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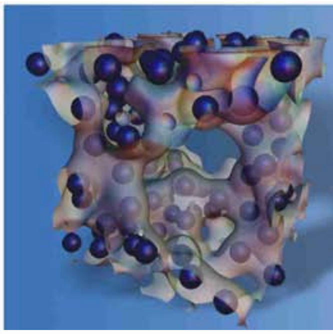
ASC™

STRATEGY

The Next Ten Years

National Nuclear Security Administration

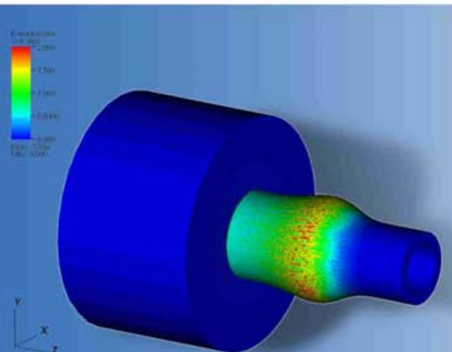
ON THE COVER:



This image shows the results of a quantum molecular dynamics (QMD) calculation of the electrical conductivity of aluminum as a function of material density. The complex structure of the electron density is depicted here. These types of *ab-initio* calculations are being used to develop improved electrical conductivity models in ALEGRA-HEDP, an ASC-funded, high energy-density physics code, used in simulating Z-pinch and other magneto hydrodynamic (MHD) phenomena. (Courtesy: Sandia National Laboratories.)

These experimental images show the evolution of three gaseous cylinders (seeded with a tracer gas) that have been accelerated by a planar shock wave. The flow fields are dominated by vortices created by the shock acceleration, so the swirling red flows are the SF6 gas being entrained by the vortices. The yellow is air. Each photo consists of two snapshots of the flow at two times (with time interval about 200 microseconds). These images are produced by a laser-induced fluorescence technique. In each image the structures are traveling from left to right at speeds of 100 m/s.

Calculations that should be able to "predict" these flows are having some success, and the codes are getting better as the theoretical fluid dynamicists are understanding better the vortex dynamics of these flows and developing improved algorithms to track highly distorted interfaces. (Courtesy: Los Alamos National Laboratory.)



This is a simulation of a gas gun-driven expanding tube fragmentation experiment on tantalum. The simulation was a run using the crystal plasticity model which naturally picked up nonuniformities in deformation and the beginning of strain localization. Contours of equivalent plastic strain are shown. The target sample is the object on the right and the "anvil" is the object to the left. In the experiments, a tube of tantalum that is half filled with lexan is impacted by a lexan projectile fired from a gas gun at 1.87 km/s. The projectile slips into the cylindrical test sample, shocking and compressing the lexan that half fills the tube causing a rapid radial expansion of the sample cylinder. The target tube rests up against an anvil which prevents the gas gun projectile from penetrating the wall of the target chamber. (Courtesy: Lawrence Livermore National Laboratory.)

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Advanced Simulation & Computing

The Next Ten Years

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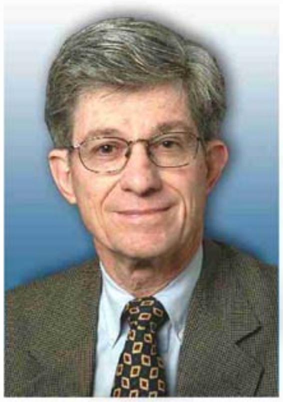
Foreword



Dr. Everet H. Beckner
Deputy Administrator for
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National Nuclear Security
Administration (NNSA)
NA-10

As complex devices in the nation's weapons stockpile age, our strategy must simultaneously evolve to better ensure and manage their performance, reliability, and safety—particularly in the absence of full-scale testing. Our understanding of science needs to increase. Our experimental program must also become more vigorous and robust. Computational simulations must be the considered choice for stockpile evaluation. Both the experiments we conduct and the fidelity of our simulations must adapt to this new environment.

Custodians of the stockpile continue to face the fact that, due largely to aging phenomena, the configurations that describe the original designs are gradually drifting away from their design and "as-built" space. This is a new challenge that we did not face in the days of underground testing. The behavior of the materials and the geometries were controlled during testing; now we must accept what nature gives us. This change represents a watershed in our response to our custodial responsibilities to the nuclear arsenal, and our new forward-looking strategy points us in the necessary directions.

The Advanced Simulation & Computing (ASC) Program has been very successful in providing the additional simulation tools and computational power to weapons designers. The designers have thus been able to investigate stockpile issues within the parameter space defined by our nuclear test data, examined potential problems, addressed issues that arose during surveillance, and have evaluated the consequences of necessary refurbishments.

The new strategic emphasis of the ASC program illuminates several directions. It recognizes that many changes in the stockpile are inherently three-dimensional and the legacy codes cannot address issues in such geometries. It recognizes that most of the changes are small perturbations that must be resolved and their effects understood if we are to avoid the most conservative and expensive fixes. Congruent with these challenges, this strategy for the next ten years recognizes and addresses the need to replace the full system experiments that were done with the best available models, material characterizations, and scientifically based representations. While the past nuclear test program allowed a particular balance between phenomenology (where our understanding was imperfect) and basic science (where we had the ability to apply it), the new policy of no full-scale nuclear experiments shifts the balance to one of minimum phenomenology and the best possible representations of physical behavior. We must still be able to reproduce the data in the Nevada Test Site suite of data, but we must do it in new ways that permit significant deviations from the design space.

The fundamental question remains whether or not we can predict with confidence the tolerances, or margins, between a weapon's expected behavior and its failure. We must determine with the tools at hand how big those margins are and with what level of confidence we can make those predictions. What are the uncertainties in our understanding of the details of performance? What are the uncertainties in our simulations of those details? In other words, with what confidence can we assure the President that he does not need to authorize nuclear testing in order to still be able to rely on all the weapons designs in the stockpile?

The focus of the ASC program is consistent with, and mutually supportive of, the entire Defense Programs effort of emphasizing small-scale experiments, building facilities with significant capability for integral studies, and developing vastly improved simulation techniques. Combined, they represent a concerted focus on better predictive capability. Phenomenology can be used to predict as long as evaluations are confined to regimes in which interpolation makes sense, even the complex interpolations built into the well-calibrated legacy codes. Extrapolation with those tools, however, is certainly perilous.

As part of the integrated strategy of NNSA to provide a broad suite of capabilities to address Directed Stockpile Work, this new ten-year plan for ASC is right on the mark.

Glossary

Many of the terms used in this document have a specific meaning within the context of the Stockpile Stewardship Program and the ASC Program.

Baseline: The model of a weapons system calibrated against available data sets. A baseline matches a subset of the data as well as possible through a process of adjusting the free parameters of the models in the codes used to perform the baseline.

Capability machines: A classification of the large parallel computing systems wherein the system is dedicated to, or capable of being dedicated to, a single calculation. Capability machines are characterized by a job mix with few simultaneous jobs, with individual jobs utilizing 40% or more of the system's compute nodes.

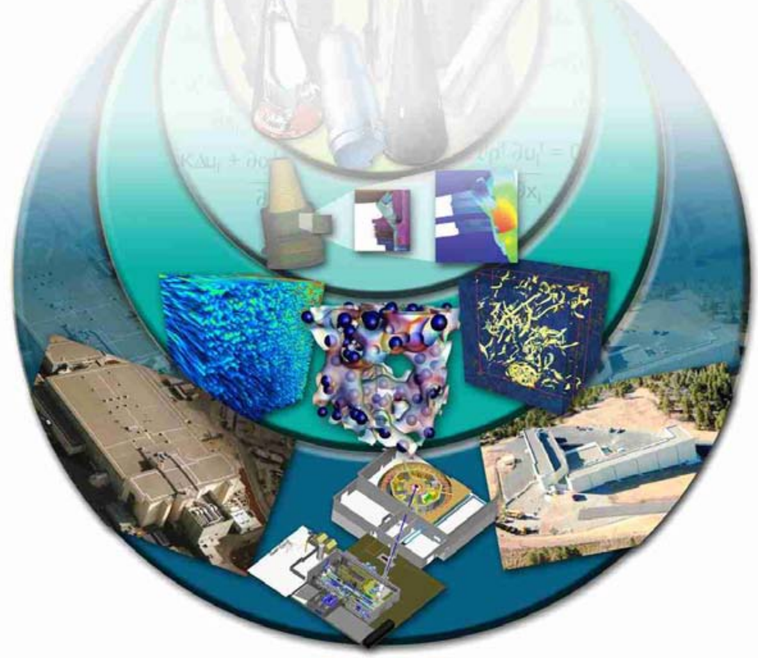
Capacity machines: A classification of parallel computing systems that are not used as capability machines. A job mix of many simultaneous jobs characterizes capacity machines. Historically, today's capability platforms become tomorrow's capacity machines as technology progresses.

Legacy code: Application codes that existed prior to the start of the ASC Program, before 1995. In many cases, legacy codes are no longer being actively developed.

Modern code: Application codes first developed under the ASC Program, starting after about 1995. Some codes that would have been classified as legacy codes have been significantly redesigned under the ASC Program and are therefore classified as modern codes.

Validation: A process applied to the model of a phenomenon, wherein it is determined to what degree the model accurately represents that phenomenon.

Verification: A process applied to an application code, wherein it is determined that the computer calculation for a particular problem accurately represents the solution of the mathematical model.



Advanced Simulation & Computing

The Next Ten Years

Introduction

The Advanced Simulation & Computing (ASC) Program has been driven since its inception by the need to ensure the safety, reliability, and performance of the nuclear weapons stockpile without nuclear testing. To do this, it has emphasized the development of high-fidelity, three-dimensional codes to address stockpile issues, created and deployed the required computational capabilities and supporting infrastructure, and fostered the emergence of a cadre of trained weapons scientists to maintain our nuclear deterrent into the future. While the ASC Program has progressed in developing the scientific base of our simulations,[1] in concert with the other weapons program science Campaigns, many fundamental issues still remain to be explored, understood, and accurately modeled and quantified.

> *The strategy for the next ten years, as discussed in this document, will set high-level directions and emphasizes a deeper understanding of the underlying science, a continual replacement of the phenomenology in the weapon simulation codes by better theoretical models, and a quantification of their limitations.*

The first ten years of ASC were dedicated to the creation of powerful and unique simulation tools, to the development of extraordinary computing infrastructure, and to the demonstration that its ambitious goals were actually possible. Less than a decade ago, there was great skepticism that any of these goals could be achieved, yet they were. While the next decade will benefit from the integration of these newly developed capabilities into the broad Stewardship Program as critical elements for success, there will also be a change in emphasis and priorities within ASC based on the progress made to date. The strategy for the next ten years, as discussed in this document, will set high-level directions that will emphasize a deeper understanding of the underlying science, a continual replacement of the phenomenology in the weapon simulation codes by better theoretical models, and a better understanding of their limitations. Thus, there will be a refinement in the quality of applications within a science-based process that seeks continuous improvement through enhanced capabilities and quantified understanding of limitations in capabilities. The ASC Program and the other Campaigns will be integrated with structured certification methodologies and will include, as an inherent element, the capability to assess and quantify the confidence in the use of ASC tools to make predictions and informed stockpile-related decisions.

Developing the tools to address evolving mission requirements is another motivator that drives us to provide a strategy for the next ten years, guiding the transition from a successful initiative to a more powerful and demonstrably predictive capability. It is also incumbent upon ASC to ensure that the predictive capabilities developed be able to respond rapidly to changing national needs and priorities. The modern tools embody the integrated representation of the knowledge gained from decades of effort in theory, modeling, experimentation, and even simulation itself. Our increasing reliance on these tools demands that we make every effort to perfect their capabilities and be able to affirm their fidelity.

For the next ten years our strategic goals are focused on:

- Improving the confidence in prediction through simulations;
- Integrating the ASC Program with certification methodologies;

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[1] *JASON ASC Study*, Report no. JSR-03-330, September 2003.

- Developing the ability to quantify confidence bounds on the uncertainty in our 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.

This strategy is intended to guide the development of the program. For example, when decisions are made for developing a workforce plan, acquiring platforms, or allocating computer cycles, recourse to this document should ensure that decisions are aligned with this strategy and that our investment profile is consistent with the future needs of the program.

The ASC Program will continue to have both short- and long-term components. It is relatively easy to develop a credible and comprehensible motivation for the program on the basis of the short-term deliverables because of the universal recognition of the importance of meeting commitments directly associated with the stockpile. It is more challenging to explain why an associated long-term research enterprise, albeit one with definable and achievable targets along the way, is both fundamental and decisive. The answer is that we have before us a continually changing and increasingly challenging goal of closing the gap between aging nuclear devices and our ability to predict their performance accurately with quantifiable uncertainty in this new parameter space. In addition, the associated talent base will be cultivated over time and should not be subject to the large fluctuations of support associated with often changing short-term requirements.

ASC's products serve as the integrators for all aspects of the nuclear weapons enterprise—from assisting the plants in their manufacturing mission through the full stockpile lifecycle, to understanding the provenance of crude terrorist devices, to considering advanced concepts for maintaining the credibility of the current stockpile. The need to predict the behavior of nuclear devices using simulation must be met as long as nuclear security is a national priority.

Simulation as a Predictive Tool

Throughout the history of nuclear weapons design, we had recourse to full-system experiments that allowed us to calibrate the codes to nuclear test results. Designs of new weapons systems relied on codes that were baselined against relevant data and combined with many simplifying assumptions. Excursions from previous underground tests were bounded, with the recognition that phenomenological models in the codes could not be pushed far in geometry or other physical behaviors from previous experiments. New materials were added, simulated, and tested as needed after careful and complete simulation and comparison with the relevant test series.

Devices are now aging, and changes are being made to meet Directed Stockpile Work (DSW) requirements, both of which require detailed three-dimensional simulation and analysis if the design symmetry has been altered. Even during the era of nuclear testing, we had to extrapolate from experimental data beyond the restrictions imposed by yield and other testing limits, to weapon operational conditions. We now have even less control on the parameter space in which simulations are performed, and the extent of the extrapolations is much greater. This clearly calls for a science-based predictive capability rather than extrapolations based on calibration and expert judgment.

For these reasons, it has long been understood that while phenomenological fits to data with models that approximate physical reality have an important place in the nuclear weapons enterprise, they are limiting. If we are to drive beyond the bounds imposed by the parameter space of previous experiments, we must increase the level of fundamental scientific understanding incorporated in the codes. The modern and powerful two-dimensional and three-dimensional ASC codes present a unique opportunity for evolution.

It is our goal to develop a road map for increasing the scientific bases that underlie the modern tools. The creation of a robust road map must be coordinated with the NNSA Office of Defense Program's Science and Engineering Campaigns. To serve the program well, the models have to enable credible extrapolation from past underground tests into new physical regimes.

An essential component of this road map is to calculate, measure, and understand the uncertainty in the predictions. This is a major issue in establishing credibility of simulations and it was identified in the first decade of ASC. However, in this evolving thrust for the future that focuses on DSW, the quantification of margins and uncertainties itself drives us toward better physics understanding and the integration of theory, archival data, and focused experiments. A second component of this strategy is to take into account that this reduction in phenomenology with an accompanying quantification of uncertainty is a computationally taxing endeavor. This goal, to move forward expeditiously, needs to be supported by a sufficiently powerful and capacious computational infrastructure readily usable by the broad nuclear weapons analysis community. Progress in these elements of our strategy will lead to a greatly enhanced predictive capability and aid the design community in making more confident decisions.

As our ability to predict weapons behavior with confidence increases, simulation will become an even more valuable component of the intellectual framework supporting the annual assessment and certification process. This applies as well to addressing Significant Findings Investigations (SFI) and quantifying the effects of changes made to support Life Extension Programs (LEP) as well as the Annual Assessment of systems in the stockpile. In the past, this process relied heavily on experienced designer judgment, informed by the baselined legacy codes and confirmed by integral experimental data (e.g., archival nuclear test data). Though codes can replace neither experiment nor the physical intuition of expert scientists, in a carefully structured technical program they can help form and test that intuition and understanding in a more fundamental way.

The ASC Program is well into focusing on its future requirements to support the needs of the stockpile. The program is evolving from a proof-of-principle initiative to a program that is providing improved capabilities essential to maintaining technical confidence in the stockpile. We have unequivocally demonstrated that we are able to acquire and use the most powerful computers to perform three-dimensional calculations that can model key details of weapons performance. This is the foundation that permits the next step. The goal now is to provide predictions of weapons behavior with a sufficiently tight quantification of confidence.

Responsiveness to Stockpile Needs

The two foci of this program strategy are not separable, but complementary and interdependent. The first focus, as discussed in the previous section, is to ensure movement toward the long-term goal of reduced dependence on phenomenology to enhance confidence. The second focus is to meet the continuing and time-constrained needs of Stockpile Stewardship, in particular, SFIs and life-extension activities. To address these needs as the properties of the devices in the stockpile change, we are forced to transition from the well baselined legacy codes, to the modern codes with their increased dimensionality and enhanced modeling capabilities. The fidelity of the modern codes will continue to be improved so that they become increasingly able to address potential stockpile problems when they are uncovered in the surveillance process.

The process of baselining a code to a weapon system traditionally implies calibrating the model against the suite of both nonnuclear (i.e., hydrodynamic) and nuclear tests that provide qualitative confidence to the user/designer that the code represents the behavior of that specific system. Baselining is absolutely essential for meeting the shorter-term needs of the stockpile, giving the designer confidence that the code in hand at least can match the archival test data that are the bedrock of our knowledge. As new physics models replace phenomenological representations of physical behavior, the codes must be verified and models validated to accepted standards and to the satisfaction of the designers and analysts making decisions about SFIs and LEPs, assessment and certification, or other stockpile questions and concerns.

Responding to DSW imperatives is a major requirements driver for our platform-acquisition timetable, just as it is a driver for our strategy to reduce dependence on phenomenology. Although longer-term science research may not appear to affect DSW deliverables directly, the value it adds will become increasingly apparent as the DSW challenges mount in the next decade. Developing and implementing more sophisticated and more realistic models will require significant innovation and skill on the part of program scientists and will also stress our computing infrastructure. Supporting this work will require a careful mix of capability and capacity[2] calculations. Given the current maturity of physics models of ASC codes, capability calculations today are measured within a window of 10 to 100 teraOPS, and each of these calculations is supported by hundreds of capacity calculations run at lower levels of computational complexity. However, the major driver for capability machines of the future, petaOPS and beyond, will be the need to model the additional physical phenomena that describe the time evolution of a nuclear device at the level of detail and fidelity that sufficient confidence demands. This includes both the requirements to simulate more sophisticated models with, for example, enhanced material models, as well as the computational load on developing those models. These capabilities will further minimize technological surprises and enable more accurate answers to questions beyond the current scope of the program.

In parallel with these efforts and in moving the program forward for future requirements, we continue to apply the new tools to a broad suite of ongoing stockpile issues and concerns and continue to meet commitments to specific deliverables related to DSW.

Model Validation, Solution Verification, and Computer Code Verification

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 to serve as the integrator for/of scientifically based decisions, our representations of weapons behavior must continue to be supported by increasingly detailed and sophisticated efforts in both verification and validation. As new models are incorporated into the codes, the models can only be rigorously tested against appropriate experiments to validate that they conform to physical reality. This strategy emphasizes the need for a strengthened program of validation and peer review that enables the users to quantify and then expand the parameter space currently spanned by the legacy codes.

Consequently, an important component of this "next ten year" strategy is to increase the emphasis on model validation through focused small-scale and intermediate-scale experiments driven by QMU (quantification of margins and uncertainties). The Science Campaigns have key responsibilities for experimental components of the Stockpile Stewardship Program. We will increase our integration with these Campaigns to the benefit of both. ASC provides the tools to help design experiments and analyze diagnostics, while the other Campaigns provide crucial assistance in conceiving, supporting, and fielding those experiments so keenly required by ASC for model validation. We are emphasizing a well-coordinated planning effort between experimental Campaigns and the ASC Campaign to define requirements and to ensure that experimental data gathered are relevant and then effectively used in model validation. As part of such an effort, one can imagine the development of ever-evolving validation suites that track and measure progress.

When algorithms are developed to represent both the existing and the new physics models in the codes, the approximations made must be understood and verified to ensure their correctness. Verification, like validation, has been viewed from the inception of the program as essential. Metrics are being developed that drive us toward, and provide confidence in, the ability of the mathematical models, algorithms codes, and physical data to represent the real world phenomena as intended. It is clear that the testing protocols will continue to be developed in order to address various components of our program. A verification suite of problems, agreed upon and tested by each of the laboratories, would enhance our

[2] See definitions in the Glossary.

comparisons and evaluations of the diversity of solution methodologies. Analytic calculations will further enable a deeper understanding of the accuracy of a particular approach.

In working towards the goal of credible simulations of nuclear-device behavior, it is appropriate to re-emphasize the role of mutual peer review among the laboratories, particularly as this applies peer review to code comparisons. At each laboratory, the designers, analysts, and code developers use their best judgment to select credible approximations, but each laboratory has its own experience base and its own philosophy in pursuing a "best" representation to the nuclear system. Certainly, an active policy of inter-laboratory peer review of the code development processes, perhaps modeled after the US/UK Joint Working Group (JOWOG) efforts, goes far to strengthen the scientific underpinnings of our efforts. All these efforts will need to incorporate serious software quality considerations to ensure the robustness of the codes necessary to the vitality of the program.

The strategy recognizes that the ASC Program is part of an integrated system that includes experiments, theories, and simulations. The experimental activities, code development, and computation needs will have to be integrated into an intellectual framework that includes a detailed quantification of uncertainties and leads to credible metrics of our confidence.

Computational Infrastructure

A powerful computational infrastructure is a key enabling technology for the ASC Program. Modern infrastructure includes many key components, from high-end storage and visualization systems to system software that is able to manage large numbers of processors and user software environments. Both the enhancement of predictive capability and the meeting of DSW simulation deliverables demand more powerful and sophisticated simulation environments. A recent requirements study done for the JASONs concluded that capability in excess of a petaflop will be needed within a decade to assess nuclear weapon performance. A 1-petaOPS computer has great symbolic value, but it is not the endpoint of the hardware core of the enterprise.[3] We recognize it as a way station along our continuing journey to provide the users with the tools that they must have for high-resolution, science-based predictive simulations toward the end of this decade and into the next decade. It is essential that the supporting infrastructure be sized to make these large computing systems usable. A simulation environment at this scale is necessary for understanding weapons performance; ASC has broken ground here, creating the first such production simulation environment, balancing data-generation capabilities with commensurate data-assessment capabilities.

Over the past decade, we have developed an expertise with this level of system that is unmatched in the history of large-scale computational science. Based on this experience, the ASC Program has refined its approach to the acquisition and use of large parallel-computing platforms.

To broaden the available long-term options, each institution will be encouraged to invest in new architectural directions in partnership with other federal agencies and computer vendors, whose business plans these investments can leverage. There are currently several major national initiatives focused on high-end computing. We are cognizant of these initiatives and continue to cooperate with, and learn from, other agencies to find cost-efficient options surfaced by these other studies that may serve our national security

[3] To give some perspective on a petaOPS computer, the 100 teraOPS platform (one-tenth of a petaOPS) was sized during original program planning activities to provide a one week turn-around time for 3-D weapons calculations, taking into account only the minimal resolution and physical models that would make such a calculation meaningful to designers. This sizing represents an entry-level calculation, still relying heavily on calibration of the codes of the time to Nevada test data. It is an important milestone, because it begins to make 3-D simulations analytical tools rather than just enabling a tour-de-force calculation. PetaOPS-scale platforms will provide similar one-week turn-around time for the more predictive class of the modern codes, currently under development. However, as we address emerging stockpile issues with improved science and the necessary higher resolution, computing in the petaOPS regime will become essential.

needs. Our emphasis is on meeting our mission-critical weapons' programmatic requirements, which leads us to select particular architectures suited to our workload. A necessary criterion is that the use of any new system be as transparent as possible to the user community, taking advantage of systems technologies that can serve as a bridge between the old and the new architectures. The optimal solution is one that meets requirements at low cost and with good overall functionality and enables continuity for the user community.

To allow informed decisions regarding choices of technology, it is critical to have a process for continuously monitoring performance and using those data to reduce the time to solution for each application on, perhaps, several platform architectures. In addition, since the complex codes and simulations that are at the heart of the ASC Program do much more than floating-point number operations, we are working to develop more meaningful metrics than the ratio of floating-point operations to peak speed. These metrics will measure the efficacy of our algorithms and demonstrate progress in improving the performance of the codes. While it is very attractive to have a single number that describes the power of a computer system and to use this number to determine the efficiency of applications, metrics tied to peak floating-point operations are deceptive for ASC applications.[4] Consequently, the ASC Program needs to pay attention to the issue of simulation efficiency that properly accounts for both machine and human time.

The speed of processors continues to increase, and it always will; however, processors are only one part of high-performance computing systems. A balanced high-end computing system has requirements that are not part of low-end systems and must be driven by ASC and other high-end computing programs within the government. Examples of areas that are required by ASC applications are processor-memory interfaces with increased speeds and lower memory latencies; processor interconnects that achieve dramatically increased bandwidths and decreased network latencies; reliability and resilience of the extremely large networked systems to errors; and programmability and usability of the systems through software enhancements. As has been true in the past, it continues to appear that without federal investment[5] as a forcing function, the industry will not naturally evolve to usable petaOPS-scale computing systems in the time required for responsible nuclear weapons stewardship. Hence, NNSA will have to continue to drive this high-end technology.

The ASC platform procurement strategy has been validated recently on the types of architectures, the associated code performance, and the size of platforms we have purchased. At the heart of this imprimatur is the credibility of the requirements drivers that were presented to the JASONs to support our acquisition strategy. It is incumbent upon the program to monitor and continually reevaluate these requirements, which are dynamic and tend to scale both with new findings that result from our surveillance activities as well as with the increased fidelity of the models we build into the codes. These requirements are the major input to the priorities we set, and we must be able to justify them and articulate their importance to sponsors and stakeholders on demand.

Implications

This evolving strategy emphasizes the need to focus on the development of a credible predictive capability and calls out the necessary pathways to accomplish this end. At the same time, it recognizes the imperative to continue to address Directed Stockpile deliverables on an ongoing basis. A great deal of work has been done in both the two-dimensional as well as the modern three-dimensional codes to incorporate the best models of the known behavior of a nuclear weapon into these codes. It is essential to build upon this work to create a predictive capability that will allow us to extrapolate outside the design

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[4] As a metric, "efficiency" focuses almost exclusively on hardware performance and does not provide a sufficiently robust measure of code performance and time-to-completion of large scientific calculations.

[5] *The Future of Supercomputing: An Interim Report*, National Research Council of the National Academies: Computer Science and Telecommunications Board, 2003, p. 30.

space bounded by nuclear test data. We are clearly in transition, and we have to engage in the work that is necessary to accelerate that transition and to reach the state where prediction with quantified confidence dominates. This is necessary to enable us to provide a greatly enhanced capability to our design community and permit it to affirm the robustness of the stockpile with scientific rigor.

The major implication around which the community can form a consensus is an increase in the emphasis on the long term. This is not a passive effort, waiting for science to catch up to our needs, but an active commitment to take certain steps. The program must allocate resources to those aspects of the program that contribute to deeper understanding of the physical phenomena and the implementation of better models based upon this understanding, even as it works to meet the day-to-day stockpile-related deliverables. We must acquire and allocate capability-machine resources for necessary capability calculations as well as for studies to test and better understand scaling and associated challenges of running over large computer systems. The motivation for siting a capability machine at a particular laboratory must be driven by the requirements of the national program.

Most particularly, we are working to collaborate closely with the Science Campaigns to ensure the vitality of the focused experimental programs upon which the credibility of new models depends.

This vision also requires that we attract scientists into the program who will learn about weapons and computational and experimental sciences within the context of science-based prediction. Partnerships and collaborations with universities remain an essential ingredient in this challenge—indeed, this vision requires science-based prediction to be a part of the academic and scientific foundation of the program.

Although we recognize the need to tie our predictive capability to a certification methodology and frame our discussion of the future in those terms, the details of this methodology remain to be worked out. The nuclear design laboratories, with appropriate support from the engineering community, must converge on the meaning of these terms and develop a road map that integrates prediction with quantifiable, defensible, and complementary certification methodologies.

Business Model

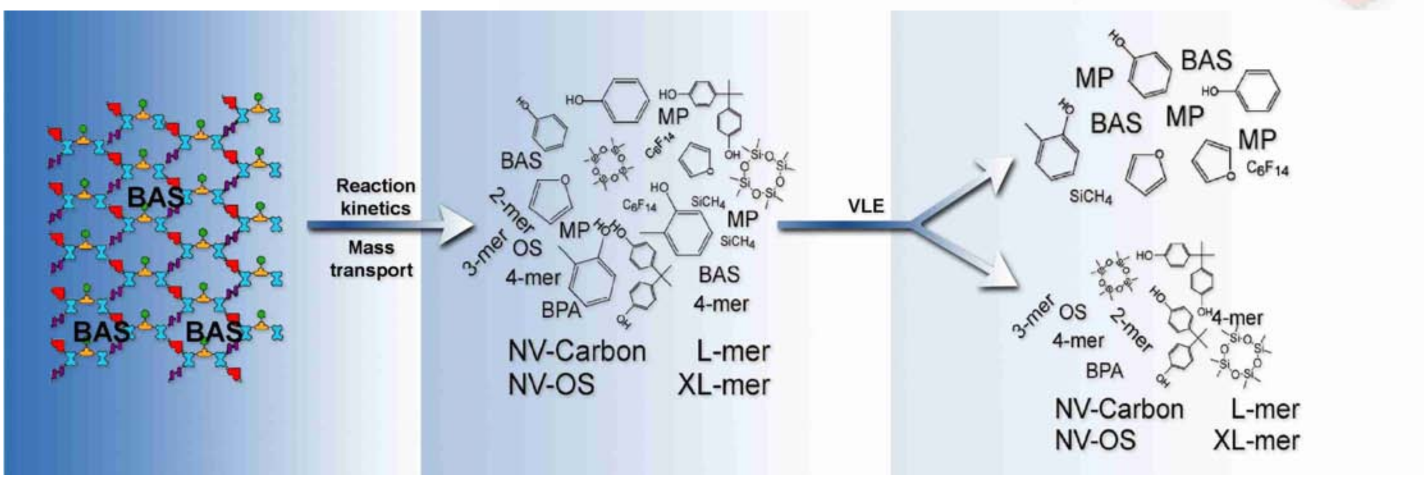
To support the implementation of this ten-year plan, we are developing a Business Model that reflects the requirements-driven underpinnings of this program. The Business Model is built on the precept that customers set requirements for suppliers and suppliers respond to those requirements. One goal of the Business Model is to increase visibility of the program's activities thus enhancing management's ability to set meaningful priorities for key program components. Prioritization will be done jointly by the federal staff and the weapons laboratories' senior leadership. By articulating in sufficient detail the purpose and products of funded activities, we can ensure that the higher priority work that is aligned with the goals of this ten-year plan is provided appropriate resources.

Making our Business Model explicit will enhance our ability to explain this program to those who are not intimately familiar with its purposes or its products. A clear exposition of the programmatic activities performed at the three weapons laboratories will facilitate the ability of the federal managers to inform Congressional staff of the immediate and future challenges and the past and present successes of the program. We must be able to answer stakeholders who question our pursuit of advanced simulation ten years after the beginnings of this initiative. By emphasizing the continuing importance of our work to our customers, we highlight both the near- and long-term relevance of our products to national security needs.

This Business Model provides a framework to explain the logic of the entire ASC program, and this framework will be populated by the data on the activities it encompasses. Our goal is to take these data and synthesize them into a coherent story that transmits the importance, the vitality, and the relevance of the program in a compelling way.

Conclusion

The overarching message of this ASC strategy is to maintain a balanced program—one that meets short- and intermediate-term stockpile needs, yet preserves enough flexibility for our scientists to advance toward a robust predictive capability. Science-based prediction cannot be sacrificed for short-term needs. For us to maintain the stockpile over the long term without testing, we must reduce the level of phenomenology and make significant advances in our ability to predict outside our normal calculational zone. The codes must be capable of simulating discoveries in the surveillance process, identifying potential failures, evaluating alternative design options for reducing uncertainty or increasing performance margins, considering advanced concepts, analyzing abnormal and primitive devices, and confronting other features that drive us outside the parameter space bounded by nuclear tests. With this strategy emphasizing a focused and concerted effort, we will achieve the challenging and essential goal of true science-based prediction in the time evolution of a nuclear device, keep pace with the challenges of an aging stockpile, and develop an understanding of the complexities of new initiatives without the benefit of full-scale testing.

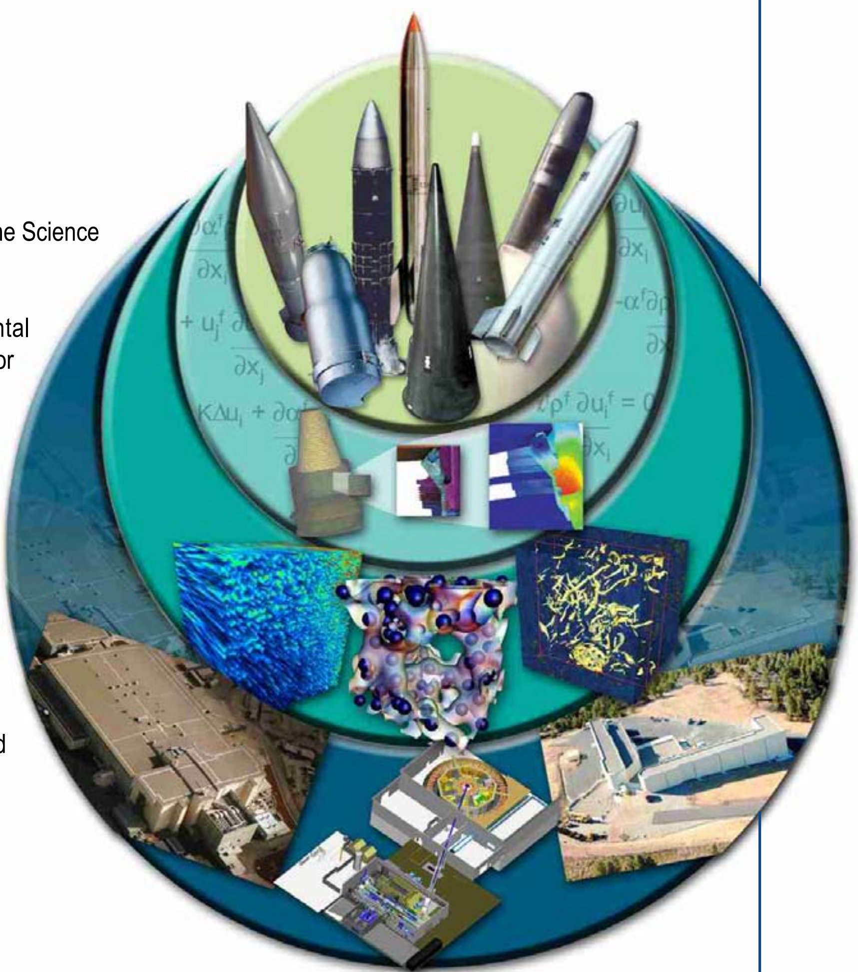


This illustration shows complex decomposition models that are based on the chemical structure of polymeric foams. The first image represents the most probable repeating unit of a polymer, essentially an infinite network composed of various sites and bridges from the ingredients used to synthesize the polymer (BAS = Blowing Agent Surfactants). When the polymeric foam is subjected to an abnormal thermal environment (fire) the repeating polymeric structure breaks into fragments, either condensed or gas phase. This is the second image. The phase partition is based on vapor/liquid equilibrium. (BPA = Bisphenol-A, OS = Octamethyl-cyclo-tetra-siloxane, MP= mixed products) This is the third image.

An enlargement of the first image above appears throughout this document.(Courtesy: Sandia National Laboratories.)

This graphic illustrates ASC's interactions with the Science and Directed Stockpile Work Campaigns.

The outermost layer shows NNSA experimental facilities that provide the elements of discovery for the development of theoretical models–models that describe the physics of nuclear weapons. Within the next layer, these theoretical models represent the basis of sub-grid scale simulations. The third layer shows continuum-scale simulations of weapon components and sub-components that are validated by experimental data from the same or similar experimental facilities. Finally, the innermost layer depicts full-scale weapons to which system-level simulations are applied for assessing safety and reliability with quantified design margins and uncertainties.



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National Nuclear Security Administration