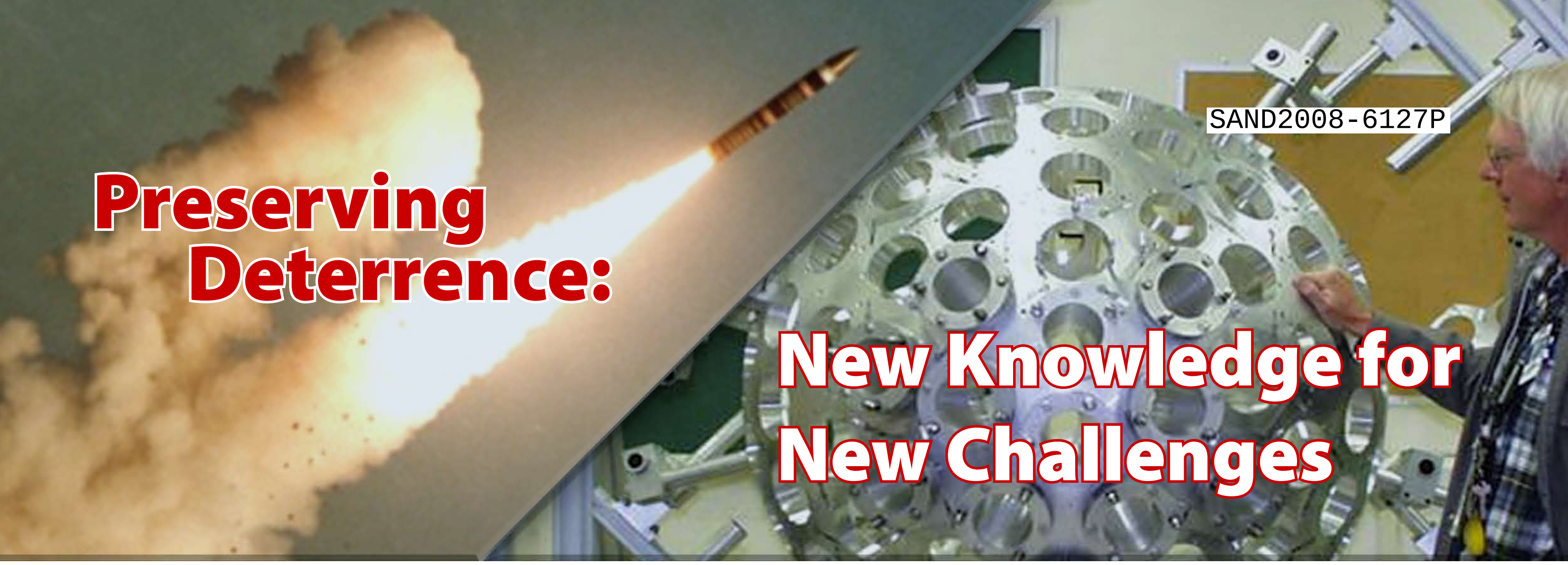


SAND2008-6127P

Preserving Deterrence:

New Knowledge for New Challenges

Deterrence is central to U.S. national security strategy. Preserving our nation's nuclear stockpile safely and securely is a responsibility of the National Nuclear Security Administration (NNSA). A critical and enabling element of our deterrence posture is the scientific, technological and engineering (ST&E) excellence of NNSA's Nuclear Weapon Complex. With a healthy ST&E foundation (both human and physical capital), we can certify the existing and future stockpile without nuclear testing, achieving the purpose of the NNSA Stockpile Stewardship Program.

A critical and enabling element of our deterrence posture is the scientific, technological and engineering (ST&E) excellence of NNSA's Nuclear Weapon Complex.

The Stockpile Stewardship Program's continued success depends on the knowledge generated by our skilled scientists, engineers and technicians using some of the world's finest, most modern experimental and computational facilities. It is this skilled workforce that has the formidable task of using knowledge to steward a smaller, older and possibly modernized stockpile. Weapons in the stockpile change with age and therefore must be modified through life extension programs to maintain their safety and reliability. They can significantly differ from those fielded at the end of the U.S. nuclear testing era in 1992. For both existing and modernized weapons, continued scientific exploration is imperative if we are to continue succeeding in our stockpile stewardship mission – providing confidence that U.S. nuclear weapons remain safe, secure and reliable.

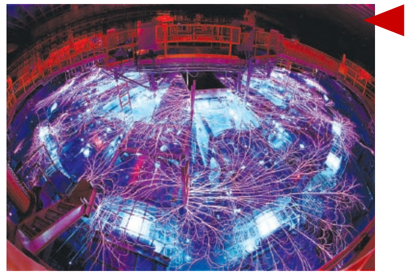
To continue to succeed in our mission, ST&E investments are required to advance the scientific understanding that we need to: (1) certify nuclear detonation performance and reliability; (2) develop and certify the integrated weapon systems with both aged components and new technologies; (3) qualify manufacturing processes and deploy new technologies to "warranty" weapons throughout their life; and (4) predict weapon behavior at each of these life cycle stages, with quantification of the uncertainties in our assessments. New knowledge also strengthens deterrence by giving us the means to anticipate, prevent, deter or respond quickly to both known and future nuclear and nonnuclear threats

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

CHALLENGES IN PRESERVING DETERRENCE

CERTIFYING NUCLEAR DETONATION PERFORMANCE AND RELIABILITY

Major uncertainties exist in our knowledge of nuclear detonation processes, including boost (fusion ignition) and energy balance. As a result, the challenge to certify the performance and reliability of our weapons is becoming increasingly difficult as our weapons change over time. Comprehensive understanding of detonation processes is also needed for us to thoroughly assess new technologies for enhancing safety and security. Further scientific investigations used to address these issues and to quantify uncertainties are:



Material Properties and Dynamics

Better knowledge is needed of the material properties of nuclear materials and high explosives and their response under extreme pressures and temperatures. This knowledge will improve our ability to assess and to predict how nuclear weapons will perform during the implosion phase of nuclear detonation.

Nuclear Physics

Improved accuracy measurements of nuclear reactions, the major source of energy in nuclear weapons, are needed to reduce the uncertainty in our ability to predict nuclear detonation.

TOP: Experiments on the ZR Facility probe material behavior under extreme conditions.

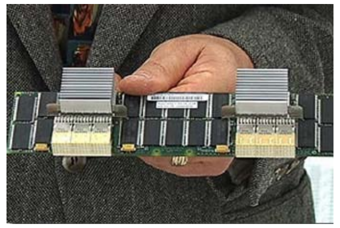
BOTTOM: The LANSCE Facility provides high-energy neutron sources for research in weapons nuclear science, high-explosive science, actinide science, materials and condensed matter science, hydrodynamics and proton radiography. Shown is a nuclear-science detector.

Hydrodynamics

Hydrodynamic investigations are needed to advance our scientific understanding of fluid flow, instabilities, material mixing, and shock propagation during the implosion phase. Quantification of Margins and Uncertainties (QMU) in this and other areas will draw on the data gathered by computation simulation on the most advanced supercomputers and new experiments on the latest and most modern facilities.

TOP: Experiments at the DARHT Facility improve our ability to predict implosion dynamics.

BOTTOM: NNSA supercomputer, Roadrunner , executing one million billion calculations per second, simulates nuclear detonation.



High Energy-Density Physics

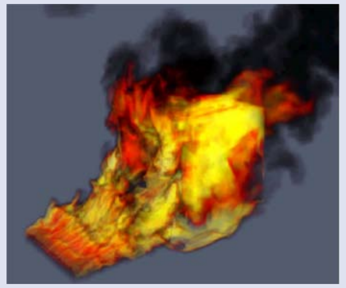
New research into the physics and properties of high energy density plasmas provides insights and enables prediction of the onset of nuclear detonation and the behavior of materials and radiation during and after detonation. This research allows us to make predictive models of nuclear performance and reliability for certification that rely less on decades-old underground nuclear testing data and that can complement and interpret that data.

TOP: Target chamber of the National Ignition Facility designed to create controlled fusion.

BOTTOM: Calculations on NNSA's supercomputer, BlueGene/L, refine the design of the National Ignition Facility. Shown is a unique BlueGene/L computer card.

DEVELOPING AND CERTIFYING THE INTEGRATED WEAPON SYSTEM

Deploying new technologies, including those that enhance safety and security, and certifying that these necessary changes to the integrated weapon systems do not affect reliability, performance or survivability presents many challenges. New ST&E capabilities are needed to design, develop, certify, and produce new nonnuclear components such as arming, fuzing and firing (AF&F) systems, neutron generators, and gas transfer systems, as well as to integrate the nonnuclear components with nuclear explosives and the military delivery systems. Applied science and engineering used to address these issues and to quantify uncertainties include:

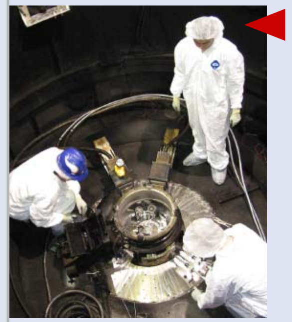


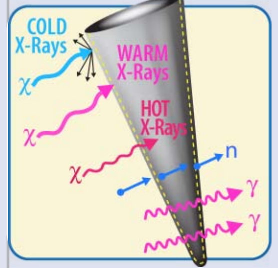
Engineering Sciences

NNSA investment in a diverse set of engineering areas associated with material and component failure provides scientific understanding and the ability to predict weapon system response in many scenarios and environments, such as accidents, fires, lightning, and re-entry. This understanding enables us to certify that an integrated nuclear weapon (aged, refurbished, or modernized) will remain safe, secure, and reliable throughout its life cycle, which can exceed 30 years.

TOP: Experiments at environmental testing facilities provide data, which in combination with computer simulations, help to certify that our weapons are safe in accident scenarios.

BOTTOM: Calculation of a fire interacting with an object in a transportation container.





Radiation Effects Sciences

To be effective as a deterrent, our weapon systems must be certified to survive radiation countermeasures. As new technologies are introduced into weapon systems, or as weapon systems age, scientific understanding ensures that weapons can survive a diverse set of radiation effects, including electromagnetic pulse (EMP) effects. Such knowledge fills in the gap left by testing environments that are no longer available: underground nuclear tests and reactor facilities that have been decommissioned.

TOP: Experiments on pulsed-power facilities provide data, which in combination with computer simulations, help to certify that our weapons will survive radiation.

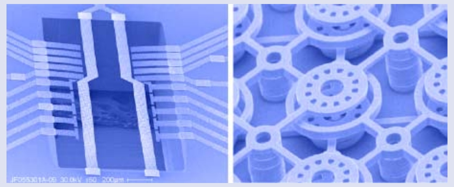
BOTTOM: Without proper design and certification, our nuclear weapons could be vulnerable to radiation bursts.

Deployment of Microengineering and Nano-Science Technologies

Advances in microelectronics, microelectromechanical systems (which combine electronics with mechanical devices), and nano-science offer new solutions for making replacement nonnuclear components more safe, secure, and reliable.

TOP: The MESA Facility provides the manufacturing of radiation-resistant integrated circuits and other advanced technologies.

RIGHT: Microelectronic and microsystem technologies.



DEPLOYING TECHNOLOGIES FOR THE "LIFETIME WARRANTY"

Research and development of advanced technologies is needed to more effectively manufacture, monitor, maintain and retire nuclear weapons. Applied science and engineering that we use to address these issues include:

ABOVE: Experiments help us to understand manufacturing processes

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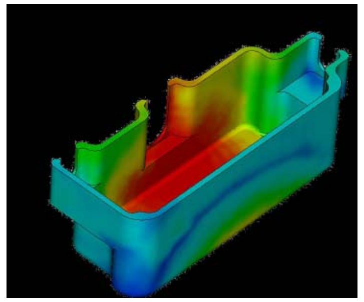
Manufacturing Technologies

Advanced manufacturing technologies will be needed as new scientific understanding allows better prediction of the performance, aging and lifetime of materials and components. Continued research in new manufacturing technologies will take advantage of our science-based knowledge to lead to efficient and cost-effective technologies while integrating new engineering approaches and eliminating hazardous materials and outdated processes.



LEFT: Computational simulation also helps us to understand manufacturing processes.

Deployment of Novel Technologies for Stockpile Surveillance, Maintenance, and Retirement

Novel technologies need to be developed to reduce the unique life cycle costs of nuclear weapons. With research and development, more effective means will be found for post-production discovery of weapon design issues, to detect and address problems (stockpile surveillance), to embed diagnostics to make a nuclear weapon "self aware" of its environment and state of health (maintenance), and to safely dismantle nuclear weapons at their end of life in an environmentally benign manner.

LEFT: New surveillance technology is deployed to detect defects.

RIGHT: Improving the maintainability of weapon systems is an especially important issue for the Department of Defense.

CONCLUSION

It is thus evident that the scientific capabilities of the Nuclear Weapon Complex are critical national assets supporting NNSA's mission to preserve deterrence. There are many important elements: best and brightest staff, and world-class experimental facilities in the service of nuclear weapon design and certification. Investment in the science, technology and engineering capabilities ensures the continued security, safety, and reliability of the existing and future stockpile. These NNSA capabilities also provide U.S. decision makers with the ability to understand the state of international scientific and technological advances and to project how those advances could change the direction and effectiveness of U.S. national policy and posture.

For more details, please refer to: "Advancing Science, Technology and Engineering for Nuclear Deterrence " (September 2008)

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