

# STRATEGIC DETERRENCE



Ensuring national security with a modernized nuclear weapons stockpile and a responsive nuclear security enterprise

The joint LLNL-Y12 Product Realization Team celebrates the First Production Unit of the W80-4 canned subassembly on September 22, 2025. (Photo courtesy of Y-12.)

LLNL's foremost responsibility is strategic deterrence. The Laboratory is sustaining weapons systems in the nation's nuclear arsenal as it engages in programs and partnerships that jointly modernize the stockpile and the weapons production enterprise. Effective deterrence relies not only on the nation's deployed weapons systems but also on the extensive science and technology (S&T) capabilities of its national security laboratories and the agility of the nuclear security enterprise (NSE) to respond to emerging national needs.

## STRATEGIC MODERNIZATION PROGRAMS

LLNL is the design agency partnering with Sandia National Laboratories (SNL), production agencies, and the U.S. Air Force to develop, deliver, and certify the W80-4 warhead for the Long-Range Standoff (LRSO) missile in

the air leg of the nuclear deterrent. The W80-4 will reuse existing designs while modernizing some components and incorporating additional safety features. The Life Extension Program (LEP), which currently is in Phase 6.4 (production engineering), is taking advantage of new manufacturing methods that help meet key requirements, minimize costs, increase throughput, and reduce the need for environmentally sensitive materials and processes. Product realization teams (PRTs) are approaching final milestones for design and production development. First Production Unit (FPU) of the W80-4 is scheduled for September 2027.

Production engineering fully engages partnerships across the NSE to improve the producibility of components. Nearly all component PRT Final Design Reviews were completed by the end of FY 2025. Other key successes include

Qualification Engineering Releases and FPUs for many components (see p. 5). Teams supported multiple flight tests of the LRSO with the U.S. Air Force. One test successfully flew and detonated main charge explosives. For the technical challenges that remain in the LEP, options have been developed to meet system delivery timelines.

LLNL and SNL are also the design agencies for the W87-1 Modification (Mod) Program. The laboratories are working with partners across the NNSA and the U.S. Air Force to deliver a warhead to replace the aging W78. The W87-1 will be the first modern warhead that is 100 percent newly manufactured; it will be deployed on the Sentinel ballistic missile that is under development. The W87-1 currently is in Phase 6.3 (engineering development). Program plans have been adjusted to meet an FY 2033 FPU to align with

a delayed Sentinel flight schedule. Development activities are proceeding on schedule, and LLNL has worked with production agency partners to pre-plan FPU dates for components to minimize overlap with production of the Los Alamos National Laboratory (LANL)-designed W93 warhead.

The W87-1 Mod team is introducing new materials, manufacturing techniques, and processes to meet W87-1 and future stockpile systems requirements. Advances in design and assessment tools will enable certification of the new warhead without nuclear explosive testing. Two major hydrodynamic tests were successfully fired in spring 2025 and several engineering tests were completed that provided key data to strengthen confidence in the design. Technical work is proceeding at a rapid pace, and by the end of FY 2025, nearly half of the W87-1 Mod PRTs had completed their baseline design reviews.

In early 2025, NNSA selected LLNL as the design agency for the Sea-Launched Cruise Missile-Nuclear, which is now designated as the W80-5. Deployment of the W80-5 will bolster deterrence of adversarial limited nuclear use. The W80-5 Modification Program is in Phase 6.2 (feasibility study and design options). PRTs were formed and have developed the Weapon Design and Cost Report, a key step to enter Phase 6.3 (engineering development), which is expected in early FY 2026. The W80-5 will proceed on a relatively compressed schedule compared to current NSE modernization programs and marks a welcome return of the LLNL's nuclear partnership with the U.S. Navy.

## PRODUCTION PARTNERSHIPS AND CERTIFICATION

Success in the modernization programs requires an integrated effort within the NSE and strong partnerships with the U.S. Air Force, U.S. Navy, and their contractors. LLNL is spearheading groundbreaking initiatives to develop innovative materials and manufacturing techniques in conjunction with NNSA production agencies. The Polymer Enclave at LLNL has enabled researchers from the Laboratory and the Kansas City National Security Center to work side-by-side. This collaboration has led to a joint pilot demonstration of a product-lifecycle digital thread for direct-ink-writing parts.



At the Site 300 EMDEC Pilot Plant, an NNSA visitor is shown the new 200-liter reactor, which enables LLNL to produce sufficient quantities of new or improved HE materials to meet its testing needs without relying on an outside partner for scaling up synthesis.

Launched in 2022, LLNL's Energetic Materials Development Enclave Campus (EMDEC) has strengthened partnerships within the NSE (see p. 7). This important collaborative effort of LLNL and the Pantex Plant is focused on the time-urgent need to manufacture insensitive high-explosive (IHE) components for the strategic modernization programs. In addition, LLNL and the Y-12 National Security Complex teamed up to rapidly modernize technology and production methods for crucial special materials. Near the end of FY 2025 and ahead of schedule, Y-12 produced the first "diamond-stamped" certified W80-4 canned subassembly, which contains the weapon's secondary stage.

Livermore is also at the forefront of NNSA's digital transformation initiative. Transformation entails simplifying and standardizing information-sharing, building a modern digital infrastructure, and adopting digital engineering practices. As a major first step, NNSA

launched the Enterprise Secure Network (ESN) Hub, a centralized classified computing environment that allows for accelerated virtual design cycles that are crucial to streamlining collaboration within the NSE. LLNL is serving as the ESN Hub's primary data center.

Key S&T capabilities at Livermore are essential to the design and certification of these and future new strategic systems. As discussed elsewhere, experiments at the National Ignition Facility gather vital data about the performance of materials and systems at extreme conditions and weapon survivability in hostile threat environments (see pp. 8-9). The El Capitan supercomputer enables the modeling of weapons at high-fidelity resolution and quantification of uncertainties in performance (see p. 6). In addition, LLNL's Superblock performs key activities that support certification of newly manufactured primary pits (see pp. 20-21).



Inside the Contained Firing Facility control room, LLNL technicians ensure precision and safety for the milestone 200th experiment.

**ANNUAL STOCKPILE ASSESSMENT**

In FY 2025, LLNL completed Cycle 30 of the annual stockpile assessment. The process included a formal comprehensive peer review between LLNL and LANL of each other's weapon systems. Testing and analysis activities enabled sustainment and assessment of the condition of the B83, W80-1, and W87-0 stockpile systems. These efforts relied on data gathered at the National Ignition Facility and other advanced experimental tools, improvements in understanding effect of material aging, and the use of high-resolution 3D analyses.

**EL CAPITAN: THE WORLD'S MOST POWERFUL COMPUTER**

In November 2024, LLNL, in collaboration with NNSA, Hewlett Packard Enterprise, and Advanced Micro Devices Inc., officially unveiled El Capitan as the world's most powerful supercomputer. The TOP500 organization verified the system's performance at 1.742 exaFLOPs (1.742 quintillion calculations per second) using its standard benchmarking tool. El Capitan currently retains its TOP500 leadership at even greater measured performance. In January, government officials, industry leaders, and Laboratory employees gathered to dedicate the machine as the first exascale system applied to

national security. With more than 11,000 compute nodes and 5.43 petabytes of total memory, El Capitan has a total peak performance of 2.79 exaFLOPs. An exascale computer can, in one second, outperform the combined effort of a billion people calculating day and night for more than a decade.

The exascale El Capitan supercomputer provides NNSA-laboratory scientists and engineers an order-of-magnitude leap forward in modeling weapon performance and safety in high-fidelity resolution with quantified uncertainties. Capabilities to routinely run large-scale 3D models are essential for maintaining an aging stockpile and certifying modernized weapon systems. In one day of operation, El Capitan can run 3,000 standard resolution 3D problems or 170 high-resolution problems. The supercomputer will also accelerate progress in inertial confinement fusion, enable discoveries in material behavior under extreme conditions, and support other critical nuclear security missions such as nonproliferation and counterterrorism.

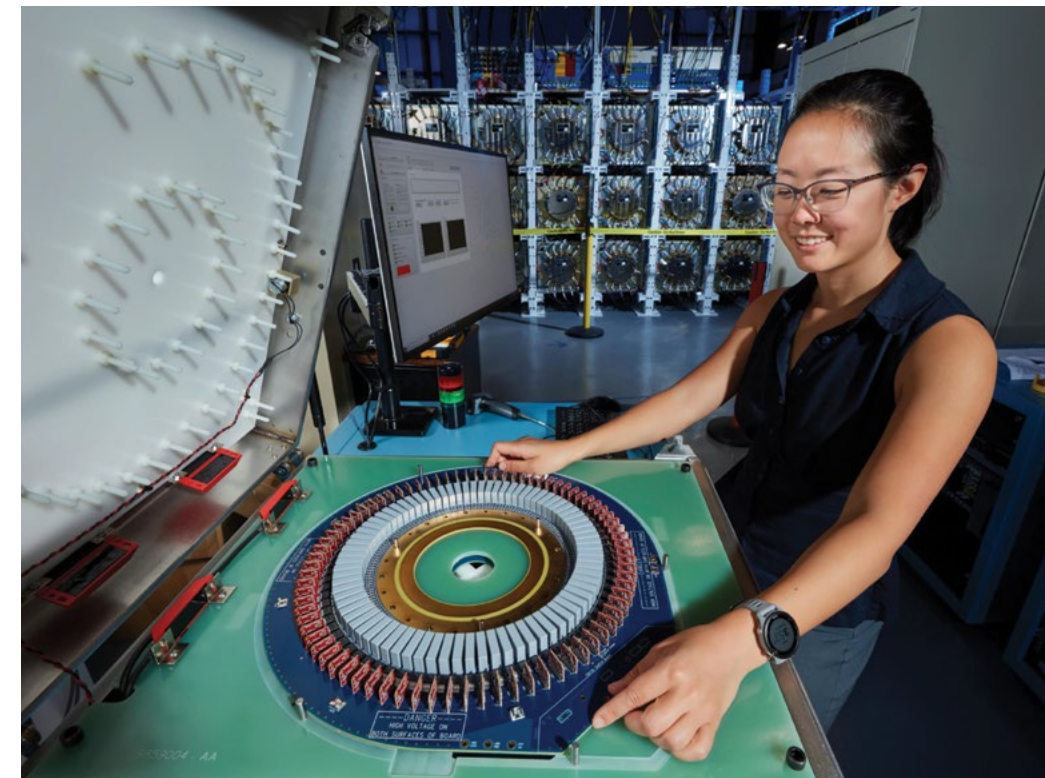
Prior to March 2024, El Capitan demonstrated its remarkable capabilities for unclassified research, including one project that was awarded the Gordon Bell Prize in November 2025 (see p. 16). El Capitan was later moved to the

classified network and after six months of final preparation, the machine made its official transition to classified production use in September.

**SITE 300, GROWING AT THE AGE OF 70**

The Laboratory's Site 300 reached its 70<sup>th</sup> anniversary in 2025. Since 1955, the 7,000-acre remote site has supported LLNL's national security missions, providing specialized high-explosive (HE) capabilities including synthesis, formulation, manufacturing, machining, testing, and disposal. Site 300 is home to the Contained Firing Facility (CFF). Large-scale, non-nuclear experiments are conducted within CFF with full containment of hazardous materials. In FY 2025, CFF achieved a major milestone: its 200<sup>th</sup> explosive experiment. Hydrodynamic experiments within CFF offer insights into the behavior of nuclear weapon components and effectiveness of new explosives formulations, enabling certification of the nuclear stockpile in the absence of underground testing. Livermore's hydrodynamic testing program serves many purposes including modernization programs, fundamental weapons science and design, counterterrorism and counterproliferation efforts, and diagnostics development.

In support of strategic modernization programs, LLNL has been upgrading many other capabilities at Site 300. One of the most ambitious initiatives is EMDEC, a joint manufacturing maturation partnership with Pantex. EMDEC encompasses the existing capabilities of HE synthesis, formulation, pressing, machining, and assembly. In 2023, the campus expanded with the opening of the Facility for Advanced Manufacturing of Energetics (FAME), which houses advanced 3D printing equipment mirrored with identical equipment at Pantex for rapid co-development of new methodologies. In February 2025, the B827D Pilot Plant became EMDEC's newest capability. It supports both the W80-4 and W87-1 programs by enabling LLNL to independently conduct pilot-scale manufacture of IHE. In addition, researchers at the Pilot Plant are able to discover, develop, and prototype new HE solutions, making the NNSA Enterprise more agile and self-sufficient in the development of energetic materials.



A hardware engineer uses an automated test station to evaluate one of the 45 carrier boards that comprise the 984 line replaceable units that provide pulsed power to the 125-meter-long Scorpius linear accelerator.

**SUCCESSFUL CONVENTIONAL HYPERSONIC VEHICLE TEST**

Conducted in December 2024, the successful end-to-end flight of the U.S. Army's Long-Range Hypersonic Weapon (LRHW) system marked a key milestone in the development of U.S. hypersonic weapons. LLNL expertise was instrumental in the test's success. A Laboratory team has served as the warhead design agent for both the Army's LRHW and the Navy's Conventional Prompt Strike programs. The warhead, a focused fragmentation design, uses the hypersonic vehicle's forward velocity to maximize its destructive potential. Laboratory scientists also developed advanced flight software algorithms to improve weapon system performance. In addition, LLNL's Livermore Independent Scoring System (LIDSS) team provided key support during the December 2024 test. LIDSS' semi-autonomous rafts equipped with various diagnostic systems captured critical data from the missile's terminal phase. The test demonstrated the readiness of the U.S. military to field these advanced systems, with data collected supporting both ground- and sea-based deployments for the Army and Navy.

**PULSED POWER FOR SCORPIUS**

The three NNSA laboratories are building Scorpius in a tunnel 1,000 feet underground at the Nevada Nuclear Security Site (NNSS). The football-field length machine will be NNSA's next-generation electron beam accelerator to diagnose subcritical experiments that compress plutonium to high density using high explosives. LLNL's responsibility is to develop and deliver a next-generation solid-state pulsed power system for Scorpius. Circuit boards in 984 line-replacement units (LRUs) rather than massive banks of capacitors will power the linear accelerator. Each LRU includes 45 printed circuit boards, totaling over 3 million electrical components in the pulsed power system. Production of the LRUs by vendors is underway, and the first four LRUs were delivered to LLNL in December 2024 for validation of the production process and quality testing before installation into Scorpius. In FY 2025, 220 LRUs were shipped to NNSS, and over the next three years another 780 LRUs (and 16 spares) will be delivered.



The December 2024 flight test for the LRHW system was the first live-fire event using a Battery Operations Center and a Transporter Erector Launcher.