Science, Technology, and Engineering for Stockpile Stewardship

Overview

This brochure describes the framework upon which the National Nuclear Security Administration (NNSA) science, technology, and engineering (ST&E) activities are focused to ensure the US nuclear weapons stockpile remains safe, secure, and reliable. ST&E is the foundation of our nation's Stockpile Stewardship Program (SSP), and has been an essential element in the ability to annually assess and certify the stockpile without underground nuclear testing, as required by Presidential Directive since 1995. In addition, a strong ST&E base allows the nation to rapidly respond to a stockpile "surprise" or to a change in the security environment. The scale of ST&E for Stockpile Stewardship is largely independent of weapons types and numbers of weapons because the scientific challenges assessing weapons performance for an aging stockpile or any future stockpile are similar. Our nation's ST&E activities for the SSP are the responsibility of the NNSA National Security Laboratories – Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), and Lawrence Livermore National Laboratory (LLNL) – and the Nevada Test Site (NTS).

Mission

The current stockpile consists of sea-based, land-based, and air-carried systems that have been in service for over 20 years. The performance of the complex nuclear explosive packages as well as many non-nuclear components in these weapons systems was historically validated with underground nuclear tests. Now, confidence in our annual assessments requires a vigorous science-based SSP. Critical mission drivers for NNSA ST&E activities include:

- Developing and ensuring a more robust, scientifically sound, peer reviewed, certification basis using quantification of margins and uncertainties for assessments;
- Conducting an aggressive surveillance program to identify defects to enable system refurbishments before aging degrades safety and performance;
- Supporting refurbishment schedules agreed to with the Department of Defense;
- Developing and assessing strategies for the future stockpile; and
- Enhancing surety (safety and security) at every opportunity.

Challenges

Meeting the SSP requirement of quantitatively and accurately assessing weapons system performance necessitates science-based predictive capability. ST&E Challenges for predictive capability have been identified by the weapons design community at the NNSA National Security Laboratories. Resolution of these Challenges are planned using near- (2009–2012), mid- (2013–2015), and far- (>2016) term NNSA goals.

Science, Technology, and Engineering Campaigns

NNSA integrates and manages the ST&E activities through Campaigns individually funded by the Congress. Because of the complexity and cross-cutting nature underlying each Challenge, multiple Campaigns are usually required for their resolution.

Key Capabilities

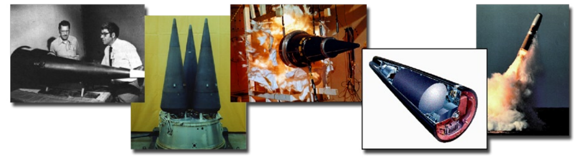
The NNSA National Security Laboratories require a broad capability base performing world-class science to fulfill their Stockpile Stewardship mission. The Challenges that must be addressed require multidisciplinary Capabilities. The same capability suite is also critical to other national security imperatives, attracts world-class talent to the NNSA National Security Laboratories, and is the basis of NNSA investments in ST&E at US universities.

Major Facilities

NNSA supports an extensive ST&E infrastructure that underpins these Capabilities, including unique and specialized facilities developed over decades at LANL, SNL, LLNL, and NTS.

Mission

	B61-3/4/10	B61-7/11	B83	W80-0/1
Description	Non-Strategic Bomb	Strategic Bomb	Strategic Bomb	TLAM-N Warhead (Navy) ALCM Warhead (Air Force)
Delivery System	F-15, F-16, NATO Tornado	B-52 (-7), B-2 (-7/11)	B-52, B-2	SSN Attack Submarine (-0) B-52 (-1)
Labs	LANL & SNL	LANL & SNL	LLNL & SNL	LLNL & SNL
Primary Use	Air to Surface	Air to Surface	Air to Surface	Underwater to Surface Air to Surface
Service	Air Force	Air Force	Air Force	Navy, Air Force
Date Entered Stockpile	Sep 1979 (-3), Aug 1979 (-4), Aug 1990 (-10)	Sep 1985 (-7), Nov 1997 (-11)	Sep 1983	Mar 1984 (-0), Feb 1982 (-1)

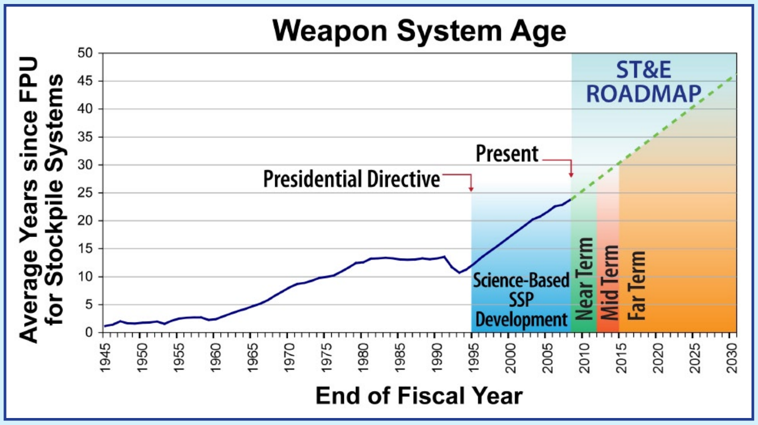


	W62	W78	W87	W76	W88
Description	ICBM Warhead	ICBM Warhead	ICBM Warhead	SLBM Warhead	SLBM Warhead
Delivery System	Minuteman III	Minuteman III	Minuteman III	Trident II (D5)	Trident II (D5)
Labs	LLNL & SNL	LANL & SNL	LLNL & SNL	LANL & SNL	LANL & SNL
Primary Use	Surface to Surface	Surface to Surface	Surface to Surface	Underwater to Surface	Underwater to Surface
Service	Air Force	Air Force	Air Force	Navy	Navy
Date Entered Stockpile	Apr 1970	Sep 1979	Jul 1986	Nov 1978	Jun 1989

Challenges

Nuclear Explosive Package (NEP) Performance
- Initial Conditions for Boost
- Boost
- Energy Balance
- Secondary Performance

Engineering Assessment
- Engineering of Integrated Weapon Systems: Material, Component and System Response
- Manufacturing



Surety
- Weapons Safety
- Use Control and Security
- Nuclear Explosive Package Surety

Survivability
- Electrical Radiation Effects
- Mechanical/Thermal Radiation Effects
- Nuclear Explosive Package Survivability
- Radiation Output Predictions

Science, Technology, and Engineering Campaigns

Science
- **Advanced Certification**
- Primary Assessment Technologies
- Dynamic Plutonium Experiments
- Dynamic Materials Properties
- Advanced Radiography
- Secondary Assessment Technologies
- Test Readiness

Inertial Confinement Fusion (ICF) and High Yield Campaign
- Ignition
- NIF Experimental Support
- Pulsed Power ICF
- Facility Operations and Target Production

ST&E Roadmap Mission Challenges

Campaigns	Nuclear Explosive Package Performance				Surety			Engineering Assess		Survivability			
	Initial Conditions for Boost	Boost	Energy Balance	Secondary Performance	Weapon Safety	Use Control and Security	NEP Surety	Integrated System Engineering	Manufacturing	Electrical Radiation Effects	Mechanical/Thermal Radiation Effects	NEP Survivability	Radiation Output Predictions
Science	■	■	■	■	■	■	■		■				■
Advanced Certification	■	■	■	■	■	■	■		■	■	■	■	
ICF		■	■	■									■
ASC	■	■	■	■	■	■	■	■	■	■	■	■	■
Engineering					■	■		■	■	■	■	■	■
Readiness					■				■				

■ *Required for Challenge resolution*

Advanced Simulation and Computing (ASC)
- Integrated Codes
- Physics and Engineering Models
- Verification and Validation
- Computational Systems and Software Environment
- Facility Operation and User Support

Readiness
- Stockpile Readiness
- High Explosives and Weapons Operations
- Non-nuclear Readiness
- Tritium Readiness
- Advanced Design and Production Technologies

Engineering
- Enhanced Surety
- Weapons Systems Engineering Assessment Technology
- Nuclear Survivability
- Enhanced Surveillance

Key Capabilities

ST&E Roadmap Mission Challenges

		Nuclear Explosive Package Performance				Surety			Engineering Assess		Survivability			
		Initial Conditions for Boost	Boost	Energy Balance	Secondary Performance	Weapon Safety	Use Control and Security	NEP Surety	Integrated System Engineering	Manufacturing	Electrical Radiation Effects	Mechanical/Thermal Radiaiton Effects	NEP Survivability	Radiaiton Output Predictions
Capabilities	Material Dynamics	■		■	■			■						■
Capabilities	Nuclear Physics	■	■		■			■						■
Capabilities	Hydrodynamics		■	■	■									■
Capabilities	High Energy Density Physics		■	■	■									■
Capabilities	Engineering Sciences					■	■	■	■					
Capabilities	Materials Science					■		■	■	■	■	■	■	
Capabilities	Rad Effects Sciences										■	■	■	
Capabilities	Microelectronics & Microsystems					■	■			■	■			
Capabilities	Computational Science	■	■	■	■	■	■	■	■	■	■	■	■	■
Tools	Simulation and Modeling	■	■	■	■	■	■	■	■	■	■	■	■	■
Tools	QMU	■	■	■	■	■	■	■	■	■	■	■	■	■

■ *Required for Challenge resolution*

The nation's Stockpile Stewardship Program requires the in-depth focus and integration of theoretical, computational, and experimental capabilities spanning diverse disciplines, including:

- **Material Dynamics:** Thermodynamic and constitutive properties, structural phase transformation, equation of state, behavior of warm dense matter
- **Nuclear Physics:** Cross sections for nuclear and thermonuclear reactions
- **Hydrodynamics:** Instabilities, shock propagation
- **High Energy Density Physics** (**HEDP**)**:** Thermonuclear processes
- **Engineering Sciences:** Solid mechanics, structural dynamics, thermal/fluid science, fire science, aero-science, multiphase flow, electrical science
- **Materials Science:** Elasticity and plasticity of materials, material damage and failure, material aging and stability, process-aware materials
- **Radiation Effects Science:** Radiation-material interactions including displacement damage, photocurrent generation and response, electromagnetic pulse effects, thermo-mechanical response, thermo-structural response
- **Microelectronics and Microsystems:** Radiation-hardened microelectronics, micro-electromechanical systems (MEMS), optoelectronics, sensors
- **Computational Science:** High-performance computing systems and operating environments, algorithms for efficient performance on massively parallel, heterogeneous, and other computers, fundamental physical data archives, remotely accessible visualization and data-analysis infrastructure
- **Simulation and Modeling**: First-principles-based physics codes and models, inter-linked-mechanism engineering codes and models, verified and validated codes
- **Quantification of Margins and Uncertainties** (**QMU**)**:** Uncertainty quantification, margin assessment, confidence factors

Major Facilities

ST&E Roadmap Mission Challenges

		Nuclear Explosive Package Performance				Surety			Engineering Assess		Survivability			
		Initial Conditions for Boost	Boost	Energy Balance	Secondary Performance	Weapon Safety	Use Control and Security	NEP Surety	Integrated System Engineering	Manufacturing	Electrical Radiation Effects	Mechanical/Thermal Radiation Effects	NEP Survivability	Radiation Output Predictions
Major Experimental & Computational Facilities	DARHT / CFF	■	■	■	■	■		■						
Major Experimental & Computational Facilities	LANSCE / P-Rad	■		■	■			■						■
Major Experimental & Computational Facilities	NIF / Omega / Z	■	■	■	■						■	■		■
Major Experimental & Computational Facilities	HEAF	■	■			■	■	■	■					
Major Experimental & Computational Facilities	CMR	■	■			■	■	■	■					
Major Experimental & Computational Facilities	JASPER	■												
Major Experimental & Computational Facilities	U1A	■												
Major Experimental & Computational Facilities	Environmental Test					■			■		■	■	■	
Major Experimental & Computational Facilities	MESA					■	■		■	■				
Major Experimental & Computational Facilities	ASC Platforms	■	■	■	■	■	■	■	■	■	■	■	■	■

■ *Required for Challenge resolution*

- **DARHT / CFF:** The Dual-Axis Radiographic Hydrodynamic Test Facility at LANL and the Contained Firing Facility at LLNL provide capability for imaging implosions to validate nuclear detonation codes.
- **LANSCE / P-Rad:** The Los Alamos Neutron Science Center / Proton-Radiography at LANL provides capabilities to image high-explosive burn, measure nuclear cross sections, and conduct material dynamic experiments.
- **NIF / Omega / Z:** The National Ignition Facility at LLNL, the Omega laser facility at the University of Rochester, and the Z-machine at SNL provide capabilities for research into HEDP, ICF, and material dynamics.
- **HEAF:** The High Explosive Application Facility at LLNL provides capability to investigate explosive properties and reactions.
- **CMR:** The Chemistry and Metallurgy Research Facility at LANL provides capabilities for metallurgical research on plutonium and other special nuclear materials.
- **JASPER:** The Joint Actinide Shock Physics Experimental Research Facility developed by LLNL and located at the NTS provides special nuclear materials property data at high shock pressures, temperatures, and strain rates.
- **U1A:** The U1A Facility located at NTS and used by LLNL, LANL, and SNL provides capability for subcritical physics experiments providing material and system response data.
- **Environmental Test:** Major Environmental Test Facilities at SNL provide experimental capabilities for research and testing of the reliability of nuclear weapon components in normal, abnormal, and hostile radiation environments.
- **MESA:** The Microsystems and Engineering Sciences Applications Facility at SNL provides experimental capabilities to research, design, develop, and produce custom war-reserve radiation-hardened microelectronics and microsystems.
- **ASC Platforms (Supercomputers):** Supercomputer facilities include general-purpose, large, leadership-class capability machines such as Red Storm (SNL), Purple (LLNL), and Zia (LANL); general-purpose capacity systems; and advanced architecture systems such as BlueGene/L (LLNL) and Roadrunner (LANL).

For additional information, http://www.nnsa.energy.gov/

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