SCIENCE & TECHNOLOGY ON A MISSION

Lawrence Livermore National Laboratory had another exceptional year pushing the frontiers of science and technology to strengthen national security in a rapidly changing world

Lawrence Livermore National Laboratory Director Kim Budil testifies before the U.S. House Science, Space, and Technology Committee's Energy Subcommittee on February 12, 2025. (Photos courtesy of U.S. House Science, Space, and Technology Committee's Energy Subcommittee.)

FY 2025 was another extraordinary year for Lawrence Livermore National Laboratory (LLNL). We are delivering on our commitments to modernize the nation's nuclear weapons stockpile, supported other critical national security missions, and made remarkable advances in science and technology (S&T) capabilities. These advances are crucial to meeting scheduled deliveries on strategic modernization programs and enable the Nuclear Security Enterprise (NSE) to modernize and respond more quickly to emerging national security threats. We are building on our heritage as a multidisciplinary "big ideas" laboratory and forging strong collaborations within the Department of Energy's (DOE's) National Nuclear Security Administration (NNSA) and with strategic partners in other key government agencies, industry, and academia.

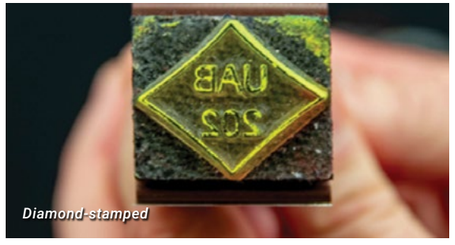
BEYOND STOCKPILE STEWARDSHIP IN THE 21ST CENTURY

Science-based stockpile stewardship has been a great success, providing a scientific toolkit of tremendous power and breadth. These advances have been sufficient for NNSA to extend with confidence the stockpile life of Cold War legacy weapon systems. However aging trends and changes in materials and manufacturing mean that life extensions are not enough and new manufacturing will be required in the coming decade. Importantly, these modern computational and experimental tools have enabled the laboratories to design, develop, and certify with confidence new components and all-new weapons to meet military requirements. Looking ahead, these new capabilities, accelerated by advances in AI, are providing the foundation for achieving a more efficient, highly integrated NSE with greater agility and responsiveness in an increasingly dangerous world.

As our *Annual Report* describes, we are engaged in three programs to modernize the nation's strategic deterrent. The W80-4 life extension program is currently in Phase 6.4 (production engineering), and the first production unit (FPU) is scheduled for September 2027. For the W87-1 Modification Program, LLNL is designing a replacement for the aging W78 ICBM warhead. With a planned FPU in FY 2033, the W87-1 will be the first modern warhead that is 100 percent newly manufactured. In addition, NNSA selected LLNL as the design agency for the Sea-Launched Cruise Missile–Nuclear warhead, now designated as the W80-5. These programs depend on key S&T capabilities: development of advanced manufacturing capabilities in partnership with NSE production agencies; high-fidelity 3D weapons performance simulations on the El Capitan supercomputer; subcritical experiments to test plutonium properties; and experiments to test weapon materials and components at extreme conditions at the National Ignition Facility (NIF). In each of these areas—and broadly across the Laboratory—we are applying AI tools to accelerate scientific discovery, enhance productivity, and streamline operations.

ENCLAVES AND PRODUCTION PARTNERSHIPS

LLNL is spearheading groundbreaking initiatives to develop innovative materials and manufacturing techniques in conjunction with NNSA production agencies. Strong partnerships are vital to increasing the responsiveness and agility of the NSE. The Polymer Enclave at LLNL has enabled researchers from the Laboratory and the Kansas City National Security Center to work side-by-side on the development of direct-ink-write parts and advancements like on-machine inspection. LLNL's Energetic Materials Development Enclave Campus is an important collaborative effort between Livermore and the Pantex Plant focused on the time-urgent need to manufacture insensitive high-explosive components for 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.



Diamond-stamped

EL CAPITAN AND HIGH-FIDELITY 3D SIMULATIONS

In November 2024, El Capitan was unveiled as the world's most powerful supercomputer with a peak performance of 2.79 quintillion calculations per second.

The exascale machine provides NNSA scientists and engineers an order-of-magnitude leap forward in modeling weapon performance and safety in high-fidelity resolution with quantified uncertainties. In addition to supporting weapon certification, El Capitan will accelerate progress in inertial confinement fusion (ICF) research, enable discoveries in material behavior under extreme conditions, and support other critical nuclear security missions such as nonproliferation and counterterrorism. Prior to classified operations, El Capitan demonstrated its remarkable capabilities with a Gordon-Bell-Prize-winning tsunami early warning framework, which is 10 billion times faster than existing warning methods.

NIF AND HIGH-ENERGY DENSITY EXPERIMENTS

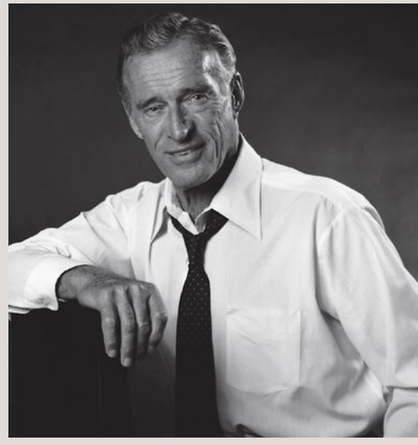
An ICF experiment in April 2025 produced a record-breaking 8.6 megajoules (MJ) of energy. Ignition shots provide unique opportunities to gather data to certify weapons performance and to assure that the nation's nuclear weapons would survive and function under hostile conditions. This year, LLNL conducted a milestone experiment to test the survivability of weapons-grade plutonium samples. The NIF team has continued work on a multiyear sustainment plan to carry out urgently needed refurbishments to assure mission delivery through the facility's design lifetime into the 2040s. Furthermore, the Laboratory's Enhanced Yield Capability project moved closer to a Critical Decision 1. The project entails boosting the laser's maximum energy from 2.2 MJ to 2.6 MJ, making fusion yields greater than 30 MJ possible.

AI AND LABORATORY TRANSFORMATION

Our *Annual Report* reveals the many ways we are at the forefront of using AI and machine learning (ML) to support strategic modernization programs and other important national security mission areas. Applications include use of AI/ML to optimize the design of additive-manufactured materials and products as well as alloys that must meet challenging specifications, increase the resiliency of energy grids, and rapidly develop effective vaccines and pharmaceuticals. In addition to transformative S&T advances in most every mission area, AI/ML is being applied to streamline operations across the Laboratory, such as maintenance at NIF and safety analysis at Superblock. Nearly all LLNL employees are using LivChat, an LLNL generative AI tool, and more than 3,200 participated in an "aiEDGE for Innovation Day" to learn how AI tools can be integrated into their daily work. We have a very strong headstart and are eager to provide leadership in DOE's Genesis Mission.

Innovation and transformation are words that have guided many institutional initiatives and inspired Laboratory staff members to do their best work—innovation to make game-changing advances in S&T to tackle the nation's greatest challenges; transformation to deliver faster, more efficiently, and in new ways. Construction projects are modernizing the Laboratory's infrastructure and planning is underway for greater improvements. We are transforming business practices and operations to increase efficiencies and paying special attention to workforce career development. About 70 percent of our outstanding workforce has less than 10 years of service at the Laboratory, and they are bringing innovative ideas, energy, and commitment to their jobs.

Building on this year's significant accomplishments, we see a bright future—sustaining LLNL values and our heritage of pursuing "big ideas" through innovation and teamwork. Working with our many collaborators, our Laboratory takes on grand challenges and delivers impactful solutions in the national interest. That is "Science and Technology on a Mission."



JOHN S. FOSTER JR. (1922–2025)

We remember Johnny Foster for his strong focus on national security, his inspiring leadership, his team-building mentorship, and his keen judgment and aptitude for scientific innovation. His leadership led to the key breakthroughs that are the foundation of today's nuclear stockpile and put the Laboratory on the road to success. Through his long, distinguished career, Johnny remained a close friend of LLNL. In his last days, he mentored and inspired researchers engaged in projects highlighted in our *Annual Report*. We will miss him.