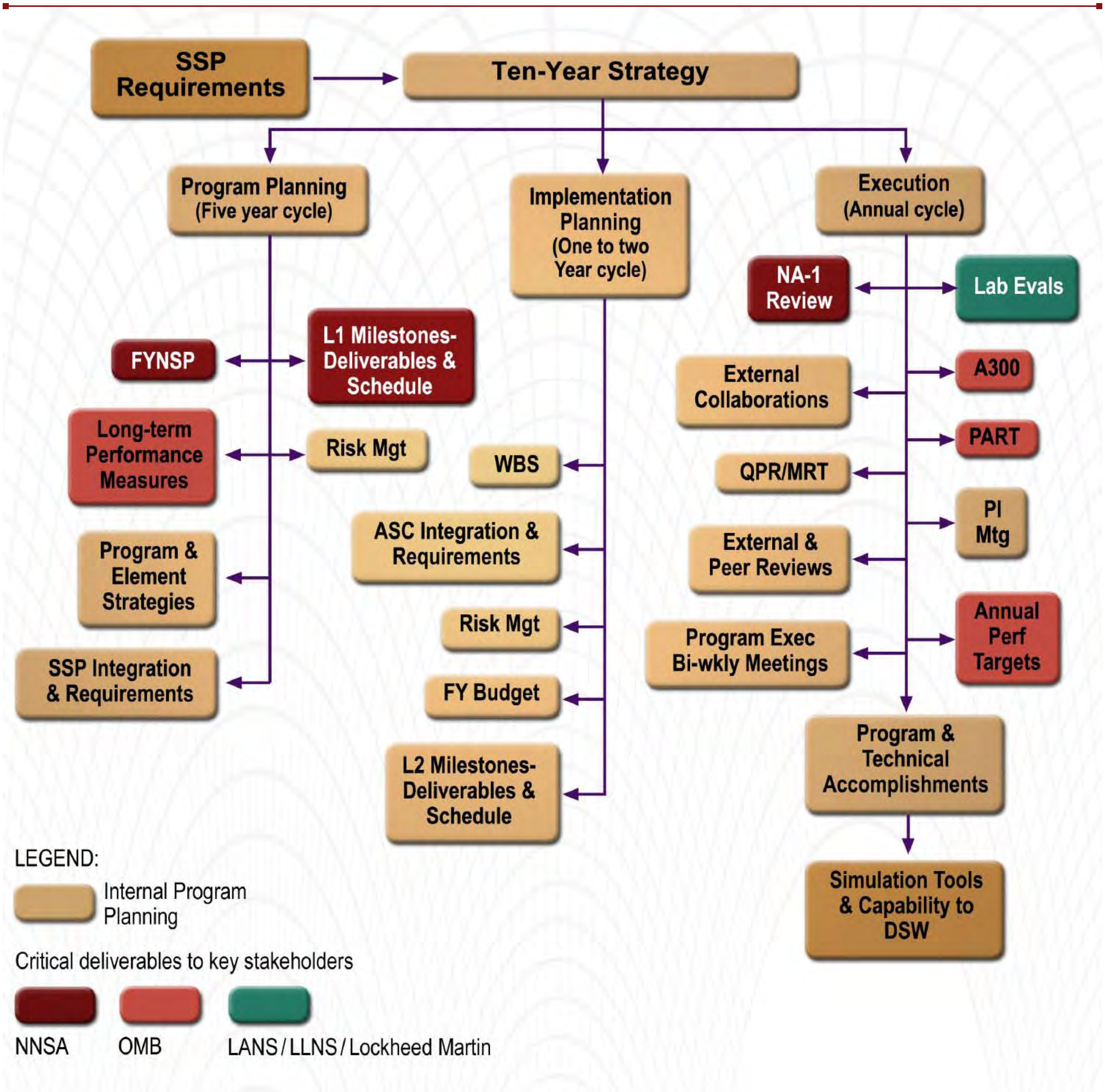
ASC program management uses a planning process made up of elements described below (Figure D-1). All planning activities follow the product-focused national work breakdown structure reflected in the Business Model.

- **ASC Program Plan (PP)**—Provides the overall direction and policy for ASC. This functions as a strategic plan, and it identifies key issues and work areas for ASC in the next six years. This document is reviewed annually to ensure that ASC supports SSP needs.
- **ASC Implementation Plan (IP)**—This document is prepared annually and describes the work planned in two-year intervals at each laboratory to support the overall ASC objectives.
- **Program Milestones**—ASC milestones are a subset of NNSA National Level 1 and Level 2 milestones. Level 1 milestones are national priorities or have high visibility at NA-10 or higher levels. They usually require multi-site and/or multi-program coordination, and provide integration across ASC, DSW, and the Campaigns. Level 1 milestones may be specific to ASC or meet other SSP objectives with significant ASC support. Level 2 milestones are designed to execute the ASC strategy, demonstrate the completion of advanced ASC capabilities, and often support ASC Level 1 milestones, DSW deliverables, and/or major Campaign milestones. ASC set requirements for Certification of Completion that constitutes a body of evidence that certifies completion of Level 2 milestones. Level 3 (and below) milestones demonstrate the completion of important capabilities within a program element and measure technical progress at the sub-program level; these milestones are laboratory specific and are managed by the laboratories. Progress on Level 1 and Level 2 milestones is recorded in the NNSA Milestones Reporting Tool (MRT) and is reported quarterly to the Defense Program Director (NA-10) via the Quarterly Program Reviews (QPR) meetings and annually to the NNSA administrator (NA-1) via the annual technical review meetings.

- **Program Collaboration Meetings**—The following meetings facilitate collaboration among the three national laboratories, industry, and universities:
  - *Principal Investigator Meetings.* These annual meetings provide a forum for ASC principal investigators to meet and discuss progress in their respective research areas. These meetings allow principal investigators at each laboratory to present and discuss their work with their peers at the other laboratories. In addition, the meetings include participants from outside the weapons laboratories in order to provide broader ASC peer review. The meetings also serve as an annual technical review for the DOE-HQ team.
  - *Executive Committee Meetings.* The ASC Executive Committee meets twice a month, via teleconference. These meetings ensure that relevant issues are identified, discussed, and resolved in a timely manner. The teleconferences are supplemented with quarterly face-to-face meetings.
  - *Sub-Program Meetings.* ASC program element teams conduct individual meetings to discuss progress, issues, and actions. The frequency of these meetings depends on the discretion of the ASC HQ program manager and his/her counterparts at the laboratories. These meetings identify issues that need to be elevated to the Executive Committee.
- **Reviews**
  - *External Reviews.* External reviews are conducted regularly by the laboratories to provide independent, critical insight to the laboratories on the technical progress of the ASC Program. The review panels consist of experts from academia, industry, and the national laboratories. Results of the reviews are provided to the laboratories and ASC HQ observers. These reviews augment other high-level reviews.
  - *Internal Program Reviews.* Program reviews are organized at various levels to provide adequate assessment and evaluation of the ASC program elements. Each laboratory and each program element determines the scope and nature of the review as well as the form of reporting the results of such reviews that best suits its needs.
- **Performance Measurement**
  - This includes performance indicators and annual performance targets, established to annually measure the successful execution of the program (see Appendix B).

    Laboratory managers are responsible for measuring and managing the performance of the projects within their purview. Each laboratory reports quarterly performance to NNSA in the form of accomplishments and progress toward Level 1 and 2 milestones.

Figure D-1. ASC Program Planning and Evaluation Activities



Appendix E
Glossary

Advanced Applications
Element of DAM program area that provides physics and geometric fidelity for weapons simulations.

Advanced Architectures
An ASC program element that is focused on development of more effective architectures for high-end simulation and computing.

AGEX
Above-ground experiment

ASC
Advanced Simulation and Computing Program. This program evolved from merging of the Accelerated Strategic Computing Initiative and the Stockpile Computing Program. The use of the acronym "ASCI" has been discontinued.

ASC BG/L
An IBM system located at LLNL. In 2005, BlueGene/L was delivered as a 360 teraFLOPS system.

ASC Purple
An IBM system located at LLNL. In 2005, Purple was delivered as a 100 teraFLOPS system split between classified and open environment in order to supply ASC Alliance support.

ASC Red Storm
A 40-teraFLOPS system, located at SNL, delivered in FY 2005.

ASCI
Accelerated Strategic Computing Initiative

ASCI Blue Mountain
A Silicon Graphics, Inc. (SGI) system located at LANL. In 1998, ASCI Blue Mountain was installed as a 3.072-teraFLOPS computer system.

ASCI Blue Pacific
An IBM system located at LLNL. In 1998, ASCI Blue Pacific was installed as a 3.89-teraFLOPS computer system.

ASCI Q
A Compaq, now Hewlett-Packard (HP), system located at LANL. ASCI Q is a 20-teraFLOPS computer system, delivered in FY 2003.

ASCI Red
An Intel system located at SNL. ASC Red was the first teraFLOPS platform in the world when it was installed in 1998 (1.872 teraFLOPS). Processor and memory upgrades in 1999 converted ASCI Red to a 3.15-teraFLOPS platform.

ASCI White
An IBM system located at LLNL. In 2000, ASCI White was installed as a 12.3-teraFLOPS supercomputer system.

B&R
DP budget and reporting classification codes.

Campaigns
An organization of SSP activities focused on scientific and engineering aspects that address critical capabilities, tools, computations, and experiments needed to achieve weapons stockpile certification, manufacturing, and refurbishment now and in the future, in the absence of nuclear testing.

capability/capacity systems
Terminology used to distinguish between systems that can run the most demanding single problems versus systemsthat manage aggregate throughput for many simultaneous smaller problems.

CSSE
Computational Systems and Software Environment

DARHT
The Dual Axis Radiographic Hydrodynamic Test Facility at LANL will examine implosions from two different axes.

DARPA
Defense Advanced Projects Research Agency

DoD
U.S. Department of Defense

DOE
U.S. Department of Energy

DP
Defense Programs, one of the three major programmatic elements in NNSA.

DSW
Directed Stockpile Work, those SSP activities that directly support the day-to-day work associated with the refurbishment and certification of specific weapons in the nuclear stockpile.

EOS
Equation-of-state

ES&H
Environment, safety, and health

FOUS
Facility Operations and User Support

FY
Fiscal Year. The U.S. Government's fiscal year runs from October 1 through September 30.

HPC
High-Performance Computing

IC
Integrated Codes

I/O
Input/output

LANL
Los Alamos National Laboratory, a prime contractor for NNSA, located in Los Alamos, New Mexico, and operated by LANS, LLC.

LCD
Liquid crystal display monitor

LEP
Life Extension Program

LLNL
Lawrence Livermore National Laboratory, a prime contractor for NNSA, located in Livermore, California, and operated by LLNS, LLC.

M&S
Modeling and simulation capability

MESA
Microsystems and Engineering Sciences Application Facility, scheduled for construction at SNL/NM, will provide the design environment for nonnuclear components of a nuclear weapon.

NIF
National Ignition Facility

NNSA
National Nuclear Security Administration, a semi-autonomous agency within DOE

NPR
Nuclear Posture Review

nWBS
national work breakdown structure

NWC
Nuclear Weapons Complex

PEM
Physics and Engineering Models

petabyte
1015 bytes; 1,024 terabytes

petaFLOPS
1000 trillion floating-point operations per second. PetaFLOPS is a measure of the performance of a computer.

PP
Program Plan

PZT
Lead zirconate titanate

QMU
Quantification of margins and uncertainties

R&D
Research and development

RRW
Reliable Replacement Warhead

SAI
Stockpile Application Index

science-based
The effort to increase understanding of the basic phenomena associated with nuclear weapons, to provide better predictive understanding of the safety and reliability of weapons, and to ensure a strong scientific and technical basis for future U.S. nuclear weapons policy objectives.

SFI
Significant Finding Investigation. An SFI results from the discovery of some apparent anomaly with the enduring stockpile. DSW Surveillance generally initiates an SFI. For complex SFIs, resolution comes from the Assessment & Certification element of DSW, often in partnership with ASC capabilities.

SLEP
Stockpile Life Extension Program. SLEP is the DP element responsible for planning and execution of component and weapons refurbishments.

SNL
Sandia National Laboratories, a prime contractor for NNSA with locations primarily in Albuquerque, New Mexico, and Livermore, California. Operated by Lockheed Martin Corporation.

SSP
Stockpile Stewardship Program, DP's response to ensuring the safety, performance, and reliability of the U.S. nuclear stockpile.

STS
Stockpile-to-target sequence, a complete description of the electrical, mechanical, and thermal environment in which a weapon must operate, from storage through delivery to a target.

terabyte
Trillions of bytes, abbreviated TB, often used to designate the memory or disk capacity of ASC supercomputers. A byte is eight bits (binary digit, 0 or 1) and holds one ASCII character (ASCII—the American Standard Code for Information Interchange). For comparison, the book collection of the Library of Congress has been estimated to contain about 20 terabytes of information.

teraFLOPS
Trillion floating-point operations per second. TeraFLOPS is a measure of the performance of a computer.

test-based
The traditional approach used for the development of nuclear weapons, based on full-scale nuclear tests.

tri-lab
Refers to the three NNSA laboratories: LLNL, LANL, and SNL.

UGT
underground testing

UQ
uncertainty quantifications

V&V
Verification and Validation. Verification is the process of confirming that a computer code correctly implements the algorithms that were intended. Validation is the process of confirming that the predictions of a code adequately represent measured physical phenomena.

WR-1
Reliable Replacement Warhead

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.

National Nuclear Security Administration

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