LAWRENCE LIVERMORE NATIONAL LABORATORY

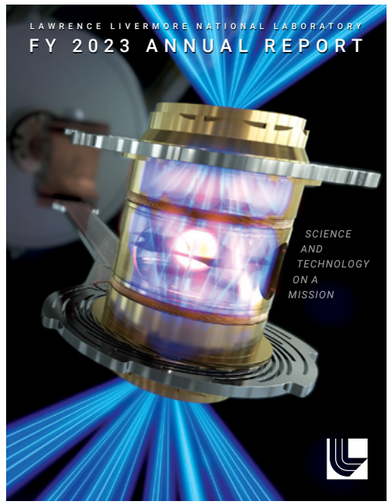
FY 2023 ANNUAL REPORT

SCIENCE AND TECHNOLOGY ON A MISSION

ABOUT US

Lawrence Livermore National Laboratory (LLNL) was founded in 1952 to enhance the security of the United States by advancing nuclear weapons science and technology and ensuring a safe, secure, and effective nuclear deterrent. With a talented and dedicated workforce and world-class research capabilities, the Laboratory strengthens national security with a tradition of science and technology innovation—anticipating, developing, and delivering solutions for the nation's most challenging problems.

The Laboratory is managed by Lawrence Livermore National Security, LLC (LLNS), for the National Nuclear Security Administration (NNSA), a semi-autonomous agency within the U.S. Department of Energy (DOE).



ABOUT THE COVER

Fiscal Year (FY) 2023 was another exceptional year for Lawrence Livermore National Laboratory. The achievement of fusion ignition and energy gain at the National Ignition Facility on December 5, 2022, was a crucial mission accomplishment and a historic event. Our *Annual Report* highlights this success and many other achievements that push the frontiers of mission-directed science and technology in service to the nation.

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INSIDE FY 2023

SCIENCE & TECHNOLOGY ON A MISSION

LLNL Director Kimberly Budil delivers opening remarks at the Ignition Day event on May 6, 2023, before an audience of invited guests, collaborators from partnering institutions, and Laboratory employees.

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

FY 2023 was an extraordinary year for Lawrence Livermore National Laboratory (LLNL). The achievement of fusion ignition and energy gain in an experiment at the National Ignition Facility (NIF) on December 5, 2022, made headline news. The lead designer of the successful target, Annie Kritcher, even made *TIME*'s list of the year's 100 most influential people. It was a deserved honor for her, and for the entire NIF team at LLNL, our many collaborators in the inertial confinement fusion research community, and those that took countless innovative steps over the past 60 years to make success possible. Ignition is a critically needed achievement as we work to modernize the nation's nuclear weapons stockpile. It also dramatically demonstrates the value of the Department of Energy (DOE) national laboratories, where researchers pursue leading-edge, multidisciplinary science and technology (S&T) striving to reach impactful long-term goals in the national interest.

Scientists in the DOE National Nuclear Security Administration (NNSA) laboratories now have a breakthrough capability to directly study the complex physics of burning plasmas and test the properties of materials at extreme conditions. A better understanding of the underlying physics enables improvements to the simulation codes used to assess nuclear weapons performance. In addition, as mentioned in our *Annual Report*, NIF researchers have used the pursuit of ignition as a pioneering test bed for combining experimental data, high-performance computing simulations, and artificial intelligence/machine learning (AI/ML) to expedite scientific discovery and the engineering design of complex systems. With imminent first use of our newest supercomputer, El Capitan, we will have an order of magnitude more computing power and are on the verge of a transformational improvement in our ability to understand nuclear weapons physics and quantify performance uncertainties as we modernize the nation's nuclear deterrent.

TRANSFORMING THE LABORATORY

Our Laboratory is undergoing a significant transformation. As a Federally Funded Research and Development Center (FFRDC), we need to change and aspire to serve as a model 21st-century national security laboratory. Greater agility is needed to anticipate and respond to growing threats to national security and international stability. We have important, technically and programmatically challenging mission responsibilities that require timely delivery within budget. And we see opportunities to make game-changing advances in national security through innovation and leading-edge S&T. Our transformation efforts align with NNSA's 2022 Strategic Vision, which recognizes the need for the nation's nuclear security enterprise (NSE) to step up to the daunting challenges our nation faces in a rapidly changing world. We need to "Innovate. Collaborate. Deliver."

Transformation is most evident in our efforts to modernize weapons systems in the nation's nuclear weapons stockpile—and in doing so, modernize the weapon-development process and production capabilities within the NSE. As our *Annual Report* describes, we are engaged in two programs to modernize stockpile systems: the W80-4 Life Extension Program, a warhead that will be carried on the all-new Long-Range Standoff missile, and the W87-1 Modification Program, a warhead for the Sentinel ballistic missile being developed by the U.S. Air Force. Through close partnerships with the NNSA laboratories, plants, and sites, we are developing new manufacturing technologies and business processes to improve efficiencies, lower costs, and increase NNSA's agility. This is a team effort within the NNSA.

BUILDING ON SUCCESSES

A decade ago, LLNL launched initiatives to advance capabilities in manufacturing for national security applications. The investment has made a major impact. In support of our stockpile modernization programs, we are closely collaborating with NNSA production sites to bring efficient, cost-effective, and environmentally sound manufacturing processes into the NSE. They will be needed for production of both the W80-4 and the W87-1, which will be the first 100 percent newly manufactured nuclear weapon system for the nation in more than 30 years. DOE/NNSA multiyear investments in exascale supercomputing have brought El Capitan to LLNL, which greatly increases NNSA's computing power and will provide important capabilities to certify a modernized nuclear weapons stockpile.

Another game-changing endeavor is underway with our leadership of the multi-institutional GUIDE program for the Department of Defense. We are building on our decades-long efforts in biosecurity and bioinformatics to achieve GUIDE's goal of developing an AI/ML-enabled capability to design effective, safe and manufacturable medical countermeasures in days-to-weeks rather than years. Many other innovative research activities ranging from global security and climate change to fundamental scientific discovery are highlighted in our *Annual Report*.

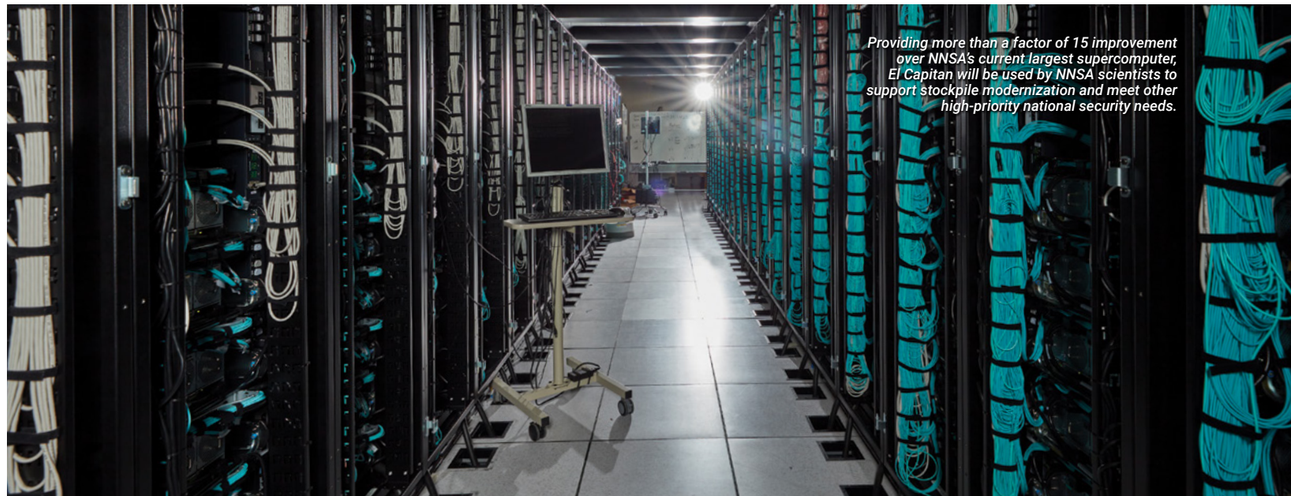
MODERNIZING FACILITIES AND OPERATIONS

LLNL is streamlining operations and providing leadership in moving forward NNSA's Enhanced Mission Delivery Initiative (EMDI), which was undertaken to make the NSE more agile and reinvigorate the working relationship between NNSA and its FFRDCs. We are participating in many EMDI pilot projects. LLNL is already benefiting from earlier actions taken by NNSA to expedite construction and lower the cost of standardized (STAR) buildings. Activities are underway at the Laboratory for six new STAR buildings and two new facilities opened in FY 2023. Our 20-year Site Development Plan, updated in FY 2023, envisions a future campus designed to enhance productivity and employees' work experience. The plan includes developing neighborhoods to increase opportunities for collaboration.

ATTENDING TO WORKFORCE DEVELOPMENT

Our successes in FY 2023 and bright prospects for the future are a credit to our outstanding workforce and the innovative ideas, energy, and commitment that our many new employees are bringing to LLNL. Nearly half of our employees have been at the Laboratory less than five years. We have established a cultural framework that focuses on addressing employees' needs, continual learning and skill development, and career planning. It also strongly promotes IDEA—inclusion, diversity, equity, and accountability—as foundational to all we do.

Our workforce is key to successful transformation of our Laboratory. We are creating an environment that fosters innovative ideas and the ability to take on the grand challenges that LLNL missions demand. We are translating innovation into impactful solutions in the national interest. Science and Technology on a Mission, indeed.



Providing more than a factor of 15 improvement over NNSA's current largest supercomputer, El Capitan will be used by NNSA scientists to support stockpile modernization and meet other high-priority national security needs.

STRATEGIC DETERRENCE

An engineer in the W80-4 Life Extension Program subjects a mock test unit to an environmental stress experiment.

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

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 weapons production enterprise. Effective deterrence relies not only on the nation's deployed weapons systems, but also on the extensive science and technology capabilities of its national security laboratories and the agility of the nuclear security enterprise (NSE) to respond to emerging national needs.

ANNUAL STOCKPILE ASSESSMENT

In FY 2023, LLNL completed Cycle 28 of the annual stockpile assessment. The process included a formal comprehensive peer review between LLNL and Los Alamos National Laboratory (LANL) of each other's weapons systems. Laboratory experiments and application of enhanced physics and engineering simulation codes provide the technical foundation for evaluating the safety, security, and effectiveness of weapons. These activities enabled an assessment of the condition and sustainment of the B83, W80-1, and W87-0 stockpile systems. LLNL also completed a significant upgrade to capabilities at the Pantex Plant for gathering surveillance data.

W80-4 LIFE EXTENSION PROGRAM (LEP)

LLNL is the design agency partnering with Sandia National Laboratories (SNL), production agencies, and the U.S. Air Force to develop and certify the W80-4 warhead for the bomber-delivered Long-Range Standoff (LRSO) missile. While challenges remain, the team is making excellent progress in the LEP. Programmatic work included executing design reviews, completing multiple high-fidelity engineering tests, efforts improving product producibility, and supporting U.S. Air Force LRSO flight-test activities. In November 2022, the development team successfully completed a critical mid-program review with the Department of Defense (DOD), showing that the warhead baseline design complies with DOD requirements and would perform as expected after surviving flight environments. This key milestone and the System Baseline Design Review prepared the LEP for transition to Phase 6.4 (production engineering) in May 2023.

Production engineering builds on the initial design phases by fully engaging partnerships across the NSE. LLNL's partnership with the Kansas City National Security Campus (KCNSC) has enabled improvements to the acceptance rate of key components needed for system delivery. LLNL has worked with LANL and SNL to integrate complex schedules and ensure that efforts focus on the key technical challenges. The partnership with Pantex has been essential to addressing challenges in the supply chain and production of insensitive high explosives (IHE), as well as preparing for assembly and delivery of systems.

The W80-4 will reuse existing designs and components while incorporating modern components and safety features. The LEP is taking advantage of new manufacturing methods that minimize costs, increase throughput, and reduce the need for environmentally sensitive materials and processes. The first production unit of the W80-4 is scheduled for September 2027.

W87-1 MODIFICATION (MOD) PROGRAM

LLNL is the design agency partnering with NNSA laboratories, plants, and sites to deliver a warhead to replace the aging W78. To be deployed on the U.S. Air Force's Sentinel ballistic missile (under development) in the early 2030s, the W87-1 will be the first modern warhead that is 100 percent newly manufactured. In FY 2023, the W87-1 Mod Program successfully moved to Phase 6.3 (engineering development). Technical activities are focused on maturing weapon design options and modern manufacturing methods. The program is pursuing innovative, transformational partnerships across the NSE to introduce new materials, manufacturing techniques, and processes to meet W87-1 and future stockpile systems requirements. Advances in the tools of science-based stockpile stewardship, including acquisition of El Capitan and the recent successes at the National Ignition Facility, enable confident certification of the new warhead without nuclear explosive testing.

ENCLAVES AND PRODUCTION PARTNERSHIPS

Success in the modernization programs depends on forging an integrated effort among the design agencies and production agencies within the NSE and strong partnerships with the U.S. Air Force and their contractors. LLNL is spearheading expanded collaborations to develop innovative materials and manufacturing techniques. Researchers from the Laboratory and KCNSC work side-by-side at the Polymer Enclave at LLNL using machines, tools, and other production equipment that are equivalent (and in some cases, identical) to resources at KCNSC. They are partnering to meet rate production goals needed for the modernization programs, and are co-developing, with other stakeholders, technological advances in additive manufacturing. In addition, LLNL and the Y-12 National Security Complex have teamed up to rapidly modernize technology and production methods for crucial weapons components.

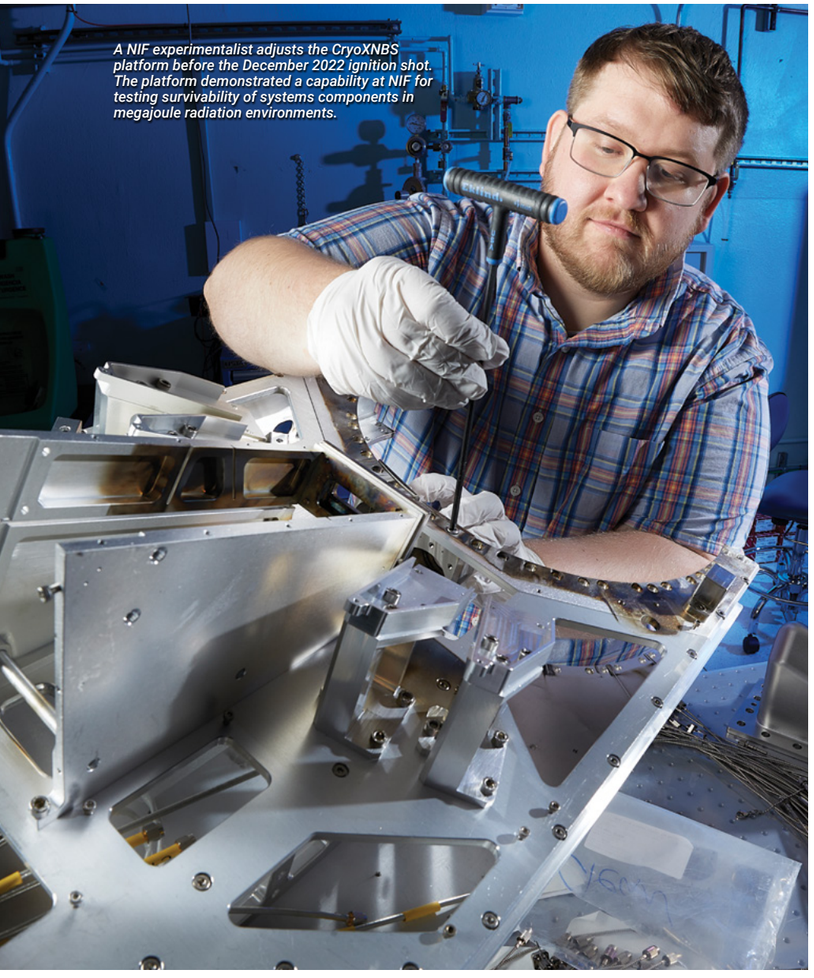
LLNL has also established the Energetic Materials Development Enclave Campus (EMDEC) as a manufacturing partnership within the NSE. It leverages the extensive suite of capabilities at the Laboratory with the goal of reducing the time to achieve high-yield-rate production. The collaboration also serves as a test bed for next-generation approaches to energetic materials. EMDEC features the Facility for Advanced Manufacturing of Energetics (FAME), where first-of-their-kind technologies have been developed and implemented to safely 3D-print IHE.

Researchers examine new capabilities in the Facility for Advanced Manufacturing of Energetics within the Energetic Materials Development Enclave Campus.

A scientist uses an Instron Universal Testing Machine to perform a nondestructive evaluation in the Polymer Enclave.

PREPARING FOR EXASCALE

Delivery of El Capitan, with a peak performance to exceed 2 exaflops (quintillion calculations per second), is expected to be completed in early 2024, with the goal to deploy it for classified use in late FY 2024. More than a factor of 15 improvement over NNSA's current largest supercomputer, El Capitan will be used by NNSA scientists to support stockpile modernization and meet other high-priority national security needs. The machine enables researchers to run ensembles of high-fidelity 3D multiphysics simulations to quantify uncertainties. El Capitan features accelerated processing unit chips with expanded memory and high processing speed together with an advanced interconnection network for large simulations that require many nodes. Building and preparing for El Capitan has been a multiyear effort that has benefited from many contributors and a strong partnership between the Laboratory and system vendors (see p. 18). In addition to the $100-million upgrade to the Livermore Computing facility, LLNL is preparing the operating and data storage systems and readying applications for efficient use on El Capitan. Much of the software ecosystem for the machine has been developed through DOE's Exascale Computing Project.



A NIF experimentalist adjusts the CryoXNBS platform before the December 2022 ignition shot. The platform demonstrated a capability at NIF for testing survivability of systems components in megajoule radiation environments.

NUCLEAR SURVIVABILITY EXPERIMENTS

The National Ignition Facility (NIF) provides unique experimental capabilities for assuring that the nation's nuclear weapons and other critical military systems would survive and function under hostile conditions in a nuclear conflict.

NIF performs an average of 40 to 50 shots per year as part of its National Security Applications program, which supports researchers across the defense community. The experiments provide x-ray, neutron, and electromagnetic pulse environments for vulnerability and hardness testing of electronics, weapons parts, and materials. Data collected during shots are used to qualify components and validate codes designed to determine the effects on systems.

Achievement of fusion ignition at NIF is very important to the success of many facets of stockpile stewardship (see p. 8). For nuclear survivability, it greatly enhances capabilities to test components and materials by exposing them to an intense dose of neutrons. The December 2022 shot not only achieved ignition, it tested new experimental hardware designed to survive megajoule exposures. The cryogenic-compatible x-ray, neutron, and blast snout (CryoXNBS) demonstrated the capability to test samples, materials, or diagnostics in megajoule environments.

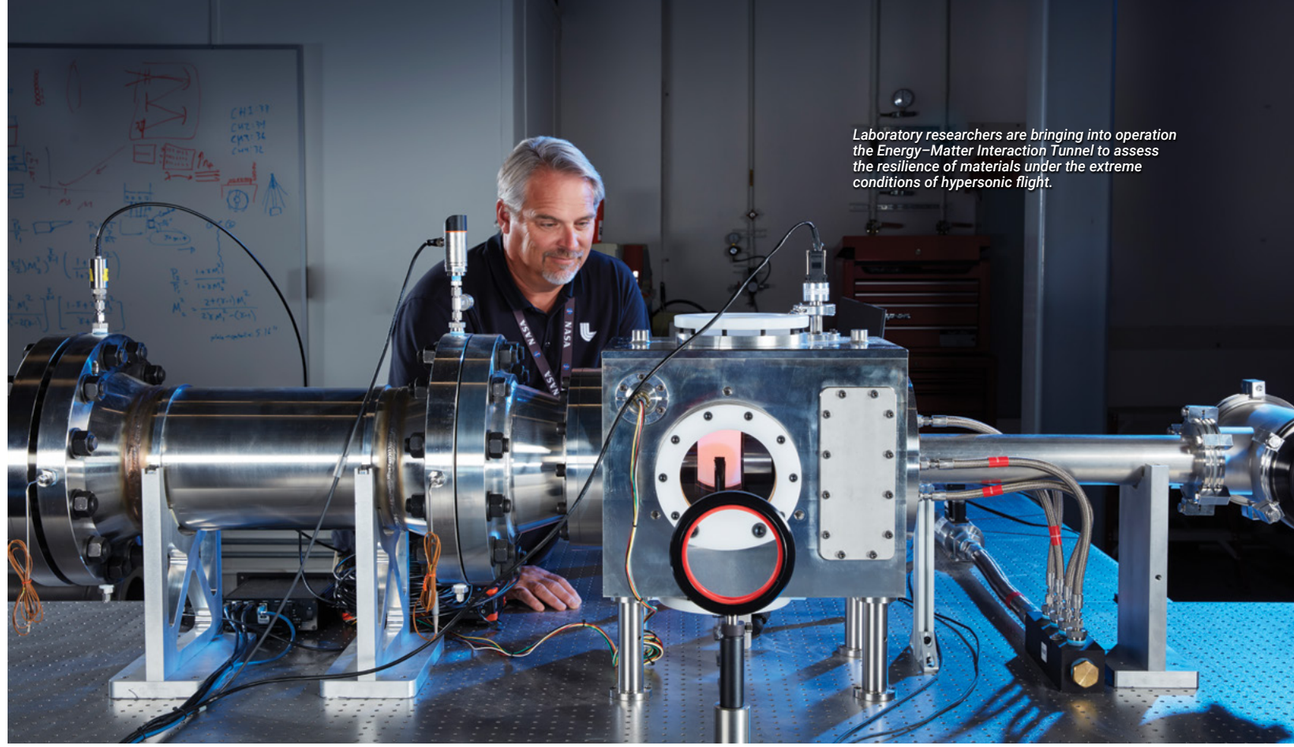
FLIGHT DYNAMICS AND HYPERSONICS

LLNL engineers have developed an advanced flight simulation package, Sora, as a new capability for use in the national security community. Historically, LLNL modeled the thermal–structural response of warheads to the extreme loads and conditions of re-entry based on data from DOD contractors' codes that simulate the flight dynamics of the delivery vehicle. Sora simulates the flight vehicle and nuclear warhead in a complex multiphysics, multiscale environment that includes hypersonic air chemistry, ablation, heat transfer, structural dynamics, weather, and cloud microphysics. Use of a combined model will streamline development of new systems, saving time, reducing costs, and leading to designs that better optimize performance. Collaboration with academic partners and the U.S. Air Force and Army laboratories has been crucial to the development of Sora. Efforts are underway to expand the user base.

Laboratory researchers are also bringing into operations the Energy–Matter Interaction Tunnel (EMIT) to assess the resilience of materials under the extreme conditions of hypersonic flight. EMIT meets the challenge of creating a test environment with both well-characterized turbulent air flow and high-temperature material, heated by a laser source outside the experimental chamber. A suite of diagnostics characterizes the mechanical and chemical response of a material coupon. The ability to conduct frequent tests—coupled with LLNL's outstanding capabilities to develop novel materials and simulate material behavior in extreme conditions—will help advance hypersonic research. Development of EMIT would not have been possible without extensive collaboration with many institutions engaged in hypersonic research, who will also be users of the facility.

PULSED POWER FOR SCORPIUS

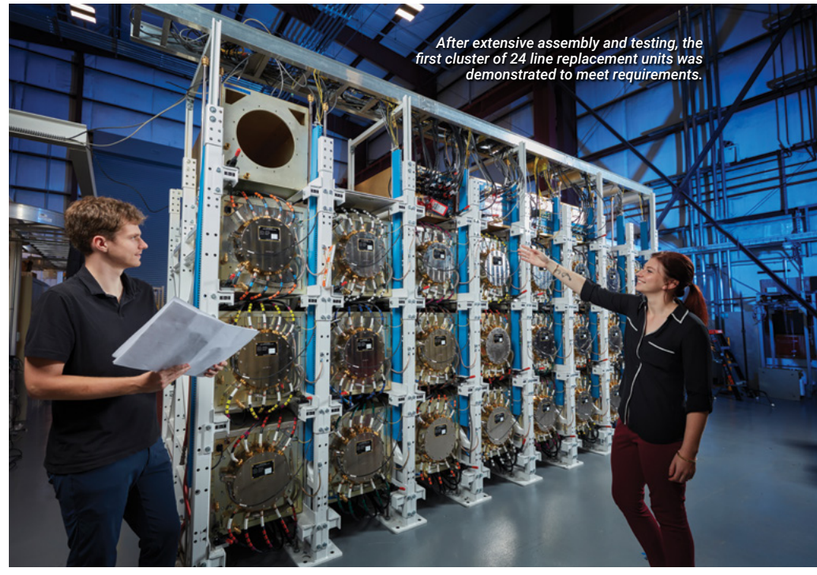
NNSA laboratories and sites are building the Scorpius accelerator in a tunnel 1,000 feet underground at the Nevada National Security Site. LLNL delivered on a major milestone in FY 2023 in support of the project. The football field–length machine will be NNSA's next-generation electron beam accelerator to diagnose subcritical experiments that compress plutonium to high density with high explosives. In these contained experiments, short bursts of x rays will take radiographic images of the material, which will be used to validate simulation codes and assess the effects of aging and manufacturing methods on weapon performance. LLNL's responsibility is to develop and deliver a 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 3.5 million electrical components in the pulsed power system. After extensive assembly and testing, the first cluster of 24 LRUs was demonstrated to meet requirements in September 2023.



Laboratory researchers are bringing into operation the Energy–Matter Interaction Tunnel to assess the resilience of materials under the extreme conditions of hypersonic flight.

EXPLORING ENERGETIC MATERIALS

In experiments and simulation, LLNL is at the frontiers of energetic materials research. In FY 2023, LLNL researchers designed a main charge that utilizes RX-72, a candidate IHE that has compelling performance properties. The team was challenged to make systems-level trade-offs in developing the new explosive, which provided staff critical training and career development opportunities. The effort culminated in the successful delivery of main charge components for integrated testing and the transfer of manufacturing technology to partners at the Pantex Plant. In other research efforts, computer simulations performed with collaborators demonstrated that crystal structure prediction is a useful tool for examining various ways the molecules can pack together in energetic materials. The method used is a physics-based approach that works by randomly generating crystal structures, optimizing them, and ranking the resultant structures by their predicted stability. It successfully predicts the crystal structure of commonly used energetic materials.



After extensive assembly and testing, the first cluster of 24 line replacement units was demonstrated to meet requirements.

NATIONAL IGNITION FACILITY

Supporting stockpile sustainment and modernization through a wide range of high-energy-density (HED) science experiments and capabilities, including fusion ignition

Technicians work inside NIF's target chamber, where the decades-long quest to achieve fusion ignition and energy gain in a laboratory setting culminated with a NIF experiment performed on December 5, 2022.

IGNITION ACHIEVED

A historic inertial confinement fusion (ICF) experiment at the National Ignition Facility (NIF) on December 5, 2022, achieved ignition and energy gain, with 2.05 megajoules (MJ) of delivered laser energy producing 3.15 MJ of fusion energy. The NIF team bettered this result in a shot on July 30, 2023, that attained 3.88 MJ of energy with the same laser energy. Subsequent experiments in October 2023 achieved, respectively 2.4 MJ and 3.4 MJ. These remarkable results were made possible by the hard work of the ICF community over many decades and benefited from key advances gained over the last several years.

Achievement of ignition and energy gain is a major accomplishment of the Stockpile Stewardship Program and vital to meeting current and future needs for stockpile sustainment and modernization. Ignition and thermonuclear burn are complex processes that involve the physics of hot, dense plasmas, which are very challenging to model even on the fastest supercomputers. NIF fusion experiments will enable scientists to gain insights and gather data to better understand the underlying physics. The knowledge gained and improvements in the physics codes will help reduce uncertainties in and assessing weapon performance. Experiments that produce copious amounts of high-energy neutrons are also important to assuring the survivability of U.S. nuclear weapons and other military systems in threat nuclear environments (see p. 6).

ICF TARGET DESIGN IMPROVEMENTS

ICF target designers use information gained from experiments to enhance multiphysics simulation codes that are applied to improve target performance. The arrival of the Sierra supercomputer in 2018 provided a major step in capability, enabling the first high-resolution spherical 3D simulations of ICF implosions with the HYDRA code. The simulations gave scientists a clearer understanding of what obstacles prevented ignition and predicted that a better target design and quality was needed to succeed. Designers used HYDRA to devise a more robust target for a higher energy laser pulse, changing the hohlraum's size and making the capsule thicker to increase the stability of the implosion. In parallel, the target fabrication team improved target production processes resulting in improved capsule quality. For the shot in December 2022, the design team estimated a slightly better than 50 percent chance of break-even fusion yield.

ICF target design is further benefiting from application of cognitive simulation (CogSim)—the combining of machine learning and artificial intelligence techniques with high-performance computing simulations and empirical data to dramatically improve predictive analysis. A promising technique, called transfer training of a deep neural network, trains the machine with simulations, and then "corrects" the model through additional training using experimental results. Transfer learning from additional experiment results leads to continual improvement of the tool.

IMPROVED LASER PERFORMANCE

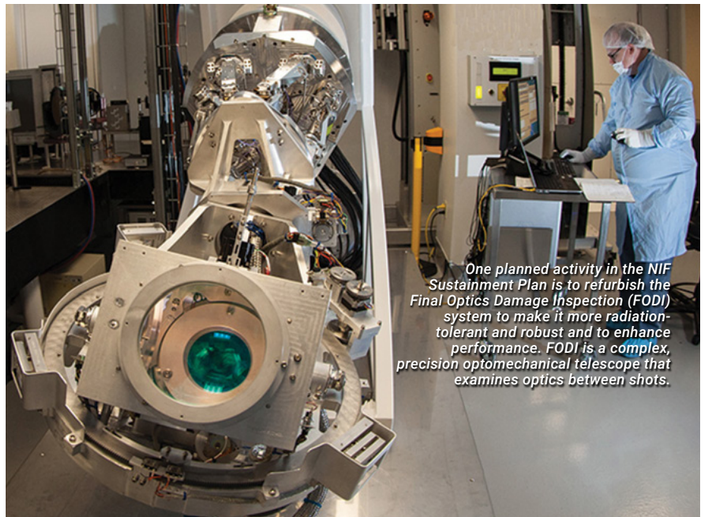
To achieve ignition, NIF's laser system needed to deliver higher energy with precise control of the energy balance across all 192 laser beams. Precision starts in the master oscillator room, which generates low-energy laser pulses that are greatly amplified. They are precisely shaped in time and frequency-broadened to help smooth the intensity of the laser beams. In 2022, the NIF team completed a three-year modernization project that upgraded the 20-year-old system to enhance its capabilities and meet more stringent performance requirements to achieve ignition.

Precisely controlled higher laser energy succeeded in achieving ignition of the improved target. Advances in optics engineering enabled ignition shots at greater than 2 MJ of laser energy. The principal challenge was better protecting precious laser optics from debris created by the experiment. NIF was designed and built with two debris shields to protect the final optics: a disposable shield and the grating debris shield (GDS). In 2021, installation began of a third layer of protection—the fused silica debris shield (FSDS)—between the two shields to protect the valuable GDS from debris from the disposable shield. The FSDS has reduced the number of damage sites on the GDS by 98 percent. This reduction and efficient processes for inspecting and repairing FSDSs has enabled NIF ignition shots at 2.05 MJ—and in early FY 2024, the first experiment at 2.2 MJ, which yielded 3.4 MJ of fusion energy.

The new fused silica debris shield optic, shown here being inspected through the Advanced Mitigation Process to improve its laser damage resistance, was a critical factor in NIF's ability to deliver more than 2 megajoules of laser energy.

SCIENCE EXPERIMENTS AT NIF

In FY 2023, the broad range of capabilities users have for studying HED science at NIF expanded with the introduction of a new experimental platform called the colliding planar shocks (CPS) platform. It promises to deliver precise measurements of the characteristics of warm dense matter (WDM), a state of matter exhibiting properties of both solids and plasmas. The CPS platform uses NIF laser beams to create two counter-propagating shock waves that produce uniform plasma conditions when they collide in the center of a cylindrical sample. Both x-ray scattering and radiographic data are obtained, enabling determination of density, temperature, and ionization state. Studying WDM, which makes up the cores of giant planets and brown dwarf stars, helps scientists gain a better understanding of the nature and evolution of the universe. The topic also sheds light on issues relevant to nuclear weapons science and ICF implosions.



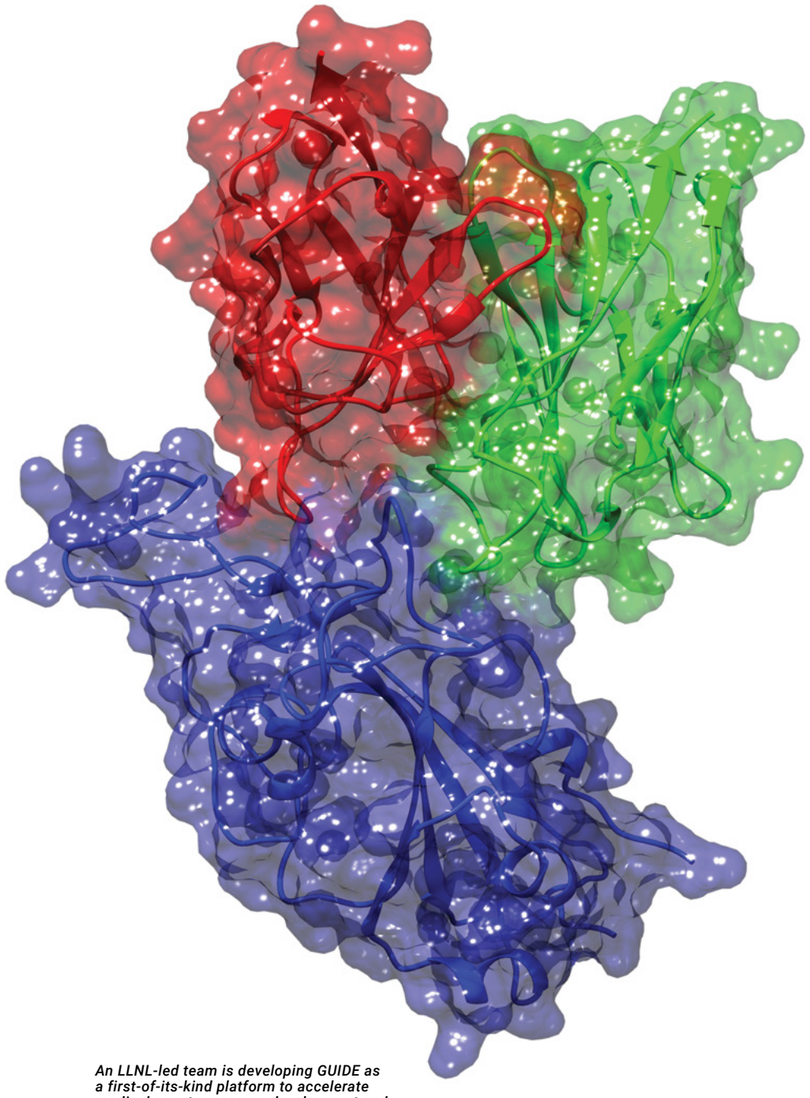
One planned activity in the NIF Sustainment Plan is to refurbish the Final Optics Damage Inspection (FODI) system to make it more radiation-tolerant and robust and to enhance performance. FODI is a complex, precision optomechanical telescope that examines optics between shots.

NIF REFURBISHMENT

In FY 2023, the NIF team began work on a multiyear Sustainment Plan to carry out urgently needed refurbishments and recapitalizations to assure mission delivery through the facility's design lifetime to 2040. Since experiments began in 2009, NIF has been exceptionally productive and reliable, with fewer than 30 days of unplanned down time in more than 2,400 days of shot operations. Maintenance has been an ongoing priority, but the facility has reached the age that a major effort is neccesary to address aging systems and reduce a backlog of deferred maintenance. The team identified 30 key refurbishment and recapitalization activities. The most urgent is elimination of debris in the amplifier and final optics systems that is threatening to lower NIF performance. In addition, obsolete components will be replaced and some equipment hardening is needed to tolerate the more extreme radiation environment produced in high-energy-yield shots. Completion of the NIF Sustainment Plan over the next several years will ensure the facility can continue to operate at high performance levels through the 2030s. The refurbishment will position NIF for future successes and is foundational to an upgrade being planned to push NIF's performance beyond the current baseline and enable higher yields for national security applications.

GLOBAL SECURITY

Reducing the threat from terrorism and weapons of mass destruction and enhancing global strategic stability



An LLNL-led team is developing GUIDE as a first-of-its-kind platform to accelerate medical countermeasure development and the timeline to clinical use. An antibody is shown interacting with the spike protein of the SARS-CoV-2 virus.

ACCELERATING DRUG DESIGN WITH GUIDE

In response to a request from the Department of Defense's Joint Program Executive Office for Chemical, Biological, Radiological, and Nuclear Defense, an LLNL-led, multi-institutional team is developing Generative Unconstrained Intelligence Drug Engineering (GUIDE) as a first-of-its-kind platform to accelerate medical countermeasure (MCM) development. Therapeutic antibody development to combat viruses has typically taken years. GUIDE combines data, structural biology, bioinformatic modeling, and molecular simulations, driven by machine learning and supercomputing, to rapidly design antibody candidates, potentially lower development costs and risk, and accelerate the timeline to clinical use. To date, GUIDE has demonstrated multiple cases of success in developing vaccines and therapeutic antibodies.

GUIDE researchers are currently developing large data sets to train artificial intelligence (AI) models for *de novo* antibody design and developability. These data sets will enable AI-based predictions of key antibody properties to facilitate unprecedented acceleration of the drug-development cycle while maintaining desired MCM critical quality attributes. GUIDE will provide a unique ability to actively respond to threats, potentially deter adversaries, and significantly advance computational biological approaches that can benefit a wide range of drug-development efforts. GUIDE is comprised of a growing coalition of interagency and public and private partners with a shared mission of transforming MCM development. When fully implemented, GUIDE will enable proactive preparedness against a broad range of known threats and reduce the development timeline from years to weeks.

IMPROVING CAPABILITIES TO DETECT NUCLEAR TESTS

On October 18, 2023, a multilaboratory, multidisciplinary team funded by the NNSA Office of Defense Nuclear Nonproliferation R&D conducted the first Physics Experiment 1 (PE1) series explosive test, detonating 16.3 tons (TNT equivalent) of chemical explosives in Area 12's P tunnel at the Nevada National Security Site. Shock, seismic, and acoustic signals propagated to sensors within minutes. Preliminary data reviews

Team members from LLNL worked to achieve the near-flawless execution of the first PE1 series detonation experiment in P tunnel at the Nevada National Security Site. (Photo courtesy of NNSA.)

reported clear seismic signals to at least 250 kilometers with high data recovery rates, which will be used to improve the United States' ability to detect low-yield nuclear explosions around the world. LLNL serves as manager of the NNSA-funded PE1 venture. Team members from LLNL, including the project engineer, deputy venture manager, chief scientist, electromagnetic instrumentation technician, seismo–acoustic instrumentation technician, meteorology instrumentation technician, and instrumentation engineer, all worked diligently in the field for months, and in some cases years, to achieve the near-flawless execution of the PE1 experiment.

SKYWING

LLNL's multidisciplinary teams of mathematicians, systems analysts, power engineers, cybersecurity experts, and computational scientists have turned to collaborative autonomy as a way to defend modern critical infrastructure and harden systems. The electrical grid that powers our homes, the pipelines that deliver water and natural gas, and our transportation networks are full of digitized components. In a power grid, distributed energy resources (DERs) such as smart meters, solar inverters, power-quality sensors, and protection devices are geographically spread out, programmable, and network connected. Collaborative autonomy is a new class of computational techniques that can be used to teach networked devices, such as DERs, how to self-organize into a collective whole. Skywing is an open-source, high-reliability, real-time platform now available to the broader research community to explore distributed decision making among infrastructure control systems for resiliency. It provides approaches and solutions for real-world applications that solve problems and lowers the barrier to entry for those who may lack fluency in collaborative-autonomy software development.

ASSISTANCE IN UKRAINE

After Russia's invasion of Ukraine in 2022, multidisciplinary teams at LLNL worked at the forefront of urgent, complex operations to improve the United States' situational awareness of a wide range of nuclear incidents in the region. Their activities informed decision-making at the highest levels of the U.S. Government and assisted with preparing for numerous contingencies with global security implications. The Ukraine Detection Assistance Team's dedication and perseverance in assisting partners in Ukraine during this time of crisis were commended, and the team's efforts were recognized with The Secretary of Energy Achievement Award. Along with their colleagues from the Office of Counterterrorism and Counterproliferation and the Office of Defense Nuclear Nonproliferation, these LLNL subject matter experts developed creative solutions to configure and adapt existing equipment to meet urgent needs within Ukraine and worked closely with the governments and embassies of multiple countries around the world to ensure that necessary equipment could be delivered to Ukraine within a matter of weeks. As a direct result of their efforts, the White House and other critical elements of the U.S. Government had necessary data to make sound judgments and decisions of the gravest national significance with great confidence.

CYBERSECURITY TRAINING FOR STUDENTS

Each summer, LLNL offers advanced undergraduate and graduate students the opportunity to join the Cyber and Critical Infrastructure Summer Institute (CSI) to work as interns on cybersecurity and critical infrastructure projects. Protecting our nation's critical infrastructure requires multidisciplinary solutions, and the CSI tests the capability of teams of interns to combine their knowledge in cybersecurity and power-systems engineering to solve unique challenges. This summer, the CSI hosted 65 interns who participated in activities including a cybersecurity capture the flag competition, tours of the National Ignition Facility and the Laboratory's quantum computing facility, tutorials and workshops, and Q&A sessions with principal investigators. Each CSI intern was mentored by an LLNL employee working in cybersecurity and/or critical infrastructure resilience. The capstone event of this year's CSI was a visit from U.S. Representative Eric Swalwell (D-CA14) and LLNL Director Kimberly Budil. The program is an important pipeline for developing future cybersecurity and infrastructure experts. LLNL has converted 28 interns to staff in the last five years.

(left to right) U.S. Representative Eric Swalwell views the work of an intern and his mentor at the CSI capstone event in July 2023.

The Simple Cloud Resolving E3SM Atmosphere Model (SCREAM) team won the inaugural Gordon Bell Prize for Climate Modelling at the SC23 Conference. LLNL staff scientist Peter Caldwell (farthest left) led the SCREAM team. (Photo courtesy of SC Photography.)

ENERGY AND ENVIRONMENT

Applying science and technology to improve national energy security and surety, protect the environment, and understand and mitigate climate change

LABORATORY researchers apply leading-edge capabilities to develop efficient and sustainable energy technologies and to investigate the processes behind climate change.

GROUNDBREAKING EXASCALE SIMULATIONS

An LLNL-led team, including researchers from seven other DOE laboratories, received the inaugural Gordon Bell Prize for Climate Modelling. The team's winning submission was the efficient and performance-portable implementation of SCREAM (Simple Cloud Resolving E3SM Atmosphere Model)—the first to break the one-simulated-year-per-day barrier for realistic cloud-resolving simulations at less than 5 kilometers of horizontal resolution. What separates SCREAM from other climate models is its ability to perform efficiently across a spectrum of computer architectures—and running faster than any other climate model on Frontier, the exascale machine at Oak Ridge National Laboratory. Another LLNL team reached a milestone in power grid optimization on Frontier. This largest simulation of its kind used 9,000 nodes to determine safe and cost-optimal power performance over 100,000 possible grid failures and weather scenarios in just 20 minutes. Ensuring the nation's electrical power grid can function with limited disruptions in the event of a national disaster, catastrophic weather, or an attack is a key national security challenge. The goal of the project was to show that exascale computers are capable of exhaustively solving this problem in a manner consistent with current practices of power grid operators.

ASSESSING HUMAN-CAUSED CLIMATE INFLUENCE

Laboratory scientists and colleagues have demonstrated for the first time that extending climate "fingerprinting" techniques to the mid- to upper stratosphere (25 to 50 kilometers above Earth's surface) improves the detection of human effects by a factor of five. New analyses also help reconcile differences between satellite data and the warming simulated by climate models, which have outpaced the observations since 1979. A number of factors may contribute to this discrepancy. Using machine learning and large ensembles of climate model simulations, the research team found that internal variations in Earth's climate have, by chance, reduced real-world tropospheric warming over the satellite era. A spurious discontinuity in prescribed biomass-burning aerosol emissions has also artificially enhanced the simulated result. These two effects largely explain the difference between simulated and observed tropical tropospheric warming.

LLNL scientists and colleagues extended "fingerprinting" to the mid- to upper stratosphere (25–50 kilometers above Earth's surface) to improve the detection of human effects on climate. Layers of Earth's atmosphere are shown in a view looking across Earth's surface. (Photo courtesy of NASA.)

MATERIALS FOR SCALABLE CARBON CAPTURE

In a significant stride toward implementing scalable climate solutions, LLNL scientists uncovered how some carbon capture materials have improved lifetimes compared to others. Researchers demonstrated epoxide-functionalization as a mechanism for extending the operational lifespan of poly(ethylenimine)sorbents, materials that are efficient in capturing carbon dioxide (CO_2) from flue-gas point sources and the atmosphere. Simulations showed that introducing new functional groups into sorbents fosters robust hydrogen bonds within the material's structure and slows undesired oxidation reactions that diminish performance. Enhanced sorbents exhibited exceptional durability over multiple cycles of use. Laboratory scientists and collaborators also investigated whether carbon mineralization of rocks might be another dependable means for long-term storage of carbon. The process occurs naturally when magnesium and calcium-rich rocks, known as ultramafics, are exposed to CO_2-rich water. The researchers used the Laboratory's Center for Accelerator Mass Spectrometry to analyze the radiocarbon content of recently exposed ultramafic rock surfaces and found that carbon mineralization was indeed sequestering atmospheric CO_2. This work supports efforts to scale up the carbon mineralization process for reliably drawing down atmospheric CO_2 levels.

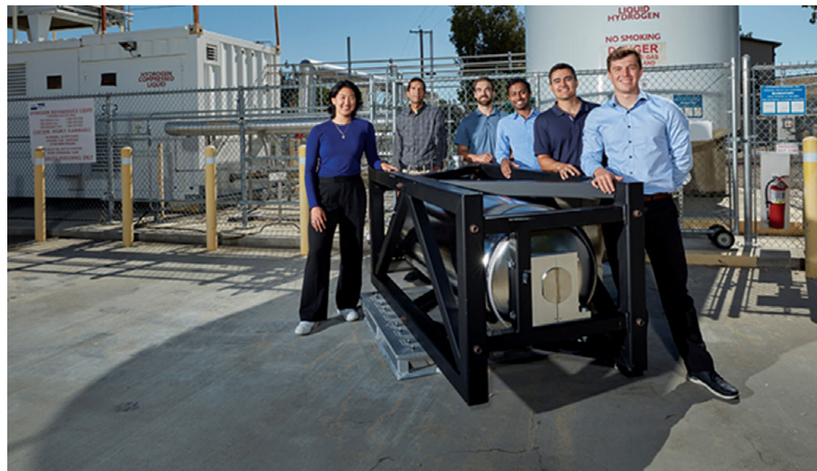
CARBON CAPTURE IN SOIL

As part of DOE's new Energy Earthshots Initiative, LLNL scientists received about $17 million to create a center, called Terraforming Soil, for advancing the fundamental understanding of atmospheric CO_2 drawdown in soils. More carbon, in both organic and inorganic forms, is stored in soil than found in the atmosphere and land plants combined. Agricultural soils in the United States have lost a vast amount of carbon over the past century through cultivation and erosion. However, active management of agricultural lands with strategies that capture atmospheric CO_2 has clear potential to reverse this trend. The new center will build on LLNL scientists' recent development of a new technique to better understand soil microbial interactions. The new method automates several steps in the stable isotope probing process, allowing investigations of microbial activity of microorganisms under realistic conditions without the need for lab culturing. In this proof-of-concept study, researchers illustrated the "food web" of interactions stimulated by mycorrhizal fungi in soil, which is theorized to be a major route for broad distribution of plant carbon within the soil.

HYDROGEN STORAGE HITS A MILESTONE

Building upon LLNL's decades of pioneering research in hydrogen storage, researchers at the Laboratory and Verne, a San Francisco-based start-up, have simulated, tested, and demonstrated a cryo-compressed hydrogen (CcH_2) storage system that for the first time is of suitable scale and high enough density to efficiently serve heavy-duty vehicles. Powering heavy-duty vehicles requires very energy-dense storage systems—better than even the most advanced batteries—and CcH_2 outperforms other hydrogen storage options. For the last two years, Verne has been testing their storage systems at the Laboratory's Cryogenic Hydrogen Fueling Facility. Recently the team tested a single tank system, demonstrating storage of more than 29 kilograms of cryo-compressed hydrogen in a system compact enough that it can fit where diesel tanks are typically installed on a Class 8 truck. Within the transportation sector, heavy-duty vehicles that rely on fossil fuels generated 23 percent of U.S. greenhouse gases.

At LLNL's cryogenic hydrogen fueling facility, researchers from LLNL and Verne stand next to Verne's cryo-compressed hydrogen storage system, the first such system to support the needs of heavy-duty vehicles. The system's internal volume is about 117 gallons.



SCIENCE AND TECHNOLOGY

Expanding the boundaries of scientific knowledge and advancing the technological state of the art to solve problems of national and global importance

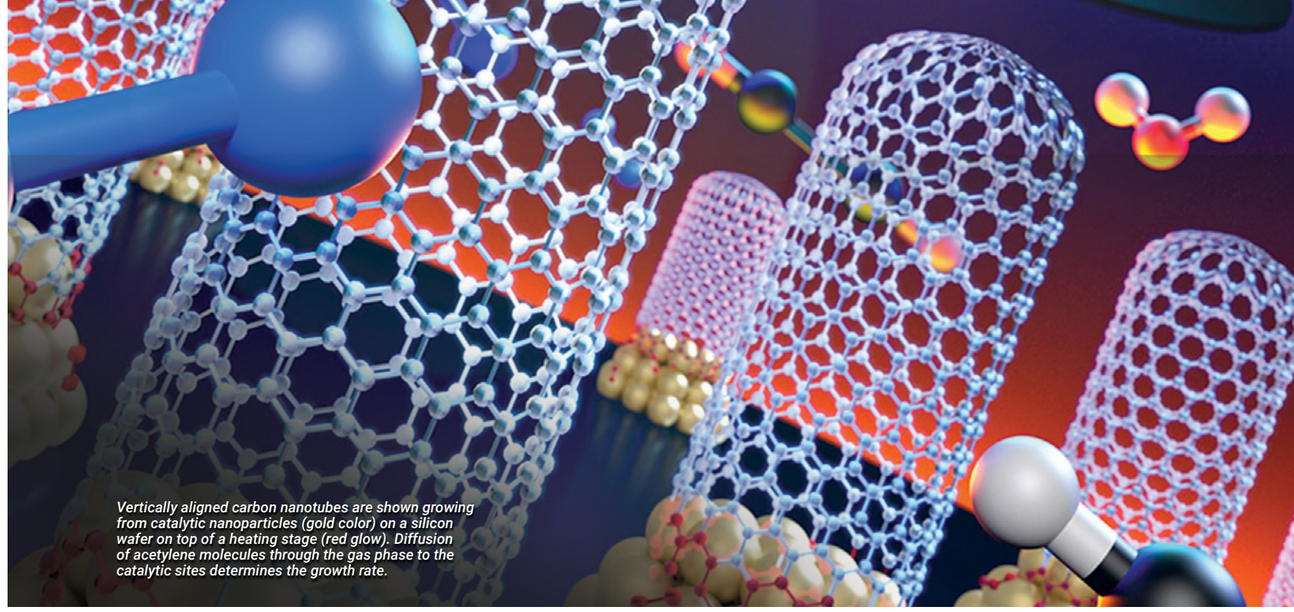
THROUGH its science and technology capabilities, the Laboratory makes fundamental discoveries about nature, develops innovative technologies that improve life and drive the economy, and carries out its mission to improve national security.

COGNITIVE SIMULATION AND MACHINE LEARNING

In May 2023, LLNL and SambaNova Systems announced the addition of SambaNova's spatial data flow accelerator to the Laboratory's high-performance computing (HPC) systems. The new hardware is part of an effort to upgrade LLNL's cognitive simulation program (CogSim), which combines artificial intelligence (AI) with HPC. Deep neural network hardware architectures are used to accelerate traditional physics-based simulations. Connecting the underlying physics to experimental data is an extremely difficult scientific challenge. CogSim AI techniques hold the key to teaching existing simulation models to better mirror experiments and improve the feedback loop between experiments and models.

AI and machine learning (ML) are widely used throughout the Laboratory to accelerate scientific discovery. For example, LLNL materials and computer scientists have developed a novel ML model that can predict 10 distinct polymer properties from known data sets more accurately than ever before. Discovering suitable polymer materials for use in applications ranging from packaging to solar cells depends on accurately predicting the properties of candidate materials. The model's success lies in a new polymer representation that compactly captures the polymer's structure combined with powerful graph-based ML techniques that autonomously learn how to best describe that structure. Previous ML approaches to predicting polymer properties could not capture the polymer's periodicity, leading to inaccurate predictions. The new ML model will enable new concepts in polymer chemistry to be rapidly tested and iterated upon for a large application space.

LLNL computer scientists stand by the new SambaNova artificial intelligence hardware that upgrades the Laboratory's cognitive simulation capabilities.



Vertically aligned carbon nanotubes are shown growing from catalytic nanoparticles (gold color) on a silicon wafer on top of a heating stage (red glow). Diffusion of acetylene molecules through the gas phase to the catalytic sites determines the growth rate.

NANO FORESTS, BIG POSSIBILITIES

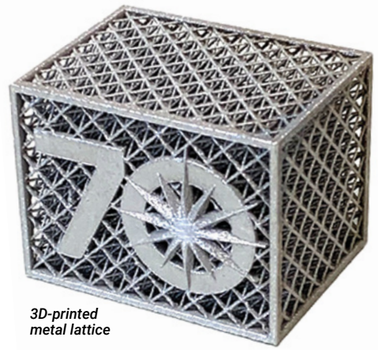
Carbon nanotubes (CNTs)—hollow graphite cylinders measuring up to 5 nanometers in diameter and tens of micrometers long—are the focus of several Livermore research efforts. CNTs have unusual strength, stiffness, and thermal and electrical conductivity. They enable faster proton transport than that in biological channels. LLNL scientists have keen interest in scaling up the production of packed arrays of vertically aligned single-walled CNTs, often called forests. Order and alignment of CNTs strongly influence the material's macroscale performance. Use of forests rather than unorganized CNT structures could revolutionize a host of commercial applications, such as energy storage and water purification. The LLNL research team demonstrated growth of vertically aligned single-walled CNTs at wafer scale under a variety of synthesis conditions and derived a kinetics model to interpret the observed growth trends. The model indicates that appropriate choice of the growth recipe and fluid dynamic conditions can significantly increase the production throughput of CNT forests.

Other LLNL scientists have applied a neural network interatomic potential within advanced computational models to understand the hydrogen bonding of water confined in single-walled CNTs. This potential allowed an efficient, computationally accurate examination of confined water for a wide range of CNT diameters at time and length scales beyond the reach of conventional first-principles approaches. An improved understanding of hydrogen bonding in nanopores bridges knowledge gaps in the structure and dynamics of confined water and promises to advance various applications, including ion-selective membranes for water desalination.

ADVANCING COMPONENT DESIGN AND MANUFACTURING

Over the last decade, Laboratory breakthroughs in additive manufacturing—often called 3D printing—have enabled production of nanoscale precision components with previously unobtainable properties made from an ever-expanding variety of materials. An invention this year was a 3D-printed material capable of replicating characteristics of biological tissue. Engineers and chemists at LLNL and Meta produced a material that is stretchable to around 200 times its original properties, and as its gradient transitions from soft to stiffer material, its toughness increases by 10 times. It can be tailored for energy-absorbing materials, soft robotics, and wearable electronic devices, including those for enhancing human performance. Other researchers at the Laboratory developed a method for detecting and predicting strut defects in 3D-printed metal lattice structures during a print using a combination of monitoring, imaging techniques and multiphysics simulations. The ability to monitor build quality in situ to decide, on the fly, if the part will satisfy quality requirements is important for manufacturing high-strength, low-density metallic lattices.

Laboratory engineers are also making major strides toward closing the gap between design and manufacturing. This year, they adapted the Livermore Design Optimization (LiDO) code to accelerate the development cycle for new parts. LiDO works in tandem with Serac—a high-order nonlinear thermomechanical simulation code—to automatically generate optimal designs based on performance metrics. Previously, designers had to write unique code to integrate Serac simulations into the LiDO framework, requiring every solver to use a separate subroutine or wrapper function. Now, designers can use a single wrapper for all Serac solvers, reducing the time, energy, and maintenance burden to facilitate changing design needs. LiDO is integral to a DOE HPC initiative that aims to create "digital twins" for expediting design and production of aerospace components.



3D-printed metal lattice

Two physicists (left) and a nuclear engineer (right) look over a prototype of the high-purity gamma-ray spectrometer that they designed and built for a more than 2 billion-mile journey to the Psyche asteroid.

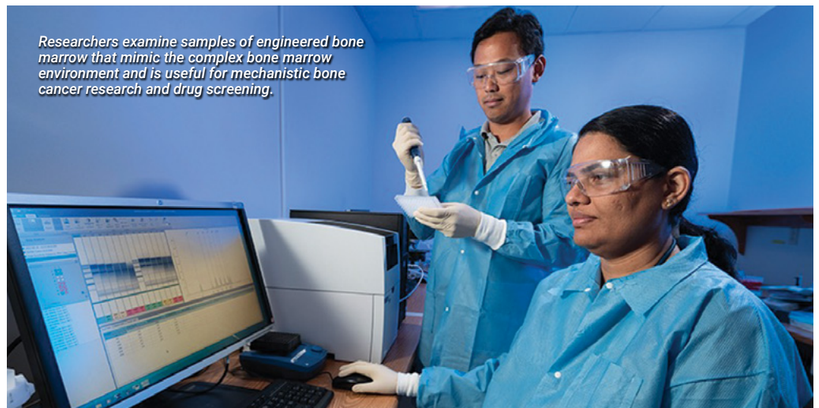
FOCUSING ON ASTEROIDS

Scientists in LLNL's Planetary Defense Program and external collaborators published the first peer-reviewed scientific results from NASA's successful Double Asteroid Redirection Test (DART), which took place on September 26, 2022. Since the DART spacecraft effectively deflected the 150-meter Dimorphos moonlet and changed its orbit around the larger Dimorphos asteroid, Laboratory researchers have been applying machine learning and multiphysics simulations, such as Monte Carlo approaches, to evaluate the data. The study provides a first look at the effects of kinetic impact on the orbital velocity of Dimorphos and identifies that substantially more momentum was transferred to the asteroid from the escaping impact ejecta than from the impact of the spacecraft itself.

This year, LLNL also saw its fourth-generation high-purity germanium gamma-ray sensor begin its 2 billion-mile journey to make the first-ever visit to Psyche, the largest metal asteroid in the solar system. Thought to be the remnant of a planetary core, Psyche offers a rare opportunity for researchers to study and better understand planet formation and the hidden cores of Earth, Mars, Mercury, and Venus. The sensor is an essential part of a gamma-ray spectrometer built in collaboration with researchers from Johns Hopkins Applied Physics Laboratory.

MATERIALS SCIENCE MYSTERIES REVEALED

Through the combined power of simulation and experiments, Laboratory scientists and collaborators have provided answers to longstanding mysteries in materials science. One team developed a scaling law for analyzing kinetics related to high-pressure, rapid solidification of metastable liquids observed in experiments over the past few decades. The researchers used a dynamic-compression platform to rapidly compress liquids in just tens to thousands of nanoseconds, allowing them to explore exotic liquid states that solidify at pressures far beyond what phase diagrams predict for equilibrium conditions. The new scaling law explains and quantifies a surprising compression-rate dependence across different experimental platforms and could accelerate capabilities for engineering and synthesizing novel materials via high-pressure techniques.

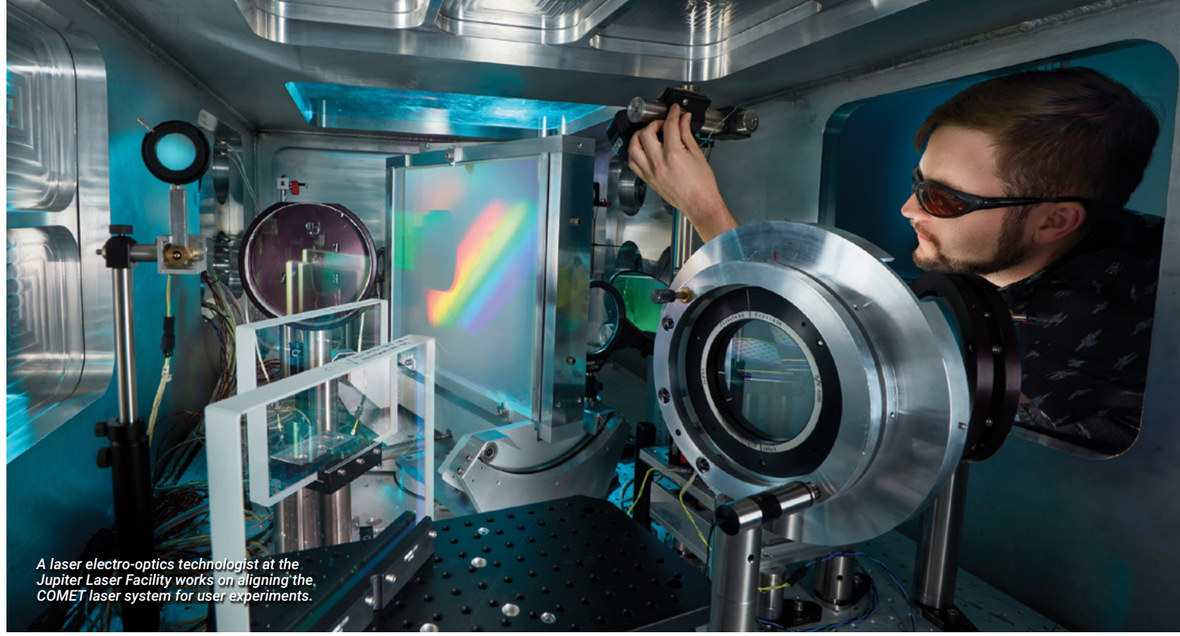


Researchers examine samples of engineered bone marrow that mimic the complex bone marrow environment and is useful for mechanistic bone cancer research and drug screening.

LLNL scientists have also identified a previously unknown ejecta production mechanism called shallow bubble collapse (SBC). It is not based on Richtmyer–Meshkov instabilities (RMI), a heavily researched process that was believed to be the main source of shock-driven ejecta production in metal surfaces. The team used high-resolution modeling of various shock conditions to identify regimes that behaved computationally different than RMI theory and then designed and fielded experiments to evaluate those conditions. The researchers found SBC can produce ten times more ejecta with two times higher temperature than RMI under similar shock strengths, presenting a new phenomenology of multishock ejecta production.

ABOARD THE INTERNATIONAL SPACE STATION

The LLNL-developed Stellar Occultation Hypertemporal Imaging Payload (SOHIP) prototype telescope is fully operational on board the International Space Station (ISS). The telescope met rigorous NASA safety requirements for inclusion on the ISS—a Laboratory first—and is already measuring atmospheric properties with high resolution at unprecedented altitudes. SOHIP uses LLNL-patented monolithic optics technology on a gimbal to detect and characterize gravity waves (oscillations of air that transport energy and momentum from the lower to the upper atmosphere as they propagate vertically and horizontally) and high-altitude atmospheric properties such as temperature, pressure, and air density profiles at altitudes up to 50 kilometers. In addition, a five-year study led by Livermore and NASA researchers of the ISS and its astronauts concluded that the habitat is safe for its residents. The ISS is one of the most uniquely sealed environments in existence, with only the arrival of new astronauts and supplies introducing new microbes. The microbiome of space station surfaces resembled that of the crew member's skin. The samples were processed using the Livermore Metagenomics Analysis Toolkit, a bioinformatics software that rapidly identifies microbes—including bacteria, viruses, or fungi—from vast DNA sequence data.



A laser electro-optics technologist at the Jupiter Laser Facility works on aligning the COMET laser system for user experiments.

TACKLING CANCER ON MULTIPLE FRONTS

LLNL scientists are pursuing wide-ranging efforts to combat cancer. As part of DOE's Exascale Computing Project, Livermore computational scientists helped develop the CANDLE (Cancer Distributed Learning Environment) software suite, which brings together machine learning, deep learning, and research data to accelerate discovery of new therapeutics and treatment options. The team developed a theoretical model, based on Dynamic Density Functional Theory, to enable more efficient molecular-level simulations of cell membranes and their lipid–protein interactions. The new model simulates molecular interactions at greatly improved length (micrometer) and time (seconds) scales, providing cancer researchers with key capabilities to investigate the behavior of cancer-causing proteins. The CANDLE project garnered a 2023 R&D 100 Award from *R&D World Magazine*.

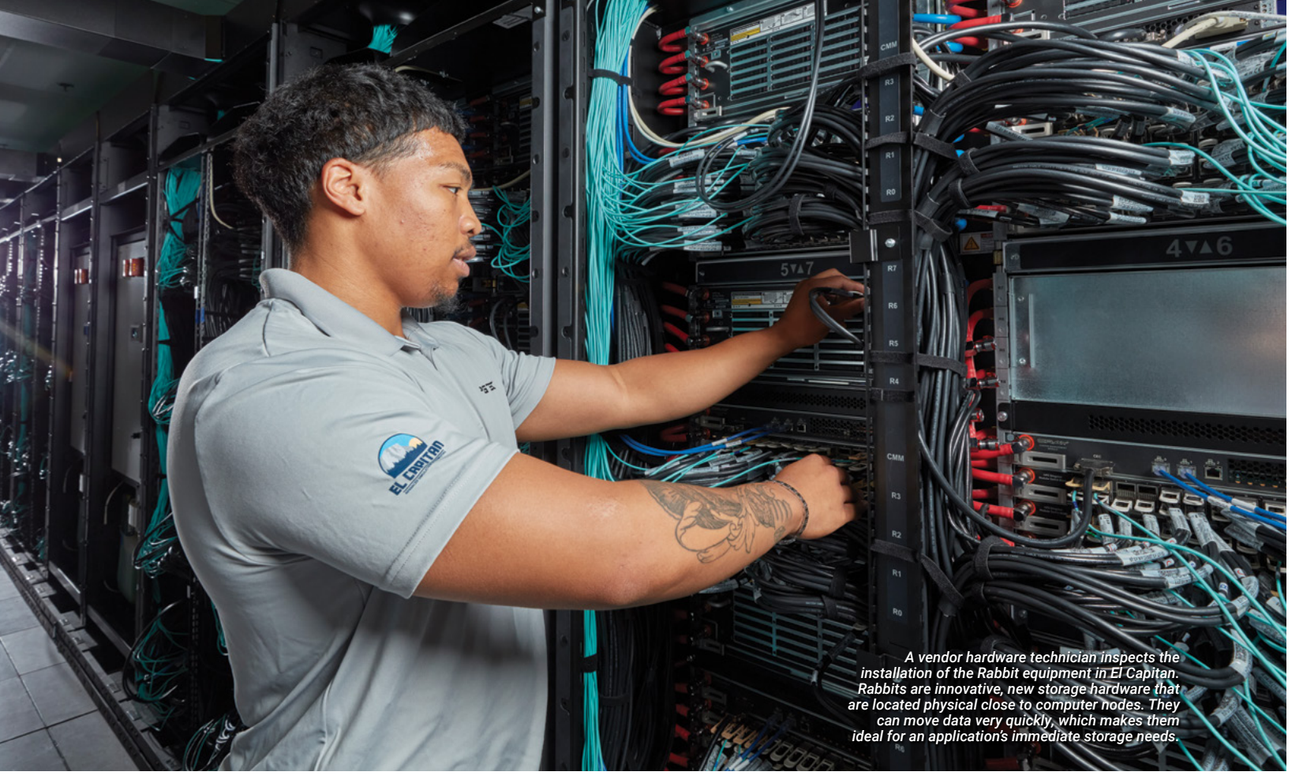
Research teams are also developing novel platforms for studying the pathogenesis of cancer types that are extremely difficult to treat. A Livermore–University of California at Davis collaboration has created a 3D platform using engineered bone marrow to study how microenvironmental and immune factors affect tumor progression for patients with osteosarcoma—the most common primary malignant bone cancer in children and adolescents. A separate LLNL team has devised a bioreactor platform to study tumor organoids from patients with colorectal cancer and subsequent stage IV liver metastasis. This in vitro platform can help researchers better understand tumor progression and treatment resistance. Such tools have potential to accelerate drug screening and discovery and improve patient outcomes.

JUPITER LASER FACILITY EXPERIMENTS

In FY 2023, the DOE Office of Science announced provision of $28.5 million in funding for LaserNetUS. The network of facilities operating high-intensity, ultrafast lasers provides open and free access to researchers and enables students to conduct work for their dissertations. LLNL's Jupiter Laser Facility (JLF) has been part of LaserNetUS since its inception in 2018. Experiments at JLF, conducted by Laboratory researchers and external users, are capitalizing on upgrades made during a four-year project to refurbish the facility. With its unique capabilities to perform hands-on high-energy-density science experiments, JLF can play an important role in advancing inertial fusion energy in addition to discovery plasma science. For example, a postdoctoral fellow at LLNL's High Energy Density Science Center is conducting innovative plasma physics experiments at JLF that "twist" laser light and create some of the strongest magnetic fields ever generated by a laser.

DENSE PLASMA FOCUS RADIOGRAPHY

The LLNL Megajoule Neutron Imaging Radiography Experiment (MJOLNIR) achieved greater than 10^{12} neutrons in a single deuterium gas shot in 2023. The result is a major step toward their goal of 10^{13} neutrons and tighter spot size, which would allow for taking still-frame pictures of light elements undergoing highly dynamic processes, for example, during subcritical experiments at the Nevada National Security Site. The MJOLNIR dense plasma focus (DPF) neutron source runs powerful electrical currents through a gas, which causes it to ionize into a plasma before generating an intense magnetic field that compresses the plasma. This pinching creates a bright but brief (100 nanosecond) flash of neutrons for rapid-fire photography. High-performance computing simulations complement the experimental activities, assisting in their design and in developing an improved understanding of DPF neutron pulse creation.



A vendor hardware technician inspects the installation of the Rabbit equipment in El Capitan. Rabbits are innovative, new storage hardware that are located physical close to computer nodes. They can move data very quickly, which makes them ideal for an application's immediate storage needs.

PARTNERSHIPS

Sharing science and technolgy expertise and capabilities to meet our nation's most important needs

LLNL engages in wide-ranging partnerships with other laboratories and research institutions, academia, and industry. Many collaborations integrate disparate expertise and capabilities with focus on innovations to meet challenging mission objectives. Others serve to transition science and technology (S&T) breakthroughs into new applications and products.

COLLABORATING TO DELIVER EL CAPITAN

The road to NNSA's first exascale supercomputer, El Capitan, has entailed many partnerships, including support from NNSA's Advanced Simulation and Computing Program and DOE's Exascale Computing Project (ECP), which was launched by NNSA and the DOE Office of Science in 2016 to prepare the DOE laboratories for delivery of exascale computing in 2022. At LLNL, the effort has engaged hundreds of employees, and in FY 2023 included hardware deliveries, environmental testing, and facility completion before arrival of El Capitan. Preparatory activities have been under the purview of the El Capitan Center of Excellence, a collaboration of developers and experts at the NNSA laboratories. Considerable effort has gone into early hardware deployment and testing to fix issues ahead of larger system deployment. For example, early access systems—predecessors to El Capitan delivered in 2021—were connected to the 85-megawatt Exascale Computing Facility Modernization infrastructure installed in 2022.

Laboratory computer scientists have provided leadership within the high-performance computing (HPC) community in developing open-source software for HPC systems—and now exascale supercomputers. For example, Tri-Lab Operation System Stack, which was developed at LLNL and is now widely employed as an operating system for commodity HPC clusters, will be used by El Capitan. Other examples include two R&D 100 Award winners in 2023. Variorum is a vendor-neutral software library for optimizing and managing power and energy on large-scale supercomputers. ZFP, also developed at LLNL, is an open-source software package that compresses numerical data exceptionally fast and allows reductions in data movement, which is critical because data movement is largely the limiting factor in HPC performance.

THE nEXO EXPERIMENT

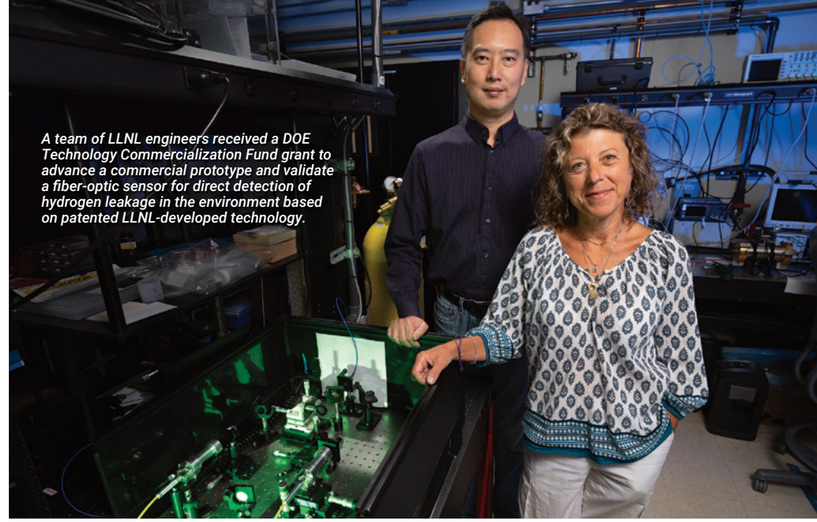
In FY 2023, DOE allocated to LLNL $2.35 million from Inflation Reduction Act funding to support the nEXO project, which the Laboratory leads for the DOE Office of Science. The project is developing capabilities and plans for constructing a large detector to search for a rare type of nuclear decay called neutrinoless double beta decay (NDBD). The large collaborative effort is engaging approximately 200 scientists and technologists from 36 institutions and eight countries, including five DOE national laboratories and more than a dozen U.S. universities. NDBD has not yet been observed and is inconsistent with known laws of physics since the decay process generates matter without creating antimatter. Detection would be a major discovery and provide key insight into the formation of the universe. The search for NDBD requires a large detector isolated from cosmic rays to be built at a depth of 2 kilometers in SNOLAB, Canada's deep underground research laboratory, located in a mine in Ontario, Canada. The funding will advance the nEXO project toward DOE Critical Decision-1.

AN INERTIAL FUSION ENERGY HUB

In December 2023, DOE awarded a four-year, $16 million project to a multi-institutional team led by LLNL to accelerate inertial fusion energy (IFE) research. This effort will be carried out by the newly established IFE Science and Technology Accelerated Research for Fusion Innovation and Reactor Engineering (STARFIRE) Hub. Supported by the DOE Office of Fusion Energy Sciences, the hub consists of members from seven universities, four U.S. national laboratories, one international laboratory, three commercial entities, one philanthropic organization, and three private IFE companies. IFE-STARFIRE will accelerate demonstration of high-gain target designs, target manufacturing and engagement, and diode-pumped solid state laser technologies. The hub and an LLNL institutional initiative in IFE synergistically complement NNSA's major investments in inertial confinement fusion research and development for national security applications.

PARTNERING WITH THE U.S. SPACE FORCE

In 2023, the United States Space Force selected subject matter experts from the Laboratory to help stand up its new Tools, Applications, and Processing (TAP) laboratory dedicated to advancing military space domain awareness (SDA).

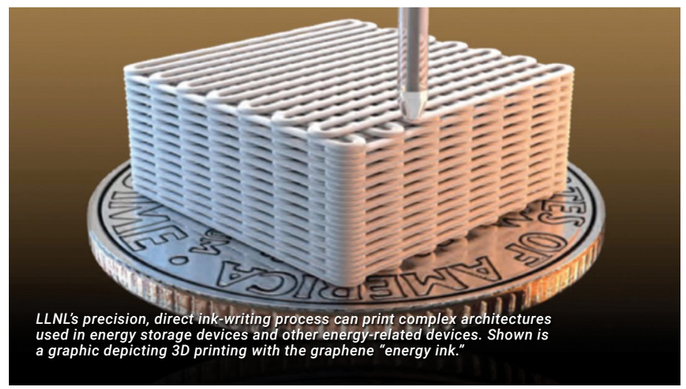


A team of LLNL engineers received a DOE Technology Commercialization Fund grant to advance a commercial prototype and validate a fiber-optic sensor for direct detection of hydrogen leakage in the environment based on patented LLNL-developed technology.

In October, the LLNL team attended a kick-off meeting of the SDA TAP laboratory's Project Apollo technology accelerator, which is designed to encourage rapid government, industry, academic, and allied collaboration. As a Federally Funded Research and Development Center partner, LLNL will perform testing and evaluation of the applications that Project Apollo produces to ensure their operational readiness. These efforts will leverage the Laboratory's unique capabilities in modeling and simulation, HPC, and uncertainty quantification.

INNOVATIVE INDUSTRIAL AND ENERGY PARTNERSHIPS

LLNL is benefiting the U.S. economy with innovative technology and methods. In FY 2023, Livermore obtained 196 new patents, asserted 91 new copyrights, and executed 7 new patent licenses. Licensing income for the year totaled approximately $6.1 million. Among honors, LLNL earned three R&D 100 awards from *R&D World Magazine*. Two awards were for software important to efficient exascale supercomputing (see p. 18) and the third award for an exascale computing project to aid cancer research (see p. 17). The Laboratory also secured four grants from DOE's Technology Commercialization Fund. LLNL researchers will work with industrial partners on 3D printing of battery anodes, hydrogen storage for heavy-duty trucks (see p. 13), a fiber-optic sensor detecting leakage from hydrogen storage tanks, and self-assembling microgrids for energy resilience. The Laboratory also was awarded a Federal Laboratory Consortium Best in Far West Region Award for its multifunctional, 3D-printable inks for energy storage applications licensed to MilliporeSigma. Additionally, energy-focused projects are being pursued with academic collaborators through the DOE Office of Science's Energy Frontier Research Centers program.



LLNL's precision, direct ink-writing process can print complex architectures used in energy storage devices and other energy-related devices. Shown is a graphic depicting 3D printing with the graphene "energy ink."

SAFE, SECURE, AND SUSTAINABLE OPERATIONS

Conducting safe, secure, and environmentally sound operations and modernizing the Laboratory's infrastructure to meet evolving mission needs

Construction is shown in progress of a new STAR facility on the Applied Materials and Engineering Campus. Other buildings in this campus have been delivered ahead of schedule and under budget.

COMMITTED to the highest level of operational performance, LLNL implements best practices in environment, safety, and health (ES&H), and security. Management systems support continuous improvement in work practices. Prudent risk management coupled with active measures to prevent accidents ensures the safety of employees and the public. Investments are targeted to modernize the Laboratory's infrastructure and continually improve operations.

STREAMLINING OPERATIONS

LLNL is streamlining operations and providing leadership in responding to NNSA's Enhanced Mission Delivery Initiative (EMDI). Established to make the nuclear security enterprise (NSE) more agile and responsive to the many challenges it faces, the EMDI focuses on reinvigorating NNSA's working relationship with its national laboratories and production sites. For example, working closely with the Livermore Field Office, the Laboratory has successfully piloted the use of Cal/OSHA regulations for construction projects as an acceptable substitute for 10 CFR 851, DOE's worker safety and health regulation. Use of California standards has permitted more local/regional construction businesses to bid on and execute projects. This change reduces confusion, lowers cost, and eliminates inefficiencies associated with subcontractor compliance with an unfamiliar regulatory framework while maintaining ES&H standards consistent with 10 CFR 851. The Laboratory and NNSA are also exploring opportunities for modifying Lawrence Livermore National Security's management and operating contract to increase efficiency through effective risk-based decision making and management.

EMDI leadership is exemplified in LLNL's partnering with all sites across the NSE to identify opportunities for improvement and use pilot projects to demonstrate that they should be standardized as best practices. In particular, the W80-4 and W87-1 modernization programs are introducing new approaches to project management as well as design, manufacturing, and certification through many pilot projects (see pp. 4–5).

ENVIRONMENTAL MANAGEMENT AND SUSTAINMENT

The 2022 Site Annual Environmental Report (issued in October 2023) documents LLNL's compliance with environmental standards and monitoring results. This year, Livermore became the first in the NNSA complex to successfully implement standards from the American National Standards Institute for clearance of radioactive materials. LLNL began removing soils from Site 300 and demolition wastes from other projects. The Laboratory also achieved the best possible score from the California Department of Toxic Substance Control for having no Class 1 violations in the past 10 years. In addition, LLNL earned an NNSA Green Fleet Award for efforts targeting government fleet conversion to zero emissions vehicles. Sustainability pursuits also included an expanded site-wide recycling and composting program. In FY 2023, eight facilities were under construction or in the design phase that meet the federal Guiding Principles for Sustainable Buildings.

The Laboratory's new Emergency Operations Center was activated to collect up-to-date information that was provided to employees during the extended period of winter storms in FY 2023.

MISSION ENABLEMENT

In FY 2023, operations at the Laboratory were well managed, with significant accomplishments and focused efforts to implement EMDI recommendations. LLNL conducted efficient, effective business operations and financial management. Individual and team efforts achieved many notable successes in ES&H, information technology management, legal services, and nuclear operations. Within the Laboratory's business services area, the shipping and distribution team processed a record-breaking 201,145 packages in FY 2023. In supply chain management, procurements surpassed $1.25 billion, which exceeded the previous year's record $1.1 billion. Small business spending topped $525 million (see p. 26). In addition, LLNL worked with NNSA's Livermore Field Office to identify areas in its purchasing system where the risk tolerance could be reasonably raised to enable the Laboratory to be more agile and meet the increasing demands of its mission.

INFRASTRUCTURE MANAGEMENT

An enormous amount of activity is ongoing to meet LLNL staff's needs for modernized facilities and infrastructure in support of continuing mission success. In FY 2023, the Laboratory's project management office supported the completion of more than 120 construction projects, valued in excess of $200 million (see p. 23). New project management tools and systems are enabling greater efficiency and streamlined project delivery. In addition, NNSA's Standardized Acquisition and Recapitalization (STAR) Initiative—launched in 2019 with pilot projects at LLNL—is reducing costs and accelerating construction of small office and light laboratory facilities by developing common standards and common scalable designs that can be used across sites. Construction is ongoing for six new STAR buildings valued at $100 million that will provide the Laboratory with about 124,000 square-feet of new laboratory and office space and nearly 500 new offices.

In addition to new construction, the Laboratory is demolishing outdated facilities, refurbishing facilities where cost effective, and attending to a maintenance backlog. Large-facility decontamination and demolition jobs over the last several years have greatly increased the volume of radioactive waste disposed of each year. More than 2,200 cubic meters (about 10,000 drum equivalents) of waste were disposed of in FY 2023, including a successful 70-drum transuranic waste shipment to the DOE Waste Isolation Pilot Plant at Carlsbad, New Mexico.

WINTER STORM EMERGENCY OPERATIONS

In January 2023, the new Emergency Operations Center (EOC) was activated for the first time. The extended winter rainstorms caused a curtailment of operations at remote Site 300 due to road closures. About a foot of rain fell over an area that commonly goes without precipitation for most of year. The EOC collected a considerable amount of data to keep information for employees up-to-date regarding current conditions and closures. Site 300 employees worked at the main site temporarily. Security officers, firefighters, and maintenance personnel kept a constant presence at the site—one team for a stretch of nearly 36 hours. LLNL maintenance crews responded to 143 storm-related work requests. The storms brought down 17 trees over a two-week period. ES&H teams focused on making sure storm water runover from construction and industrial areas did not reach local streams. The workload was heavy for LLNL operations, but damage was minimal and construction crews were able to recover schedules after the storms passed.

A container is being prepared for shipping at the Site 200 Shipping and Receiving warehouse, which had a busy year and a record number of packages received and delivered.

MANAGING FOR THE FUTURE

FY 2023 was a year of building for future mission successes through new initiatives, attention to workforce needs, and expanding partnerships.

Moving the Laboratory forward in science and technology excellence directed at important national missions

STRATEGIC LEADERSHIP

DOE Secretary Jennifer Granholm, DOE Under Secretary for Nuclear Security and NNSA Administrator Jill Hruby, and U.S. Representative Zoe Lofgren (D-CA18) were among the speakers at Ignition Day, held at the Laboratory on May 8, 2023, celebrating the historic success at the National Ignition Facility (NIF). The event honored the recent achievement and the many individuals and institutions that contributed to the inertial confinement fusion (ICF) effort over six decades. In addition to ICF, LLNL is providing NNSA with technical leadership through broad partnerships in many facets of its national security mission and efforts to modernize the NNSA complex. The Laboratory is engaged in two nuclear warhead development programs (see pp. 4–5) and is collaborating with other NNSA sites to develop technologies and procedures that will accelerate the weapon design-to-production process. These efforts are benefiting from major advances in high-performance computing and machine learning, additive manufacturing, and experimental capabilities to certify weapons performance and advance fusion research. LLNL is also actively engaged in many process improvement pilot projects aligned with NNSA's Enhanced Mission Delivery Initiative recommendations (see p. 20).

SUPPORTING A CHANGING WORKFORCE

An outstanding workforce is LLNL's principal strength. Recruiting, training, and retaining exceptional talent is a top priority at a time of rapid change in our workforce. In support of performance excellence, Laboratory culture is focused on employees and their individual needs. This focus on employees includes adoption of workplace flexibility, an award program recognizing excellent performance, and management initiatives to expand leadership training programs, pursue options to improve employee benefits, and establish an improved performance management system at the start of FY 2024 that emphasizes setting development goals and career planning.

Broad support for IDEA—inclusion, diversity, equity, and accountability—provides the foundation for creating an environment where the diverse talents, perspectives, ideas, backgrounds, and life experiences of all employees are valued and respected. Such an environment fosters innovative ideas and the ability to take on grand challenges that LLNL missions demand. The Laboratory's IDEA Office emphasizes culture-enhancing behavior and encourages activities of employee support groups that celebrate diversity. IDEA goals are also championed in the Laboratory's many outreach engagements with academia, veterans, and summer interns as well as STEM activities for pre-college students (see p. 24).

(left to right) Presenters at the Ignition Day event included NNSA Livermore Field Office Manager Janis Parenti, NNSA Deputy Administrator for Defense Programs Marvin "Marv" Adams, DOE Secretary Jennifer Granholm, DOE Under Secretary for Nuclear Security and NNSA Administrator Jill Hruby, LLNL Director Kimberly Budil, and U.S. Representative Zoe Lofgren.

The cross-institutional team that worked on the multiyear redesign effort for LLNL.gov was recognized with a Director's Institutional Operational Excellence Award at the 2023 Director's Awards ceremony. Visit LLNL.gov to learn more about the Laboratory.

RIBBON-CUTTINGS AND NEW FACILITIES

In FY 2023, several key facilities began operations in support of LLNL's national security missions. In May, a ribbon-cutting ceremony officially marked the opening of the Advanced Characterization and Evaluation Laboratory, which will enable more rapid maturation of nondestructive evaluation (NDE) capabilities for NNSA's stockpile modernization programs. Advances in NDE are broadly needed for U.S. industry to accelerate manufacturing tools and processes and produce higher quality parts. Another ribbon-cutting ceremony marked the opening of a new Stockpile Modernization building that will add more than 100 offices for staff working on the W87-1 Mod and other programs. In addition, an open house in July 2023 welcomed newly modernized laboratory facilities and redesigned workspaces that support LLNL's excellence in materials science. The combination of unique capabilities and user workspaces enable researchers from across the Laboratory to pursue current projects with enhanced tools and to undertake exciting new research opportunities.

In FY 2023, site preparation began for construction of DICE—the Digital Infrastructure Capability Expansion. The facility will provide a major upgrade to LLNL's current networking and communications infrastructure and support future needs. DICE is a line-item construction project that is benefiting from NNSA's efforts to streamline construction projects and lower costs (see p. 20). The new facility will be LEED gold certified.

THE SITE DEVELOPMENT PLAN 2023

In July 2023, the Laboratory issued its updated Site Development Plan, which lays out a 20-year roadmap for disposition and construction on Sites 200 (the main campus) and 300. The plans are focused not only on new facilities and modernized infrastructure, but how they are arrayed to enhance the productivity and work experience of future generations of employees. The plan includes the creation of neighborhoods to increase opportunities for interaction, and it envisions a more central location for the Director's Office and core nuclear weapons program activities. A centerpiece will be the National Security Innovation Center (NSIC), a five-building complex consisting of 1,000 offices and an auditorium planned for the center of the Laboratory. The NSIC received a Critical Decision-0 sign-off at NNSA, and construction of the first building is expected to begin in 2026.

LLNS BOARD OF GOVERNORS ACTIVITIES

The LLNS Board of Governors and its committees provide oversight to the Laboratory and delve into issues crucial to mission and mission-support activities. External review committees (ERCs), panels of independent experts including Board members, periodically met in FY 2023 to critically assess the quality of the Laboratory's technical workforce and the effectiveness of research efforts in meeting mission goals and future national needs. Their reports, which provided DOE/NNSA with an independent validation of work quality, consistently affirmed the mission relevance and high impact of Laboratory research. The Board chartered functional management reviews (FMRs) on an as-needed basis. Six FMRs were completed in FY 2023 in topical areas ranging from Superblock operations and site security to work planning and control. Recommendations provided by Board committees, ERCs, and FMRs have led to substantive responsive actions.

Construction will begin in 2026 for the first of five buildings planned for the National Security Innovation Center which will consolidate related activities and be centrally located in LLNL's campus.

COMMUNITY CONNECTIONS

Partnering with our neighbors through science education and charitable giving

Students attending the SAGE camp enjoy some free time in the newly refurbished Discovery Center.

THE Laboratory is an active member of local communities, offering a wide variety of programs to enhance science, technology, engineering, and mathematics (STEM) education. Many more students visited LLNL in FY 2023 with the post-COVID reopening of the Discovery Center. This year LLNL staff and LLNS donated more than $4.1 million to local nonprofits, while hundreds of employees donated their time to local service agencies.

DISCOVERY CENTER REOPENED

On February 1, 2023, LLNL's Discovery Center reopened after a nearly three-year closure due to COVID-19. The fully renovated facility includes a host of new hands-on exhibits related to the Laboratory's research programs, institutional history, and role in the community. Exhibits are designed to excite the next generation of researchers about new innovations and work performed at LLNL. They showcase state-of-the-art research ranging from high-performance computing and bioscience to advanced materials and manufacturing. Visitors can step inside a replica of the National Ignition Facility (NIF) target chamber. The Discovery Center is open from noon to 4 p.m. on weekdays.

PROMOTING STEM EDUCATION

The resumption of onsite visits and programs brought many enthusiastic faces to the Laboratory. The pre-pandemic field-trip program resumed, with fifth-grade students from local elementary schools visiting the Discovery Center and enjoying interactive Fun with Science performances. This year, more than 1,600 fifth graders participated, and they learned about NIF and the concepts of light, lasers, optics and physics through demonstrations, hands-on activities, and science displays. In addition, more than 300 high-school students came to LLNL for the Day at the Lab program, which included tours of the National Atmospheric Release Advisory Center, NIF, and the Advanced Manufacturing Laboratory (AML).

Other in-person STEM outreach activities also resumed in FY 2023. In February, the Science on Saturday lecture series opened at the Las Positas College campus. More than 2,000 middle- and high-school students heard from Laboratory researchers about biology, computing, additive manufacturing, and fusion science. The Teacher Research Academy program also restarted, with three workshops for middle- and high-school teachers. In addition, in June, nearly 30 high-school students performed science experiments with their smartphones at the STEM with Phones workshop. The summer boasted a variety of programs and events with the arrival of more than 800 undergraduate and graduate student interns. At the Biotech Summer Experience, local high-school students participated in immersive research projects in molecular biology and bioinformatics. Science Accelerating Girls Engagement (SAGE) in STEM returned for its second year. At the weeklong camp, 28 participants learned about scientific research and careers at the national labs.

STRONG TIES WITH THE CITY OF LIVERMORE

For more than 70 years, the Laboratory and the City of Livermore have grown together, and events throughout 2023 highlighted the strong working relationship. In April, LLNL hosted more than 40 managers from the City of Livermore. At the Livermore Valley Open Campus (LVOC), they met with Director Kimberly Budil, who observed that the many amenities in the community help the Laboratory attract top talent. Following a presentation on ignition, the visitors toured the AML and Discovery Center. May 30 brought the celebration of Livermorium Day at the city's Livermorium Park. In June, at the invitation of the Livermore Rotary Club, Director Budil and members of the NIF fusion team served as Grand Marshals at the 2023 Rodeo Parade. The 105th Livermore Rodeo provided an opportune venue for LLNL to celebrate achieving ignition with the local community.

At the Open House, a Laboratory employee and guests pose by a poster thanking all employees for their contributions to LLNL, which enabled successful achievement of ignition.

HANDS-ON, PRACTICAL EXPERIENCE IN DATA SCIENCE

On International Women's Day in March, the annual Women in Data Science (WiDS) regional event was held at LVOC, in conjunction with the global WiDS conference. Attendees met online and in-person for the forum. Students engaged with Laboratory mentors in small groups to discuss career paths and some of the challenges of being a woman in a male-dominated field. In May, high-school students from Livermore and Tracy jointly attended a collaborative "Altamont Connection" Girls Who Code (GWC) event. Students from the two school districts toured research facilities at LLNL, engaged in hands-on activities, and interacted face-to-face with Laboratory computer scientists who had been their mentors in the GWC after-school program throughout the year.

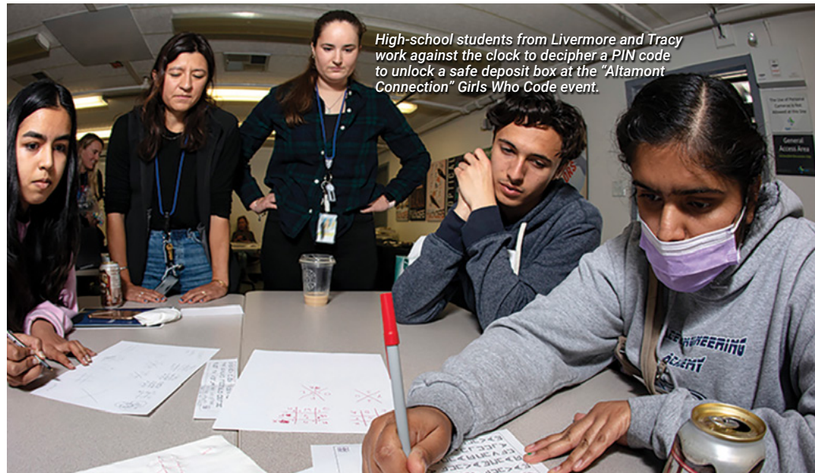
In July, 35 undergraduate and graduate students from the University of California (UC) at Riverside and UC Merced joined forces for the Laboratory's two-week Data Science Challenge. Hosted in the newly renovated University of California Livermore Collaboration Center at LVOC, the event focused on a real-world problem in machine-learning assisted heart modeling. The Data Science Summer Institute brought to the Laboratory students from all over the country—and from Japan.

EXPLORATION AT OPEN HOUSE

In October 2023, the Laboratory hosted nearly 19,000 employees and guests for tours, activities, and fun on campus. Every corner of LLNL was packed with information, with volunteers encouraging participants to experience the Open House's theme: "Explore, Discover, Innovate." To that end, children created elephant toothpaste using chemical reactions, lines of people snaked through NIF to get a glimpse of the target chamber, and staff members showed off their normally secluded offices. For many employees, Open House was their first opportunity to bring friends and family to LLNL. The event allowed them to share a part of their lives, show off the incredible work done at the Laboratory, and inspire the next-generation workforce.

ANNUAL GIFT GIVING

In 2023, the 49th year of the Laboratory's Helping Others More Effectively (HOME) campaign, employees and LLNS raised over $4 million. This year marks the first time the campaign has surpassed the $4 million mark. Employees pledged over $2.8 million, while LLNS matched $1.3 million. The donations will benefit more than 1,500 community nonprofit agencies selected by LLNL employees. In January 2024, LLNS announced the recipients of the 2023 Community Gift Program, with funds totaling $220,000. Many of the awards serve children in the Tri-Valley area as well as Contra Costa, San Francisco, and San Joaquin counties, and focus on literacy, STEM education, and cultural arts. Other recipients focus their charitable efforts toward individuals and families in need of assistance.


High-school students from Livermore and Tracy work against the clock to decipher a PIN code to unlock a safe deposit box at the "Altamont Connection" Girls Who Code event.

WORKFORCE RECOGNITION

Acknowledging exceptional performance and expertise

THE recognition by the scientific community and other stakeholders affirms the high quality of Livermore's work and innovative spirit. The awards on these pages showcase the efforts of the Laboratory's talented staff.

Jon Benjamin received DOE's Facility Management Contractor Small Business Program Manager of the Year Award for FY 2022. The award recognizes his significant contributions in the small business community and across the DOE complex.

Daniel Casey and Gauthier Deblonde

GOVERNMENTAL AGENCY AWARDS

Physicist **Daniel Casey** and chemist **Gauthier Deblonde** are among the 93 awardees who received a 2023 DOE Office of Science Early Career Research Program Award. Typical awards for DOE national laboratory staff are $500,000 per year for five years.

Several hundred LLNL employees, participating in five project teams, earned DOE Secretary's Honor Awards for work done in 2022. The awards are DOE's highest internal recognition for service to the department and the nation (e.g., see p. 11).

Hannah Farquar and **Roger Werne** of the Innovation and Partnerships Office received the 2023 Best in Class for Innovative Technology Transfer Award and the DOE Office of Technology Transitions Director's Award for developing the National Lab Accelerator Program, which supports successful technology commercialization.

Electrical engineer **Vincent Riot** is among those who received a special project management award from the DOE Office of Science for work done on the Legacy Survey of Space and Time camera for the Vera C. Rubin Observatory in Chile.

Teresa Bailey, **Brent Blue**, **Elizabeth Wheeler,** and **Lance Kim** were among 34 individuals representing all 17 DOE national laboratories that were honored as 2023 fellows in the Oppenheimer Science and Energy Leadership Program. The program brings together exceptional leaders to explore the complexities, challenges, and opportunities facing the national laboratory system and DOE.

Infrastructure and Operations Deputy Associate Director **Harold Yeldell** received the Patriotic Employer Award from the Employer Support of the Guard and Reserve, in conjunction with the Department of Defense.

PROFESSIONAL SOCIETY ACCOLADES

The American Physical Society announced **Manyalibo "Ibo" Matthews** and **Frank Graziani** as fellows in 2023. Matthews was distinguished for pioneering research in optimizing metal 3D printing and laser materials processing. Graziani was chosen for theoretical and computational contributions to the study of non-ideal plasmas, and for exceptional leadership in mentoring and educating the broader high-energy-density (HED) physics community.

The Society for Industrial and Applied Mathematics named **Chandrika Kamath** as a fellow honoring exemplary work in data science for scientific and engineering applications.

Physicists **Félicie Albert** and **Craig Siders** have been elected as fellows of Optica (formerly OSA). Albert was selected for pioneering research on x-ray sources driven by laser-wakefield acceleration and leadership in LaserNetUS (see p. 17). Siders was selected for contributions to the research, application, and development of high-intensity lasers in both basic and applied sciences.

Teresa Bailey, Brent Blue, Elizabeth Wheeler, and Lance Kim

Staff scientists **Alison Christopherson** and **Art Pak** have been elected Kavli fellows of the U.S. National Academy of Sciences.

Jeremy Feaster

Chief Technology Officer for Livermore Computing, **Bronis R. de Supinski**, was named as a 2022 fellow by the Association for Computing Machinery. He was recognized for contributions to the design of large-scale systems and their programming systems and software.

The American Society of Safety Professionals, San Francisco Chapter, awarded National Ignition Facility (NIF) operations manager **Bruno Van Wonterghem** the "Managers Who Get Safety" Award. Van Wonterghem was selected for his dedication to the safety of his employees and maintaining a proactive safety culture.

Nino Landen

SCIENCE AND TECHNOLOGY AWARDS

The European Cooperation in Science and Technology awarded **Alex Zylstra** the 2023 Edouard Fabre Prize for his exceptional contributions to the physics of laser-driven inertial confinement fusion (ICF) and laser-driven plasmas.

The Fusion Energy Division of the American Nuclear Society recognized **Nino Landen** as one of two recipients of the 2023 Edward Teller Award for his pioneering contributions to ICF and HED science and for his leadership in achieving ignition at NIF.

The American Institute for Chemical Engineering announced staff scientist **Jeremy Feaster** as one of its "35 Under 35" award winners for 2023, honoring Feaster for his outstanding contributions to the field and the chemical engineering community.

The Krell Institute awarded physicist **Tammy Ma** with its 2023 James Corones Award in Leadership, Community Building and Communication in recognition of her outstanding contributions to and leadership in the fusion energy science community.

SPECIAL HONORS

TIME named design physicist **Andrea "Annie" Kritcher** to its annual list of the 100 most influential people in the world. Kritcher was honored for her role as principal designer on the December 2022 experiment at NIF that resulted in fusion ignition.

HPCwire recognized Livermore's Deputy Associate Director for High Performance Computing (HPC) **Terri Quinn** among its "People to Watch" for 2023. The list recognizes HPC professionals who play leading roles in driving innovation within their chosen fields and make significant contributions to society.

The University of California President's 2022 Lindau Nobel Laureate Meetings Fellows Program selected four postdoctoral appointees, **Sijia Huang**, **Sarah Sandholtz**, **Sean Leonard,** and **Wonjin Choi**, to attend the 72nd annual meeting in Germany. The international scientific forum provides an opportunity for about 600 international students and postdocs to engage with 30 to 40 Nobel laureates.

Daniel Schwalbe-Koda was named one of Forbes "30 Under 30" in 2023 for his work to develop new, low-cost, sustainable materials using large supercomputers to simulate formulas that have the highest probability of being synthesized in practice.

Laboratory Director **Kimberly Budil** was selected by *Fast Company* as one of the "Most Creative People in Business" for 2023. The annual list recognizes individuals making an impact in society via daring achievements in their chosen fields. Budil was selected for leading the team that achieved fusion ignition at NIF.

The Telly Awards, which honors excellence in video and television across all screens and platforms, recognized the Laboratory with five awards for two videos developed to announce the successful fusion ignition achievement and visualize how NIF experiments happen. Employees in the Technical Information Department and the Office of Strategic Communication collaborated on the winning projects.

Annie Kritcher

LAWRENCE LIVERMORE NATIONAL SECURITY, LLC

Overseeing management and operation of the Laboratory for the U.S. Department of Energy and the National Nuclear Security Administration

An aerial view looks west toward the East Gate of the Laboratory.

LLNS is a limited liability company managed by Bechtel National, Inc.; the University of California; BWXT Government Group, Inc.; and Amentum Environment & Energy, Inc. Battelle Memorial Institute also participates in LLNS as a teaming subcontractor. Cutting-edge science is enhanced through the expertise of the University of California and its 10 campuses and LLNS' affiliation with the Texas A&M University system.

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RICHARD W. MIES AWARDED WITH JOHN S. FOSTER JR. MEDAL
Members of the national security community honored Richard W. Mies as he was presented the John S. Foster Jr. Medal in September 2023. Mies was recognized for his exceptional and inspirational career dedicated to national security, nuclear deterrence, and scientific innovation. He served a 35-year career in the U.S. Navy, led U.S. Strategic Command for four years, and continues to provide thoughtful leadership within the defense community. He is the eighth recipient of the Foster Medal.

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Nominations and Compensation
Science and Technology

LLNS PRESIDENT AND LABORATORY DIRECTOR
Kimberly S. Budil

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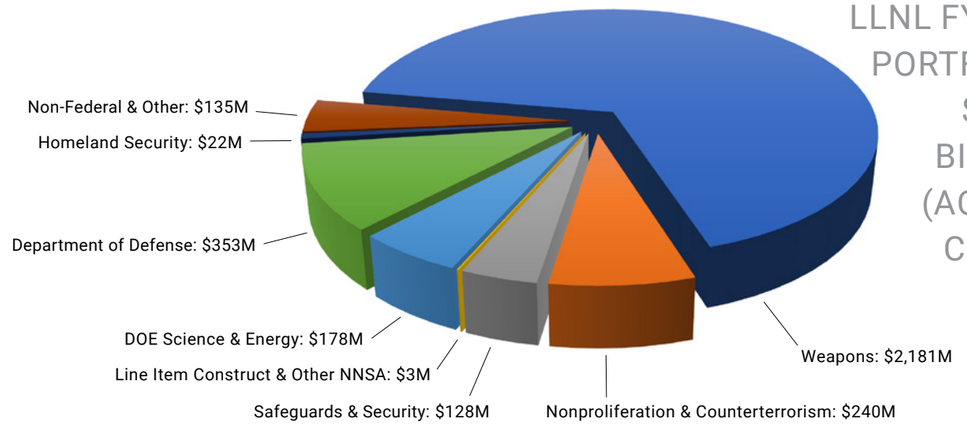
Computing
Engineering
Physical and Life Sciences

MISSIONS AND PROGRAMS
Global Security
Strategic Deterrence
NIF and Photon Science

OPERATIONS AND BUSINESS
Business
Human Resources
Project Management Office
Security Organization
Environment, Safety, and Health
Infrastructure and Operations
Office of the Chief Financial Officer

LLNL FY 2023 PORTFOLIO: $3.241 BILLION (ACTUAL COSTS)



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