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Advanced Simulation and Computing

PROGRAM PLAN
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Executive Summary

The Stockpile Stewardship Program (SSP) is a single, highly integrated technical program for maintaining the safety, security, survivability 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, engineering and manufacturing processes, (c) analyze accident scenarios and weapons aging, and (d) support stockpile Life Extension Programs (LEPs) 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 has restructured its business model from one that successfully delivered an initial capability, to one that focuses on increasing predictive capability in the simulation tools. 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, some of the fastest supercomputers in the world, supply the compute cycles for SSP. ASC sees integration as vital to achieving the next level of predictive capability. To that end, ASC activities are coordinated with Science, Engineering, Inertial Confinement Fusion (ICF) Campaigns and Directed Stockpile work (DSW) through the Predictive Capability Framework (PCF), an integration tool used by the DP Campaigns to plan scientific work for tackling difficult problems in select weapons physics and engineering areas.

This Program Plan describes the ASC strategy and deliverables for the FY2009-FY2020 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

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, survivability, 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. To meet this challenge, a new set of aboveground, nonnuclear experimental capabilities was required 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 of the operation of nuclear weapons systems. The Advanced Simulation and Computing Program (formerly known as the Accelerated Strategic Computing Initiative, or ASCI) was established to create and shepherd this capability.

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 balanced program that focuses on providing simulation capabilities needed to analyze and predict the performance, safety, survivability, and reliability of nuclear weapons. To realize its vision of "predict with confidence," the ASC Program develops advanced weapons physics and engineering codes that incorporate modern theory and models based on understanding of past nuclear tests and current aboveground experiments. These codes are executed on state-of-the-art high-performance supercomputers that are capable of returning simulation results in a reasonable time span to allow the scientists and engineers to make further advances in their understanding of the weapons behavior. The expected outcomes will be predictive simulations that enable assessment and certification of the safety, performance, survivability, and reliability of nuclear weapon systems. These simulation capabilities will also help scientists understand, evaluate, and respond to weapons issues such as aging and the effects of changes in parts, materials, and fabrication processes to weapons safety, security, survivability, and performance

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 decentralized 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.

For this transformation, it is not unreasonable for each program in Defense Programs (DP), including the ASC Program, 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? In this Complex Transformation, the Nuclear Weapons Complex is envisioned to transition to an integrated national security enterprise. At the end of 2008, the ASC Program finds itself at the mid-point in answering these questions. Considerable progress has been made in computing by establishing two user facilities for production capability computing for the Complex, one at Lawrence Livermore National Laboratory (LLNL) and the other through the Alliance for Computing at Extreme Scale (ACES) partnership between Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL). The establishment of these two centers utilizes the combined strengths of the national laboratories most efficiently in establishing a robust framework for servicing the high-performance computing needs of the Complex. Capabilities associated with the development and support of the ASC simulation tools, including validated physics models and verification and validation techniques and methodologies, have been under intense scrutiny throughout 2008, driven by the need to answer the above questions in these areas; this evaluation is in progress and is expected to continue into 2009. Achieving the appropriate balance between all parts of the program within the context of the predictive capability framework (PCF) is a key element of ASC's response to the Complex Transformation.

ASC's simulation tools for the nuclear stockpile have natural applications for a broader national security mission. In conjunction with developing science-based, predictive simulations capabilities for nuclear weapons assessment, ASC has supported the research, development, and application of these tools for nuclear forensics, the science of post-detonation analysis for the identification of the composition of the nuclear device. The goal of this development is to provide full operational capabilities, with quantified uncertainties, for the partner agencies by 2010. ASC is committed to further explore areas of national security mission where the ASC simulation toolset may enable faster turnaround of operations, higher-fidelity simulations, and improved scientific understanding of the underlying physical phenomena. These mission areas include nonproliferation applications such as seismic and optical signal monitoring and detection technology, and nuclear counterterrorism applications such as analyses of improvised nuclear device (IND) and radiological dispersal device (RDD).

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 the QMU methodology, "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 the center of this predictive capability.

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. Empirical and sometimes 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 only limited resources could be spent on verification and validation, and that there was a greater reliance on subjective judgments 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 explore long-standing physics, engineering, and algorithmic issues and bring scientific rigor to simulation science. It is in this modern environment that one can now consider the possibility of removing historical *knobs* and replacing *ad hoc* models with ones grounded in physical reality.

ASC, however, must collaborate with other Campaigns to provide increased predictive capability for the Complex. The credibility of simulations needs to be affirmed by experiments. Theory and modeling work is conducted in all of science and engineering. Stockpile assessment requirements are set by Directed Stockpile Work (DSW).

To best utilize the resources of the Complex, NNSA Defense Programs has begun crafting the **Predictive Capability Framework** (PCF) to best combine the strengths and capabilities of each Campaign. This Framework is a program planning and integration tool for activities that are needed to improve fundamental understanding of the physics of nuclear weapon systems. It provides links between long-term integrated goals and progress in enabling capabilities. These links allow the synchronized delivery of experimental platforms and data, and the development of advanced computational platforms and models to address the major scientific uncertainties associated with nuclear weapon systems.

Major ASC Objectives— To meet the science and simulation requirements of the SSP, the ASC Program's core mission, vision, and goal are as follows:

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 operate 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 proliferant devices and their effects, vulnerabilities to electromagnetic pulse, and advanced weapon concepts that could respond to possible new threats.

Strategy—ASC has adopted a strategy that emphasizes providing a science basis for models used 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.

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[2] Source: DP Program Planning and Resource Call Guidance
[3] Source: *ASC Strategy*, NA-ASC-100R-04-Vol.1-Rev.0, August 2004

The ASC Program and the other Campaigns will be integrated through the PCF. As stated earlier, the PCF is a program planning and integration tool for the activities that are needed to improve our fundamental understanding of nuclear weapon physics and engineering. The PCF links the progress in four *predictive* capabilities: Safety and Surety, Nuclear Explosive Package Assessment, Engineering Assessment, and Hostile Environments Outputs and Effects, to the progress of five *enabling* capabilities: (1) theory and model development, (2) integrated code and algorithm development, computational and experimental facilities, (3) experimental data acquisition (diagnostics development) and analysis, (4) QMU and (5) Verification & Validation (V&V) capabilities. The linkage of the enabling capabilities to major areas of interest in weapons physics and engineering allows the synchronization of the delivery of experimental platforms and data and the development of advanced computational platforms, models, and integrated codes to address the major scientific uncertainties associated with nuclear weapons. The ASC strategy is aligned with the PCF to maximize the leverage of other Campaigns toward a demonstrable predictive capability.

The ASC strategy has 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), Life Extension Programs (LEPs), Annual Assessments (ARs) and Major Assembly Releases (MARs). As modern simulation capabilities have matured demonstrably over the first decade of ASC, more and more stockpile issues are being resolved through the use of modern 3-D integrated codes with high-fidelity models and enhanced performance. 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.

The long-term component of the strategy is to ensure movement toward science-based, predictive capability that will enhance confidence in the simulation results. To ensure that they are grounded in physical reality and provide a foundation for scientifically based decisions, the representation of weapons behavior must also be supported by an increased focus on verification and validation and uncertainty quantification. To translate this vision of science-based weapons simulation into reality, the ASC Program has embarked upon the formulation of strategies for specific application areas. The three areas under consideration are Integrated Codes (IC), V&V, and Physics and Engineering Models (P&EM). Work on the IC and V&V strategies has begun. These developing strategies are complementary to the ASC Platform Strategy, which provides both stable compute cycles for the nuclear weapons program as well as promotes innovation in high-performance computing so that the compute cycle needs for predictive nuclear weapons calculations in the next decade would be fulfilled.

The ASC Code Strategy, to be published in FY09, is based on the vision of "simulation-enabled complex transformation." The overall objectives of the *Code Strategy* are to enable world-class predictive science, QMU-based certification, responsive infrastructure through pervasive simulation, and broadened national security mission. Based on these objectives, a national simulation portfolio for weapons sciences and engineering is established to ensure adequate capability to perform the stockpile stewardship mission and peer review. In addition, the code strategy identifies areas of computer and computational sciences for focused investment in order to respond to changes in DP mission, computer architecture, and possibly the nuclear weapons posture of the nation.

The *ASC V&V Strategy*, also to be published in FY09, spells out a vision of assessing simulation credibility, advising the simulation community, and advocating simulation capability. The objectives of the *V&V Strategy* is to provide quantified credibility to simulations, facilitate communications among those who perform simulations and those who use simulations to make decisions, and advance simulation science. Like the *Code Strategy*, the *V&V strategy* also needs to anticipate and respond to uncertainties of the future; however, it aims to provide a basic, broad set of action plans that will be applicable for the next decade – and adaptable to the ever-changing landscape of the Complex.

Throughout its history, the ASC Program has demonstrated pioneering capabilities by proof-of-principle calculations. The continued success of the ASC Program is a testament to the breadth and depth of scientific capabilities and the desire to push the frontier of science at the NNSA laboratories. 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; 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.
- **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.
- **In 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.
- **In 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. 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.
- **In FY 2008,** ASC's Roadrunner, an advanced architecture platform sited at LANL, became the first supercomputer capable of sustained 1 petaFLOPS performance.
- **By FY 2010,** ASC will deliver solutions to the energy balance knob, including high-fidelity models made possible by the Roadrunner platform.
- **By FY 2012,** ASC will demonstrate Uncertainty Quantification aggregation methodology for full-system weapon predictions.

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

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

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	FY10 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	FY12 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	TBD (beyond FY12 Q4)	C11, C1, C2
5. Capabilities for SFI response improvements.	HQ, LLNL, LANL	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
- 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 subprogram 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

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[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

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. Significant investment of resources goes to the area of **Modern Multi-Physics Codes**, which are 3-D codes that contain the latest fruits of scientific research, such as numerical algorithms, physics and engineering models, and fundamental data, for simulations of 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 rapidly superseding previous generation codes, the second product area, **Legacy Codes** provides an option in the transition: as users learn to use the modern multiphysics codes, as code developers migrate physics capabilities not yet implemented in the modern codes but exist in these legacy codes, and as a reference point for weapons analysts who are developing new baseline models using the modern multiphysics codes. **Engineering Codes** are the third product area of this sub-program, providing comparable advanced simulation capability for addressing the most challenging engineering-related aspects of nuclear weapon **system** safety, survivability, performance, and reliability.

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 Predictive Science Academic Alliance Program (PSAAP) 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 and 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 (P&EM)

This sub-program develops microscopic and macroscopic models of physics and material properties, as well as special-purpose physics codes required to investigate specific physical phenomena in detail. This program works with the IC subprogram to develop new models, and is responsible for the initial validation and incorporation of these new models into the integrated codes.

There is also extensive integration between the model development program and the SSP experimental programs executed by the Defense Science Division Campaigns, 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 P&EM sub-program has the following high-level goals:

- Development of special-purpose physics codes and direct numerical simulation capabilities to investigate complex physical phenomena;
- Science-based replacements for *knobs* (*ad hoc* models) in performance and engineering codes;
- Implementation of models to support simulations required for assessment, 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;
- Developing and deploying improved material data libraries (equation-of-state, nuclear data, opacities, material constitutive properties, 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 Complex 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 (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 V&V, 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 physics and engineering 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, surety, survivability, 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:

- National V&V Strategy;
- Assessment of major simulation uncertainties;
- Demonstration of uncertainty quantification (UQ) methodology for QMU.

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 simulation requirements of NNSA. It strives to provide a stable and seamless computing environment for ASC capability, capacity, and advanced systems. The complexity and the scale of nuclear weapons performance and analysis 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 influence the evolution of computational environments. At the same time, however, CSSE must also provide the stability that ensures productive system use and protects the large ASC investment in its simulation codes.

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 and engineering studies, and enhanced predictive capability. The immediate focus areas include moving toward a standardized user environment, deploying more capacity computing platforms, developing petascale computing capability for integrated weapons and engineering codes, 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 exascale level performance, as stated in the *ASC Roadmap*.

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;
- Developing and implementing problem setup, data management, data analysis, and visualization tools for ASC weapons simulations;
- 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:

- 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 Compute System Scheduling Governance Model.
- Ensuring that the physical plant has sufficient resources (such as space, power, cooling) to support future computing systems.
- Providing, developing, and maintaining a wide area infrastructure (links and services) that enables remote access and data movement across ASC sites.
- Enabling remote access to ASC applications, data, and computing resources to support computational needs at the plants.
- Providing user services and help desks for laboratory ASC computers.

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, survivability, 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) — Within the Defense Programs, the Office Research and Development of National Security Science and Technology is the umbrella organization for the Campaigns, including ASC, Defense Science, Engineering and DSW R&D, and National Ignition Campaigns. It is within these Campaigns where the theory and modeling, experiments, and simulation capabilities within the Complex reside.

Individually, these Campaigns develop the science basis for stockpile stewardship. For example, using its facilities such as, the Dual Axis Radiographic Hydrodynamic Testing (DARHT) Facility at Los Alamos, the Microsystems and Engineering Sciences Applications (MESA) Facility at Sandia, and the National Ignition Facility (NIF) at Lawrence Livermore (soon to be operational), the Defense Science and Engineering Campaigns produce high-quality physics data, which ASC incorporates into its integrated codes, either to be used as fundamental data or to inform models. The ASC integrated codes in turn are used by these Campaigns to design experiments, prioritize model development efforts, or perform discovery and assess model uncertainties.

In the post-nuclear-testing era, the integration of theory and modeling, experiments, and simulation capabilities is critical to our ability to assess the safety, reliability, and performance of the nuclear stockpile. The need for integration has prompted the Campaigns to develop, cooperatively, the PCF.

As discussed in the Introduction, the PCF is a program planning and integration tool for activities are needed to improve fundamental understanding of the physics of nuclear weapon systems.

The PCF identifies a list of long-term integrated goals in four main areas:

- Safety and Surety,

- Nuclear Explosive Package Assessment,
- Engineering Assessment, and
- Hostile Environments, Outputs and Effects.

Additionally, the PCF links the progress in the above predictive capabilities to the progress in the following enabling capabilities:

- Theory/Model Capabilities,
- Code/Algorithm Capabilities,
- Computational and Experimental Facilities,
- Experimental Data and Diagnostics, and
- QMU and V&V Capabilities.

These links allow the synchronized delivery of experimental platforms and data, and the development of advanced computational platforms and models to address the major scientific uncertainties associated with nuclear weapon systems.

The PCF allows DP to manage the Campaigns as one integrated program with respect to the areas of Safety and Surety, Nuclear Explosive Package Assessment, Engineering Assessment, and Hostile Environments, Outputs and Effects. In the PCF "Tier 1 matrix," the time-dependent state – including the desired state – of these four areas are described. Under each of these four areas are broad subject areas, whose progress, linked to the abovementioned six enabling capabilities are described. This is the "Tier 2" matrix. These two matrices help each Campaign to plan its work so that overall progress toward predictive capability is achieved in a coordinated, timely manner. ASC, as a cornerstone in the science-based stockpile stewardship program, contributes to theory and model development, integrated code and algorithm development, V&V and UQ, and computational facilities.

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.

Table 2. ASC Top 10 Risks

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.
7.	Model development or code validation efforts will be insufficient to provide the confidence necessary to certify weapon performance.	High	Moderate	Medium	**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 erodes.	High	Moderate	Medium	Put in place programs to retain and train quality staff at the Labs 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. The budget is reported monthly by ASC laboratory resource analysts and by laboratory management. Funding and costs are tracked and reported at the product level using DOE's Budget and Reporting (B&R) codes and Financial Information System.

VI. Revision

This is a revision of the *FY08 ASC Program Plan* (NA-ASC-111R-06-Vol.1-Rev.0).

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*.

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[8] "Role of the Federal 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 2007–2010. ASC Level 1 milestones, and those shared with other entities, are highlighted in this table.

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
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
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

NA-10 Level 1 Milestones (continued)

MRT ID	Milestone Title	Campaigns	Organizations	Due Date	Programs
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
360	Begin first integrated ignition experiments.	C10	NA-16	Sep-10	ICF

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%	100%	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	10%	25%	37%	50%	62%	75%	87%	100%	By 2013, ASC codes

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.									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 under costing nor over costing 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% under costing or less than 5% over costing 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% under costing or greater than 5% over costing 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% under costing or greater than 10% over costing 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% under costing or greater than 10% over costing 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-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:** Non-challenging 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 below evaluates risk exposure, based on consequence and likelihood. Different risk-handling methods that relate to this exposure include:

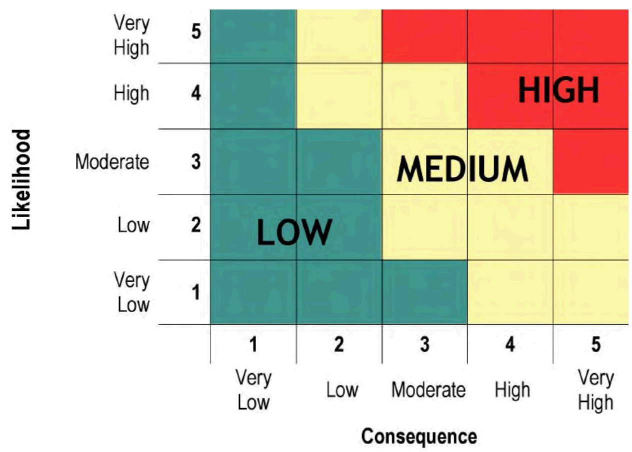
• *Avoidance* – Uses an alternate approach, with no risks, if feasible. This approach can be applied to high and medium risks.

• *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-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)**—This document 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.

• **Other ASC Strategy and Planning Documents**— In addition to the above, ASC has also published a suite of strategy and planning documents. These include the *ASC Strategy* (NA-ASC-100R-04-Vol.1-Rev.0); the *Business Model* (NA-ASC-104R-05-Vol.1-Rev.1); the *ASC Roadmap* (NA-ASC-105R-06-Vol. 1), *Total Cost of Ownership* (NA-ASC-108R-06-vol.1-Rev.0); and the *ASC Platform Strategy* (NA-ASC-113R-07-Vol. 1). Two documents will be published in FY09: the *ASC Code Strategy* and the *ASC V&V Strategy*.

• **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 multisite 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 bi-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.

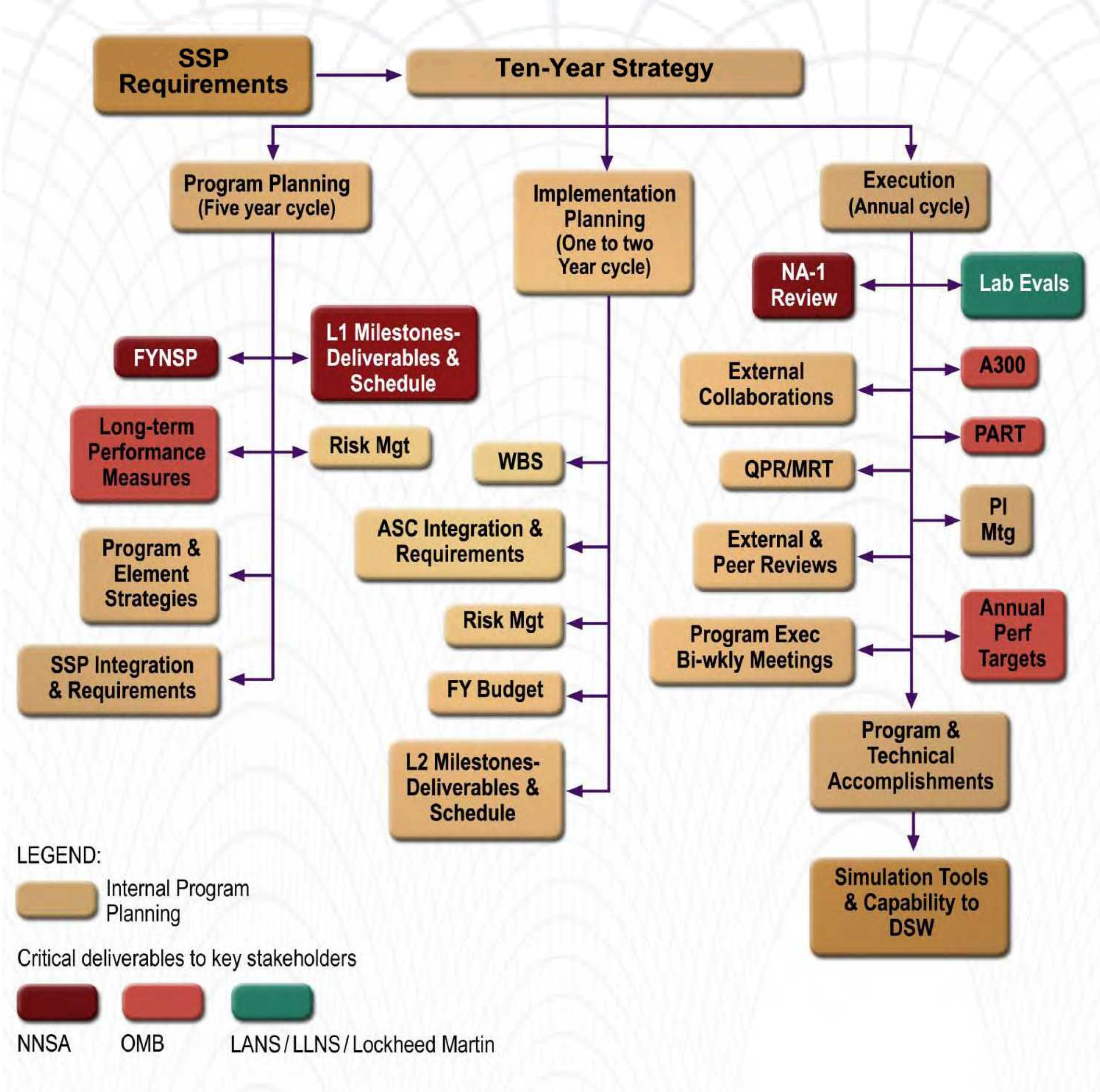
  ♦*Internal Program Reviews.* Program reviews are organized at various levels to provide adequate assessment and evaluation of the ASC program elements. Each laboratory and each program element determines the scope and nature of the review as well as the form of reporting the results of such reviews that 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

ACES:
The NNSA New Mexico Alliance for Computing at Extreme Scale (ACES) is an NNSA ASC alliance between LANL and SNL devoted to providing High Performance Capability Computing assets required by NNSA's stockpile stewardship mission. The Alliance was formed through a Memorandum of Understanding between the two Laboratories executed in 2008.

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.

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-tera-FLOPS 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.

M&S
Modeling and simulation capability

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

NIF
National Ignition Facility

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.

capability/capacity systems
Terminology used to distinguish between systems that can run the most demanding single problems versus systems that 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 examines implosions from two different axes.

DARPA
Defense Advanced Projects Research Agency

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

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

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

LEP
Life Extension Program whose purpose is to refurbish and/or replace nuclear weapons parts, including, but not limited to, those with limited lifetime..

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

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.

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

QMU
Quantification of margins and uncertainties

R&D
Research and development

RRW
Reliable Replacement Warhead

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.

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.

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

UGT
underground test (usually nuclear)

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.

SAND xxxx
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