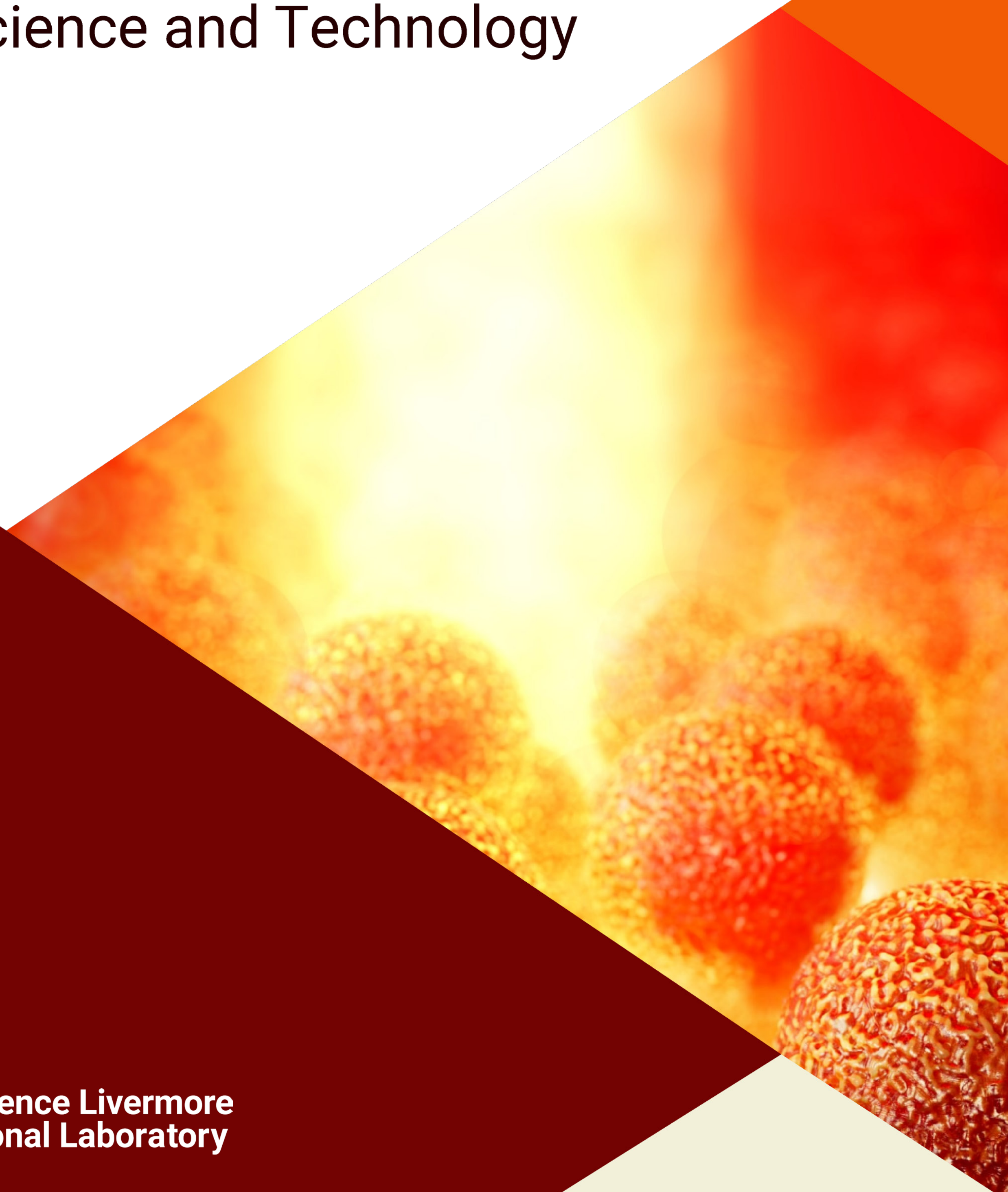
2026

INVESTMENT **STRATEGY**

for Science and Technology



Lawrence Livermore
National Laboratory

Science and Technology on a Mission

PATRICIA FALCONE
LLNL Deputy Director for Science and Technology

Lawrence Livermore National Laboratory (LLNL) was founded as a “big ideas” laboratory, a place where innovative scientific and technological solutions to the nation’s most difficult security challenges are created. Today, we continue this tradition and live by our motto, “Science and Technology on a Mission,” broadening the frontier of what is or might be scientifically and technically possible. At the core of our mission is strategic deterrence: we deliver world-class scientific and technological innovation to ensure the safety, security, reliability, and effectiveness of the U.S. nuclear weapons stockpile and to support national and nuclear security more generally by leveraging advances in high energy density science, advanced materials, high-performance computing, data science, and related domains. The LLNL investment strategy described herein is designed to strengthen key scientific disciplines and domains embodied in our seven Core Competencies as well as to enable new tools and approaches for delivering on our mission. While our Core Competencies are steadfast, applications of relevant science and technology (S&T) are continually evolving.

In this era of rapid change and global competition, new technologies and increased scientific understanding are essential for advancing U.S. security and strategic competitiveness. Consistent with previous years’ documents, the priorities for this year’s Laboratory Directed Research and Development (LDRD) program investments are described to support the FY27 call for LDRD research proposals. Looking ahead, three areas of focus in LDRD are emphasized: high yield facilities and inertial fusion energy (HYF/IFE), advanced materials and manufacturing (AMM), and artificial intelligence (AI). These areas of focus are further described below.

Beyond ignition, the technological terrain of higher yield fusion systems is of great interest. Deep understanding and experimental investigation of high yield systems are essential for addressing key questions in nuclear deterrence and for making advances toward the potential of fusion energy. Further research in HYF/IFE science is to enable the development and construction of a future high yield experimental facility and to advance the foundational S&T required to realize fusion as a practical energy source. LDRD-supported research in HYF/IFE not only strengthens LLNL’s core mission in stockpile management and modernization and high energy density science but also positions the Laboratory as a key contributor in the national and international fusion energy community.

New breakthroughs in AMM will enable LLNL to deliver agile and responsive solutions for national security challenges. Researchers aim to accelerate the discovery, design, and deployment of novel materials with tailored properties for extreme environments. Integrating AI and machine learning with experimental workflows will dramatically reduce the design-to-deployment timeline for new alloys, energetic materials, and advanced components. These efforts not only support modernization of the nuclear stockpile and the broader security enterprise but also drive innovation in energy, aerospace, and industrial applications, ensuring LLNL continues to work at the forefront of materials science and manufacturing technology.

Artificial Intelligence is a cross-cutting LDRD priority. Expert uses of these newly developing tools are fundamentally reshaping scientific discovery, mission delivery, and operational efficiency. Our goals for AI target the development of advanced machine learning algorithms, trustworthy and safe AI systems, and automation for experimental and manufacturing platforms. Advances in these domains will enable rapid data analysis, adaptive experimental design, and the acceleration of hypothesis generation and testing. Through internal investments and partnerships with industrial and academic colleagues, we aim to ensure that AI research excellence supports U.S. leadership in the global AI landscape. Going forward, AI is envisioned as a foundational element in every facet of our Laboratory, enhancing our ability to respond swiftly and effectively to emerging needs.

The *2026 Investment Strategy for Science and Technology* encompasses strategic elements for further investment by highlighting mission-relevant challenges and anticipating where pushing the boundaries of new science, technology, and innovation could lead. Our enduring commitment to stockpile management and modernization supporting national strength and global stability is evident across the Laboratory, with cross-cutting support from each organization: Computing, Engineering, Global Security, National Ignition Facility and Photon Science, Operations and Business, Physical and Life Sciences, and Strategic Deterrence. We are grateful for the ability to make strategic investments that sustain LLNL as a national resource for innovative scientific solutions and an employer of creative and committed people.

Pat Falcone

Section 1: LLNL Overview

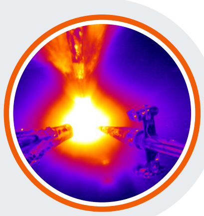
One Mission, Many Domains. Lawrence Livermore National Laboratory serves a wide variety of national security mission areas by applying science and technology to our enduring responsibilities in nuclear deterrence. Established in 1952 at the height of the Cold War to advance nuclear science and technology, we recently celebrated seventy years of addressing the challenges of strategic deterrence and nonproliferation in an increasingly complex geopolitical environment. Continuing federal support for our defining responsibility has enabled the Laboratory to serve the nation with state-of-the-art facilities, world-class competencies, and a talented workforce, fostering our reputation as a global resource for questions of deterrence and stockpile management and modernization.

Through the last three decades of stockpile management and modernization, LLNL has made game-changing advances in our S&T capabilities and associated flagship facilities. These capabilities are necessary to safeguard the nuclear stockpile and enable innovative and transformational solutions for equally important challenges to national security and global stability.

Through that lens of national security, we've transformed many of the tools and approaches applied to our original national security mission to meet the pressing issues of our time. We apply cutting-edge S&T to achieve breakthroughs in enterprise resilience, counterterrorism, defense and intelligence, energy security, and research and development to produce fundamental science discoveries and faster innovation cycles. The accelerating global pace of innovation in space, cyber, and biothreats heightens the value of S&T superiority as a strategic asset. No matter the application, the Laboratory's scientific research always supports our mission.

Section 2: Mission and Vision Statements

Our Mission: LLNL's mission is to enable U.S. security and global stability and resilience by empowering multidisciplinary teams to pursue bold and innovative science and technology.



Our Vision: We fearlessly and relentlessly pursue big ideas to solve the most important security challenges facing the nation and the world.

Who We Are: Our multidisciplinary teams bring together exceptional scientific, technical, administrative, business, and operational experts to accomplish our important missions.

Section 2.1: Mission Areas

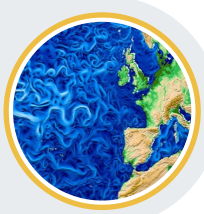
Major domains of mission responsibility

For more than 70 years, Lawrence Livermore National Laboratory has applied science and technology to make the world a safer place. The Laboratory strengthens the United States' security by developing and applying world-class science, technology, and engineering that enhances the nation's defense, an increasingly complex task with nuclear armed adversaries, aspiring proliferants, the militarization of space and cyber domains, and a rapidly advancing pace of change in artificial intelligence and biotechnology. In a complex geostrategic environment, the ability to respond to issues of national importance with vision, quality, integrity, and technical excellence has never been more critical.

Our broad and evolving mission shares commonalities in four areas relevant to the current and future stability of our world. By strengthening their underlying S&T requirements, we are better able to address issues of nuclear deterrence, threat preparedness and response, energy security, and multi-domain deterrence. While the four Mission Areas differ in size (Nuclear Deterrence is the largest Mission Area), each one includes significant work at a range of technology readiness levels, from foundational research through applied research to preliminary deployment of prototypes. Each has a history of major mission and science contributions, and each enriches and draws from LLNL's Core Competencies. By acting as good stewards of all available resources—time, effort, knowledge, and taxpayer dollars—we continue to adapt our core mission to changing national needs and priorities.

Nuclear Deterrence: develop and apply scientific insight and engineering prowess needed to assure the safety, security, and reliability of the U.S. nuclear stockpile in an ever-changing threat environment and enable the modernization and transformation of the National Nuclear Security Administration (NNSA) production enterprise.

Threat Preparedness and Response: develop and deliver enduring science-based, intelligence-informed expertise and capabilities to stem the proliferation of nuclear, chemical, and biological weapons of mass destruction, understand adversary capabilities, anticipate adversarial actions, and support consequence mitigation of natural and man-made threats.



Energy Security: advance understanding of Earth system dynamics, develop technologies to secure domestic energy production and environmental sustainability and provide reliable and resilient energy transport and distribution in response to evolving energy demand and resource availability.

Multi-Domain Deterrence: create a global strategic advantage through innovative technologies, strategies, and analyses to bolster capabilities across the full spectrum of domains, including strategic defense, conventional strike warfare, space, cyber, and technology competition.

Section 3: Science and Technology Enterprise at LLNL

Laboratory leadership adopted Objectives and Key Results (OKRs) as a management framework to advance science innovation and operations excellence and enable us to fulfill mission deliverables. The Laboratory's science and technology objective engenders innovation, technical excellence, and strategic impact through multidisciplinary foundational and applied research and development—which requires processes and procedures to maximize quality and drive resource allocation decisions. As the entity charged with stewardship of the Laboratory's S&T enterprise, the Office of the Deputy Director for Science and Technology (DDST) is responsible for executing the following Objective:

Science & Technology Objective: Align S&T capabilities to the vision for the Laboratory of the future. This vital objective comes with three Key Results:

2025 Key Result 1: Implement a data governance and management process.

2025 Key Result 2: Work with Advanced Micro Devices (AMD) and other Labs to mature the software stack to enable leading edge scientific AI on AMD platforms.

2025 Key Result 3: Develop strategy for AMM at LLNL.

Fulfillment of Key Result 1: The Data Governance Plan that was completed in September has been well received by the Director's Office. Laboratory leadership was briefed on the Key Result efforts to date in mid-November 2025. The plan to stand up a metadata catalog by the end of the calendar year remains on track. Procurements are underway, and we have some early adopters ready to go.

Fulfillment of Key Result 2: To help AMD mature the AI software stack for deployment on El Capitan and future AMD systems, the LLNL team has focused on multiple levels of engagement with AMD. Specifically, we are co-leading the Iron (Fe) Partnership with Oak Ridge National Laboratory (ORNL) and AMD to develop solutions for ongoing problems and identify new issues within the AMD AI software stack. Additionally, we have established a new project, Livermore AI Readiness (LAIR), that will be evaluating and optimizing state-of-the-art AI algorithms for the AMD GPUs, as well as developing novel algorithms that leverage unique features of the AMD MI300A compute architecture. These optimizations will be showcased using flagship applications as well as through collaborative publications. Finally, we are maintaining a high-tempo engagement with the AMD technical team through the El Capitan Center of Excellence, Iron Partnership, and LAIR project.

Fulfillment of Key Result 3: AMM is a key enabling capability making critical impacts across LLNL's national security programs. We have a history of developing and maturing bespoke material and manufacturing solutions for our stakeholders and a sustained track record of AMM innovation coupled with excellence in high-performance computing and world-class scientific talent. Continuing to advance our AMM capabilities will be increasingly crucial to enable rapid delivery of national security solutions. Our AMM mission is to develop and deploy advanced materials and manufacturing solutions for the national security enterprise. We envision a future where we can complete deployment of critical national security systems in less than a year, making LLNL uniquely able to anticipate, innovate, and deliver national security solutions. Our efforts to date include completing a landscape and gap analysis; developing an investment roadmap for future science and technology capabilities and strategic partnerships; raising brand awareness; and realizing a modern, agile infrastructure centered on the Vertically Integrated Prototype Realization Enclave (VIPRE) complex.

Section 3.1: Science and Technology Framework

LLNL's Science and Technology enterprise has three constituent parts referred to as S&T Mobilizers: talented staff, Core Competencies, and state-of-the-art facilities. The Framework below is a broad look at the Laboratory's scientific strategic approach: we've created, nourished, and grown our three S&T Mobilizers to serve us well in delivering on our mission, as illustrated within the Vision and Strategy pillars. Execution involves tracking milestones and deliverables against scope, budget, and schedule—and is outside the purview of this document. The Review pillar signifies our approaches to update plans, respond to changes in technology and the national security landscape, and make judicious investment decisions.

By guiding internal investments and overseeing the integration of S&T expertise and resources with the Laboratory's programmatic Mission Areas, the DDST Office supports, strengthens, and enhances premier S&T across a range of disciplines.

Section 3.2: Office of the Deputy Director for Science and Technology

On behalf of the Laboratory, the Office of the Deputy Director for Science and Technology (DDST) leads the process of investing in the Laboratory's science and technology enterprise. This approach ensures Livermore's world-renowned research excellence balances innovation with disciplined execution, and multidisciplinary teamwork with individual initiative. The combination of mission focus and scientific expertise is central to the Laboratory's strategic approach. The key functions of the DDST Office are to:

Invest: Coordinate internal investments to keep the Laboratory's research activities and staff at the forefront of science and technology

- **Laboratory Directed Research and Development (LDRD)**
  Serving as the primary resource to drive excellent science and technology for today's needs and tomorrow's challenges.
- **Institutional Science Capability Portfolio (ISCP)**
  Supporting multi-programmatic and cross-directorate efforts, including capability sustainment, workforce support and recognition, scientific infrastructure and equipment, and sponsor engagement.
- **Licensing and Royalties (L&R)**
  Investing Laboratory royalties generated from successful intellectual property in the next generation of science and technology.

Partner: Grow relationships in service to scientific excellence and mission delivery

- **Academic Engagement Office (AEO)**
  Fostering collaborations and sustainment of long-term academic partnerships among LLNL researchers and the academic community. Programs engage students and faculty in collaborative research, work study opportunities, and educational activities.
- **Innovation and Partnerships Office (IPO)**
  Serving as the engine to bring scientific breakthroughs to market by protecting and then transferring LLNL technology to the private sector through licensing and partnerships.
- **Science Education Program**
  Providing professional development instruction to teachers and enrichment opportunities ranging from field trips to virtual tours to online videos and science experiments students can try at home.
- **Engagement with the Broader Science Policy Community**
  Offering perspectives to policy makers and U.S. government officials while providing awareness and training to LLNL staff.
- **Commitment to International Partners**
  Creating and nurturing purposeful strategic science and technology partnerships with allies to bolster deterrence and build resiliency through fundamental and applied research.
- **Livermore Valley Open Campus (LVOC)**
  Bringing people together in an open, unclassified environment to solve global challenges and strengthen American industry by discovering new applications for cutting-edge science.

Section 3.2: Office of the Deputy Director for Science and Technology (cont.)

Communicate: Explaining our research approaches and outcomes to staff, sponsors, partners, and the community

- ***Investment Strategy for Science and Technology***
  Outlining our strategic support of the quality, health, and sufficiency of the Laboratory's scientific and technical foundations in an annually updated document.

- **Performance Evaluation and Management Plan (PEMP)**
  Emphasizing research and development, effective partnerships, and technology transfer, the Laboratory's annual evaluation report showcases our innovative science, technology, and engineering achievements.

- ***Science & Technology Review*** **(S&TR)**
  Highlighting LLNL's significant technical accomplishments, *Science & Technology Review* magazine provides in-depth scientific news to general audiences.

Enable: Ensuring our scientists and engineers are supported with tools and programs to exercise and grow their capabilities

- **Awards and Recognitions**
  Providing awareness and support to those looking to nominate individuals and teams for our prestigious internal and external awards, and professional societies.

- **Science and Technology Institutional Assessments**
  Stewarding our External Review Committees and Board of Governors S&T Committee meetings to assess and provide feedback on the quality of our Core Competencies and strategic plans, and implementing S&T Awards.

- **Postdoctoral Program Support**
  Developing the ST&E workforce pipeline of the Laboratory by furthering postdoc career development through connections with the scientific community.

- **Postdoc and Mentor Career Development**
  Equipping postdocs and their advisors and mentors with the essential skills and knowledge for impactful careers in science and technology.

- **Proposal Development Support Office (PDSO)**
  Working with investigators and their external collaborators to analyze calls for proposals, generate a compelling research plan that responds to all requirements, and facilitate internal reviews that refine the project objectives.

- **Library Resources**
  Enhancing discovery, delivery, and access to scientific content by effectively organizing, describing, and preserving our scientific and cultural heritage.

- **Archives**
  Preserving LLNL's records of people, events, programs, and accomplishments for use by Laboratory staff and historians.

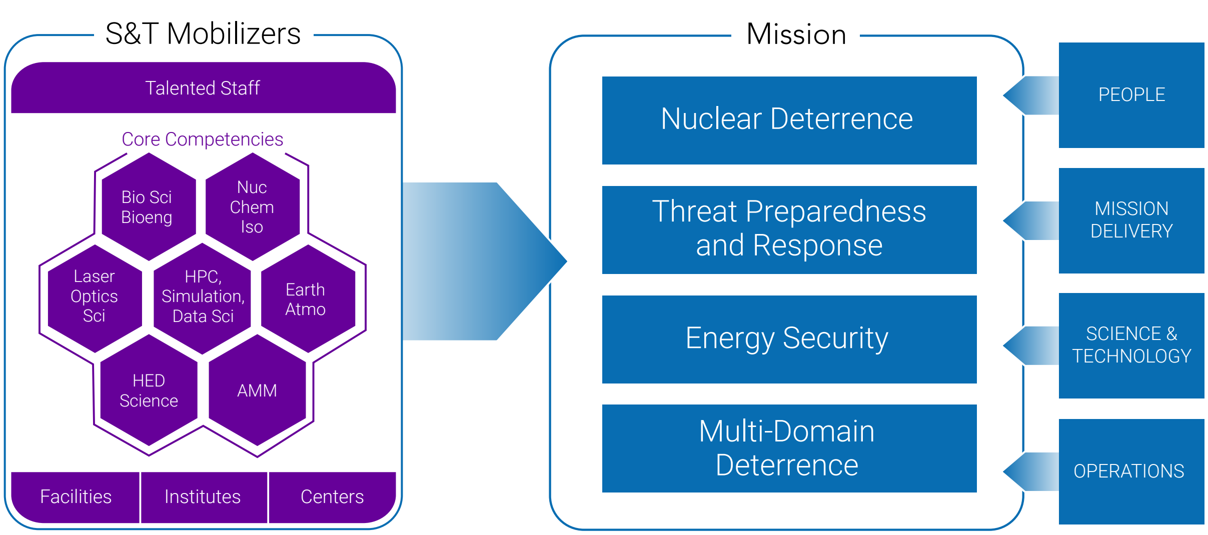
Section 3.3: S&T Mobilizers

Each part of LLNL's Science and Technology enterprise is addressed in the Science and Technology Framework, and the importance of our S&T Mobilizers—our talented staff, Core Competencies, and state-of-the-art facilities—is noted throughout. This section examines the current state of each S&T Mobilizer; future-minded evolutions are outlined in Section 6.

Our workforce is at the heart of everything we do. Staff fulfill a variety of roles at LLNL, from serving as an LDRD principal investigator to leading a high-consequence program to running a Center or Institute or forming academic partnerships through collaborations based around LLNL facilities. Centers, institutes, and facilities also serve as organic recruitment pipelines, drawing motivated staff and inspiring innovative collaborations. Through thriving Core Competencies, researchers conduct impactful R&D in key areas that position them among the world's experts in their chosen field.

S&T Mobilizers work together as a combined set of skills, tools, and resources to underpin our mission-driven work. Mission delivery requires talented and committed staff, state-of-the-art facilities and equipment, and robust partnerships with colleagues at other laboratories, universities, industry, nonprofits, and government organizations. These factors have been essential to the Laboratory's many achievements and continue to be indispensable for the Laboratory's vital missions and the advancement of science and engineering.

Discipline organizations at LLNL foster excellence and innovation in the key research disciplines needed for the Laboratory's Core Competencies. The Computing directorate advances scientific discovery through foundational and innovative research in mathematical methods; modeling and simulation; high-performance computers; operational algorithms and workflows; mission-driven data science; and software solutions. The Engineering directorate invents, designs, simulates, prototypes, builds, and deploys creative technologies including new materials, components, and systems. The Physical and Life Sciences directorate delivers multidisciplinary scientific theoretical, experimental, and computational expertise to advance knowledge and to support mission-critical research with novel insights, data, and phenomenological understanding.



As illustrated above, the S&T Mobilizers contribute to mission success by advancing scientific discovery. Note that the Laboratory's institutional Mission comprises four Mission Areas.

Section 3.4: S&T Mobilizers—People

Supporting and engaging our current and future staff members

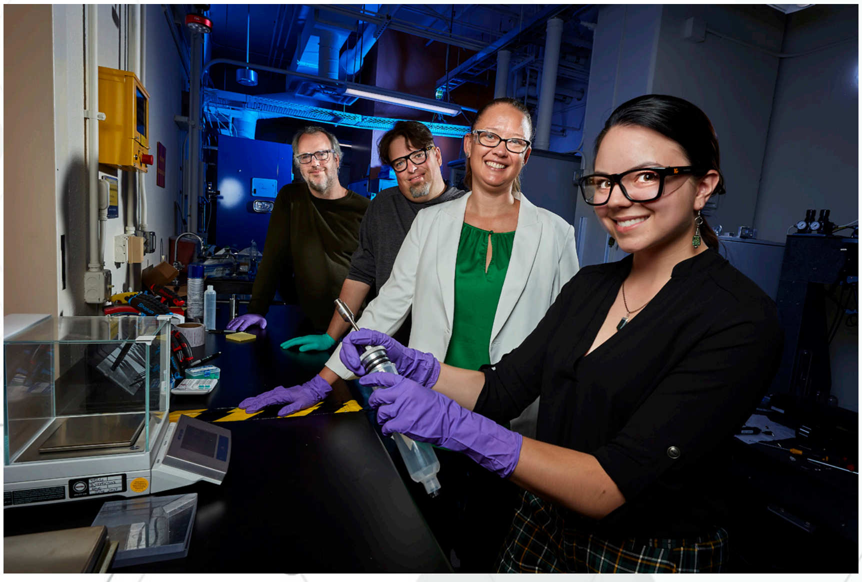
Livermore's talented staff is its key asset. The Laboratory's many scientists and engineers bring their knowledge, expertise, and experience to address mission-critical challenges. They do so with extreme curiosity and a drive to uncover knowledge and better understand how things work with a continuously improved set of tools and approaches. Staff work individually, in multidisciplinary teams, and with partners at other laboratories, universities, and institutions. Examples of investments that support people are listed below in two categories: investments that support individual skills and effective teaming, and those that support effective collaborations.

Skill Development

Career Development: Training, workshops, presentations, webinars, and conferences are a few of the many ways we ensure that our thousands of talented researchers, operations staff, and creative professionals advance their individual skillsets.

Postdoctoral Program: LLNL employs more than 235 postdoctoral scholars, also called postdocs, as a cohort of our research community and valuable pipeline of talent. During their tenure, postdocs conduct research publishable in peer-reviewed journals, develop scientific expertise in their field of research, present their research at national and international meetings, and learn how to be successful professional researchers. LLNL supports professional development with resources, targeted training, and events such as the annual Research SLAM competition.

STEM Pipeline: Laboratory initiatives and programs help attract, develop, and retain high-caliber employees. Sustaining an end-to-end workforce pipeline continues to be an important focus, from recruiting new talent and mentoring career development to recognition of career achievements.



Section 3.4: S&T Mobilizers—People (cont.)

Partnering and Engagement

Academic Engagement Office (AEO): The Academic Engagement Office fosters collaborations and partnerships between Laboratory researchers and the academic community. The team provides students and faculty at K-12 schools, community colleges, vocational schools, universities, and postdoctoral programs with research assignments, work-study opportunities, and educational activities.

Innovation and Partnerships Office (IPO): This team serves as a focal point for LLNL engagement with industry partners. Through research collaborations, commercialization of scientific discoveries, and empowering entrepreneurship among Laboratory researchers, IPO enables national security and economic competitiveness by transferring breakthroughs from mission-driven work back into U.S. industries.

Science Education: LLNL's Science Education Program offers a wide variety of experiences to students and teachers. From workshops on molecular biology and robotics to summer camps empowering women in STEM, a multitude of options exist to spark scientific discovery and leadership in students and teachers alike. The Discovery Center at LLNL provides insight into our state-of-the-art research programs for visitors of all ages.

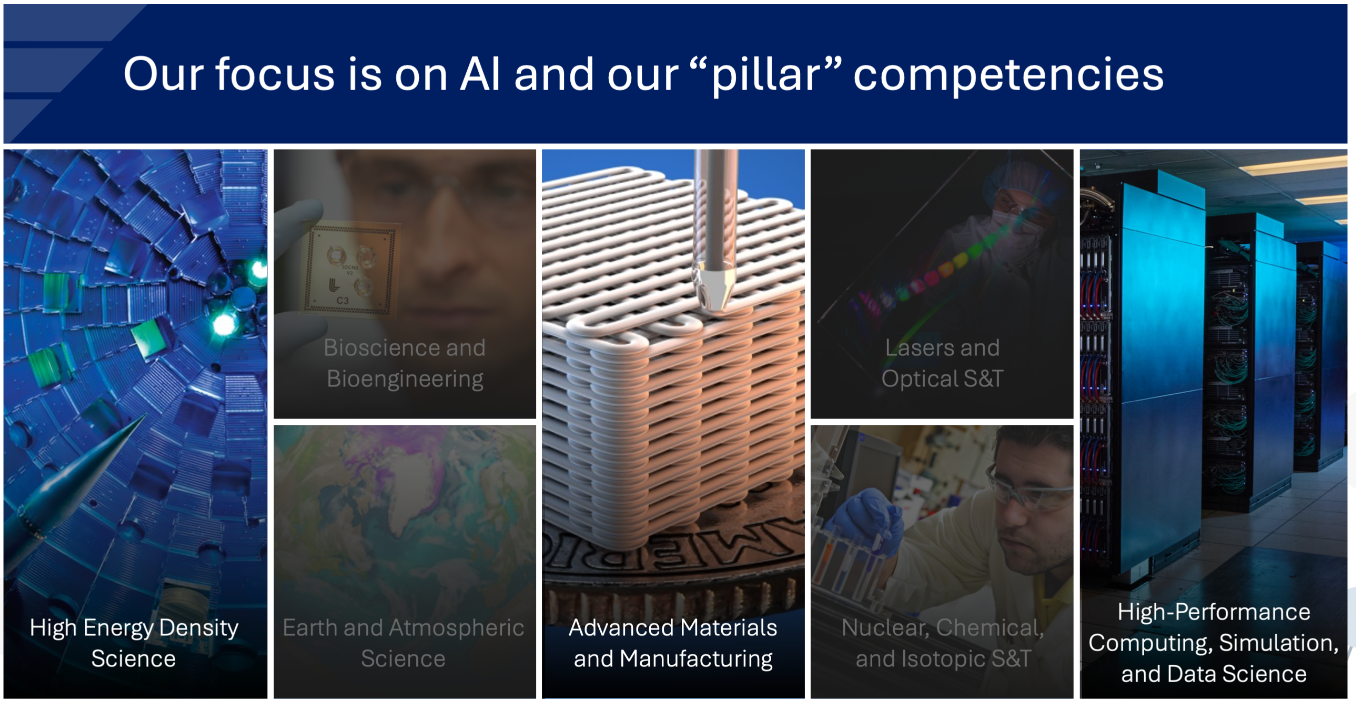
***Science & Technology Review* (S&TR):** S&TR is published eight times a year to communicate our scientific accomplishments in support of national security. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

Section 3.5: S&T Mobilizers—Core Competencies

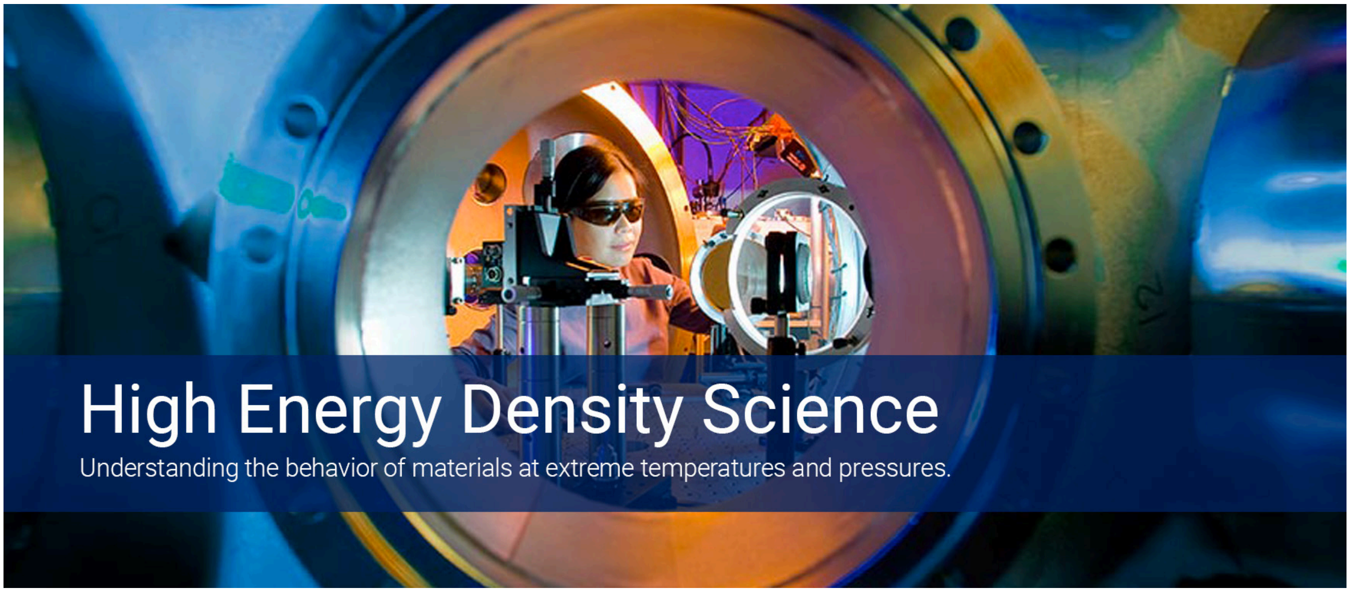
Applying our unique capabilities to today's biggest challenges

Core Competencies are areas of special capability or expertise in which LLNL seeks to contribute as a national—and often world—leader. From basic research to applied science and engineering, we leverage Core Competencies to understand, respond, and adapt to pressing issues. Our seven Core Competencies (Advanced Materials and Manufacturing; Bioscience and Bioengineering; Earth and Atmospheric Science; High Energy Density Science; High-Performance Computing, Simulation, and Data Science; Lasers and Optical S&T; and Nuclear, Chemical, and Isotopic S&T) are continually strengthened through cutting-edge research and collaborations with other laboratories, government organizations, industry, and academia.

Mission Applications:
Our three "pillar" Core Competencies (High Energy Density Science; Advanced Materials and Manufacturing; and High-Performance Computing, Simulation, and Data Science) drive the scientific and technological research—from the experimental design process to application—underpinning our mission of national security and global stability. Internal investments and externally funded activities in these areas sustain Livermore as the nation's "Big Ideas" laboratory that provides innovative solutions to challenging national security problems. While artificial intelligence is not technically a Core Competency, it is integrated in all we do—from national security S&T to daily operations.



Core Competencies



Description

High Energy Density (HED) science explores matter under extreme conditions—temperatures higher than 180 million degrees Fahrenheit, pressures of more than 500 billion Earth atmospheres—across time scales spanning from equilibrium to trillionths of a second. This research probes and discovers new scientific frontiers in the fundamental properties of matter, ranging from condensed phases to plasmas, and studies the pressure-volume-temperature relationship (commonly known as the equation of state) and radiation transfer at unprecedented pressures and temperatures. LLNL researchers develop and use a variety of experimental platforms with exquisite diagnostics. Experimental results inform advanced predictive theories and large-scale simulation and modeling on world-leading high-performance computing systems. HED research yields essential data for understanding nuclear weapons' conditions, delivering extreme condition physical property data for weapon simulations, validating predictive theories used in weapon simulation codes, and advancing inertial confinement fusion and related technical areas.

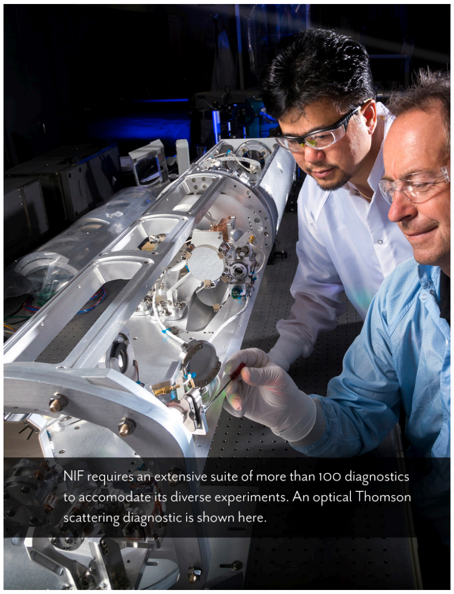
Mission Applications

The Laboratory's innovative and collaborative staff advance mission-critical work in nuclear deterrence and energy security while strengthening inertial confinement fusion research. In support of the National Nuclear Security Administration's stockpile management and modernization efforts, HED science research delivers critical experimental data and predictive models used to simulate and ensure the reliable operation of nuclear weapons as they age, are subjected to the extreme conditions of a thermonuclear explosion, or are refurbished as part of lifetime extension or modification programs. Advanced simulations of material dynamics and full systems on the Laboratory's world-leading high-performance computers complement and are anchored by experiments to fully explore and deliver predictive models of the behavior of matter in extreme conditions.

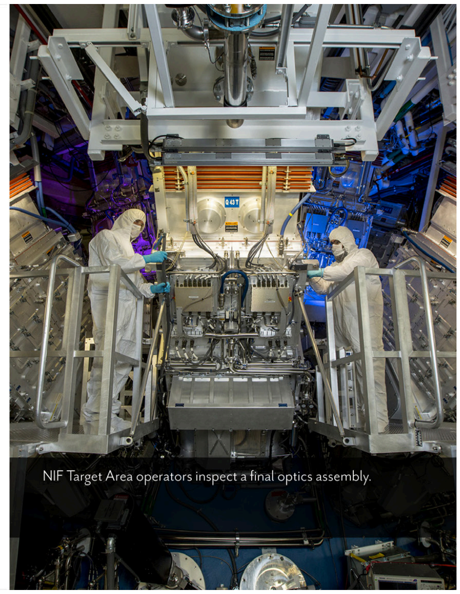
Accomplishments

- After more than 60 years of work, LLNL researchers and colleagues achieved fusion ignition (energy produced exceeding driver energy input) on December 5, 2022. Fusion ignition has since been repeated at even higher levels of energy gain, opening new vistas of HED science and enabling new experimental platforms to test the survivability of materials subjected to high fluxes of x-rays and neutrons.

High Energy Density Science


NIF requires an extensive suite of more than 100 diagnostics to accomodate its diverse experiments. An optical Thomson scattering diagnostic is shown here.


A cryogenic target used in NIF fusion experiments.


NIF Target Area operators inspect a final optics assembly.

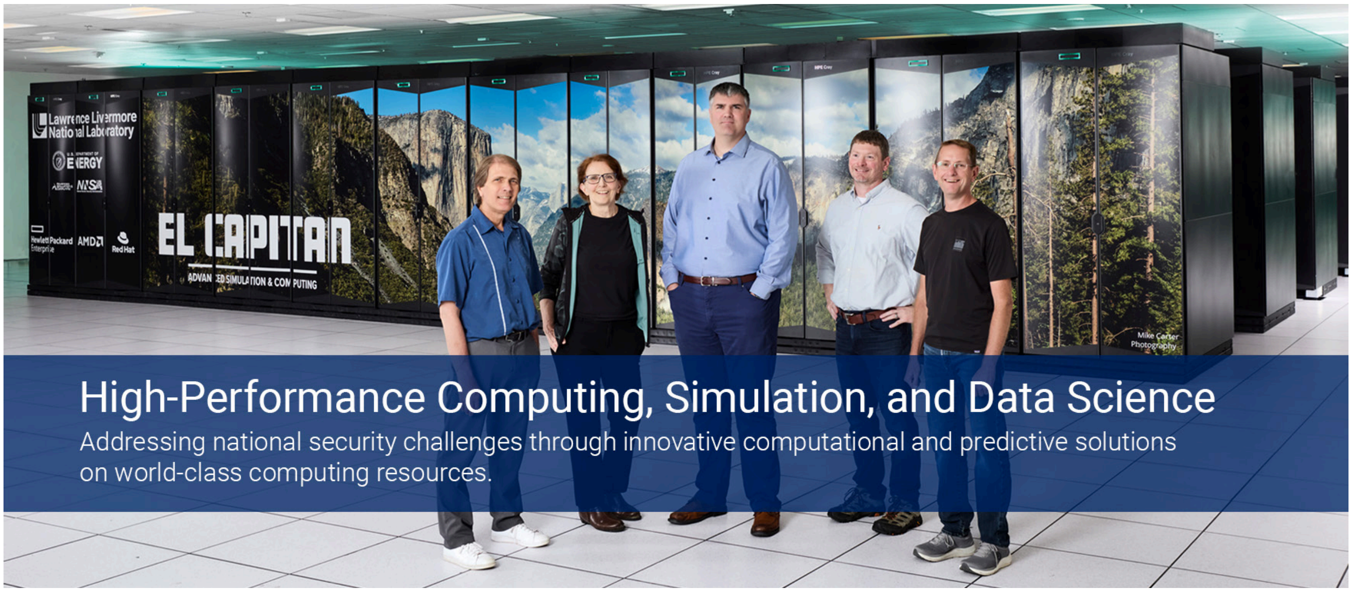
- Within HED science, LLNL has developed multiple diagnostics necessary for measuring material properties on short time scales and at high densities and temperatures. LLNL researchers developed high-speed cameras to create "movie frames" of experiments with time resolution better than 1/10th of a nanosecond using x-rays capable of probing ultra-dense materials.
- LLNL and partner institutions have developed the OPAL radiation opacity code, which is part of the Standard Solar Model and provides opacity measurements for astrophysically relevant conditions at NIF.
- Using high-performance computing, LLNL scientists developed novel machine learning algorithms to predict the probability of achieving ignition in inertial confinement fusion (ICF) experiments.
- The Energetic Materials Center, the focal point of expertise in high explosive and energetic materials science, performs bespoke experiments at the High Explosives Application Facility and the Site 300 Experimental Site, located 15 miles east of Lawrence Livermore's main campus, to enable nuclear security programs.

3–5-Year Vision

Improvements in experimental platforms, diagnostic measurement techniques, and advanced theory and modeling will enable scientists to better understand matter under extreme conditions—including stellar interiors, supernovae, conventional ICF reactions, magnetic fusion reactions, conventional fission reactions, and nuclear device explosions. Scientists will enhance the range of experimental platforms and the accuracy of temperature diagnostics through techniques used at the Nevada Test Site's JASPER facility. A new Extended X-ray Absorption Fines Structure system recently commissioned at NIF will further constrain the equation of state properties of materials at high pressures. LLNL scientists have developed a Hazardous Materials Chamber to study stockpile-relevant radioactive and toxic materials driven to HED conditions using penetrating hard x-rays at the premier U.S. synchrotron x-ray source (Dynamic Compression Sector/Advanced Photon Source/Argonne National Laboratory).

New capabilities will include the ability to create time-resolved "movies" capturing the structural and phase evolution of matter under dynamic loading conditions. In step with experimental advances, HED experiment simulations and modeling will use high-performance computing at new scales to gain microscopic insights on the properties of matter at extreme conditions. The repeated achievement of controlled fusion ignition opens new fields of study on the effects of neutron energy deposition. Ignition and high gain allow LLNL to carry out experiments across a broader range of conditions to improve our stewardship science capabilities.

Core Competencies



Description

High-performance computing (HPC), simulation, and data science are used to understand physical phenomena and processes and create models that reliably predict outcomes in varing conditions of interest. State-of-the-art simulations running on the world's most advanced computers are the integrating element of science-based stockpile management and modernization and broadly underpin our ability to meet national security needs across our mission-driven work. The ever-increasing capabilities of artificial intelligence/machine learning (AI/ML) are creating new ways to predictively model fundamental properties of materials from both large and sparse datasets in support of national security interests. Combining simulation and data-driven methods, the expanding scale and complexity of the Laboratory's mission requires new data-driven and AI/ML-augmented approaches to scientific discovery and engineering design. These techniques applied to massive datasets help researchers better understand and predict the behavior of complex systems and design new materials and systems from the ground up.

Mission Applications

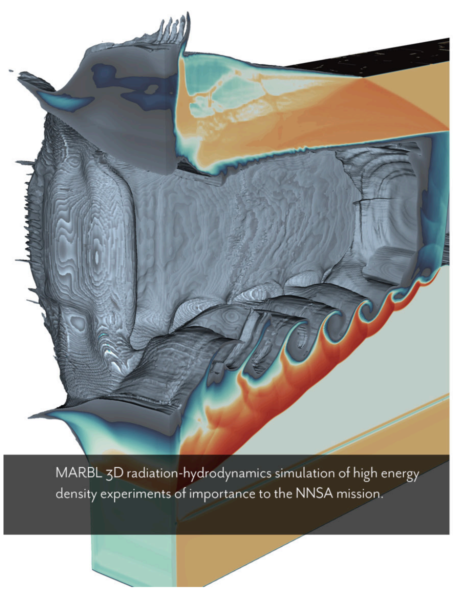
HPC at LLNL has a long history of success in close association with the Laboratory's nuclear deterrence mission. Computer scientists, software engineers, data scientists, statisticians, and mathematicians collaborate with domain scientists to develop and use simulation methodologies and HPC to support nuclear deterrence, national security, and basic scientific research. HPC capabilities remain critical to the Laboratory's science-based stockpile management and modernization efforts, ensuring the nation's nuclear weapons systems are safe and reliable. Leveraging the work rooted in deterrence, LLNL also uses HPC to continuously improve both the scientific underpinnings of this deterrent, such as studying the effects of materials aging, and today's broader missions. HPC also facilitates stockpile modernization with newly designed and manufactured systems—like the W80-4 life extension and the W87-1 modification programs as well as upcoming SLCM-N and multiple Phase 1 studies.

Accomplishments

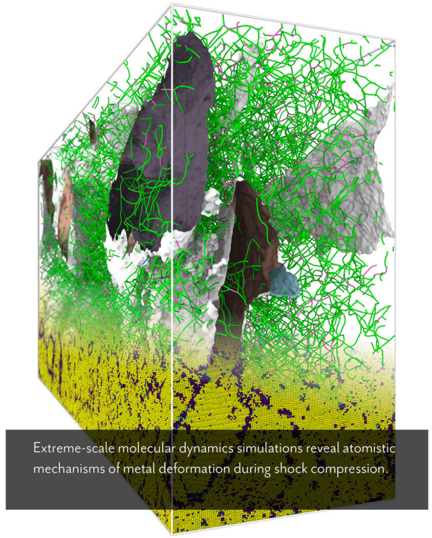
- New molecular discovery models significantly outperform the state of the art for predicting synthesis routes for small molecules, especially energetic molecules and their formulations. These models are being coupled with large language models to provide augmented laboratory assistance for synthetic chemists.

To view a list of LLNL computing publications, please visit: https://computing.llnl.gov/casc/publications

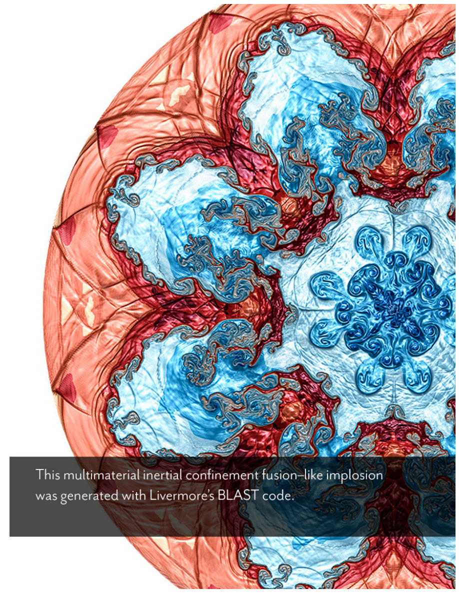
High-Performance Computing, Simulation, and Data Science



MARBL 3D radiation-hydrodynamics simulation of high energy density experiments of importance to the NNSA mission.



Extreme-scale molecular dynamics simulations reveal atomistic mechanisms of metal deformation during shock compression.



This multimaterial inertial confinement fusion–like implosion was generated with Livermore's BLAST code.

- LLNL brought El Capitan, a 2.79-exaflop supercomputer, online to run mission-critical codes thanks to sophisticated portability software and diligent preparatory work in collaboration with industry partners.
- ElMerFold is a record-breaking protein-folding workflow and the first AI application to run at scale on El Capitan. It combines mission significance, programmatic relevance, and open science impact in exascale computing.
- On Nov. 20, 2025, researchers at LLNL, the University of Texas at Austin's Oden Institute, and Scripps Institution of Oceanography at the University of California San Diego were awarded the 2025 Association for Computing Machinery (ACM) Gordon Bell Prize for developing a tsunami early warning framework powered by El Capitan.
- Autonomous Multiscale Simulations (AMS) combine software engineering, trustworthy ML, and advanced modeling to make multiphysics simulations faster, more accurate, and portable.
- LLNL is defining the future of scientific computing by advancing cloud and HPC: allowing scientific workflows to run faster and more efficiently by combining HPC with the portability and automation of cloud computing. Our scalable, next-generation workload management framework—Flux—helps make this flexibility possible.

3–5-Year Vision

As LLNL's mission expands in scale and complexity, so will our computational and predictive capabilities. A computational ecosystem built on exascale performance enables data-driven approaches to scientific discovery and engineering design in support of critical missions. Expertise in hardware, software, algorithms, data workflows, and physical sciences combined with new computing technologies will improve our understanding of complex phenomena. We will shape the future of scientific computing by leveraging the principled and judicious use of AI for LLNL's mission.

- **Quantum computing as an HPC accelerator:** Quantum and hybrid quantum-classical algorithms applicable to mission problems and the Application Programming Interfaces (APIs), system software, and other infrastructure necessary to combine these technologies.
- **Low- and mixed-precision computing:** Tools to help developers reason about finite-precision errors and robust algorithms that can use low-precision processors and data types to solve mission-relevant problems.
- **Data-centric computing:** Data abstractions to support performance and portability across current and future data-centric architectures and disaggregated systems.
- **AI-assisted science and engineering:** New AI capabilities that aid hypothesis generation, experimental design, software development, and data collection and analysis.

Core Competencies

Description

LLNL brings a multidisciplinary approach to the rapid development of advanced materials and manufacturing (AMM) processes. Livermore continues to advance manufacturing technology, enabled by the development of customized feedstocks and unique fabrication techniques. Novel diagnostic methods are developed and used to monitor and control both legacy and emerging manufacturing methods—accelerating the Laboratory's ability to deliver timely solutions. AMM creates a more agile, responsive material development and manufacturing ecosystem to meet the needs of national security stakeholders. Scientists and engineers explore ways to reduce costs, material waste, and energy consumption while enhancing functionality and accelerating discovery, development, and scalability timelines. LLNL also uses multiscale/multiphysics predictive modeling and machine learning with experimental efforts to co-design and deploy new materials and components and reduce uncertainties on how a material will perform at scale, in relevant conditions, and over its service lifetime. LLNL scientists and engineers engage in broadly collaborative efforts to achieve these goals, including strategic engagement with industry, academia, and laboratories across national and international partners.

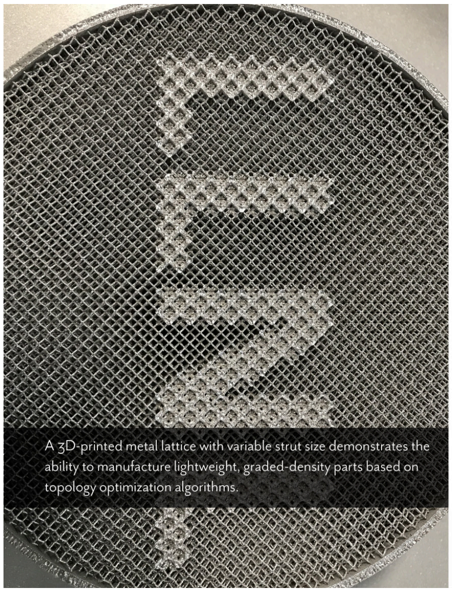
Mission Applications

Current research builds on decades of experience studying a spectrum of materials, manufacturing technologies, and mission-relevant applications. Livermore's expertise spans the entire design-development-deployment cycle, including materials that can meet emerging mission needs, capabilities to produce materials at scale, advanced manufacturing methods, and structures tailored to meet specific performance requirements. Scientists and engineers develop innovative materials with tailored properties that can be used for energy absorption, dissipation, generation, or storage; energetic materials; bioinspired structures for drug delivery; advanced optics for satellites, telescopes, and high-power lasers; quantum materials; designer materials, metamaterials, and metasurfaces that enable novel devices across a broad electromagnetic spectrum; and components that can function effectively in extreme environments, including fusion reactors.

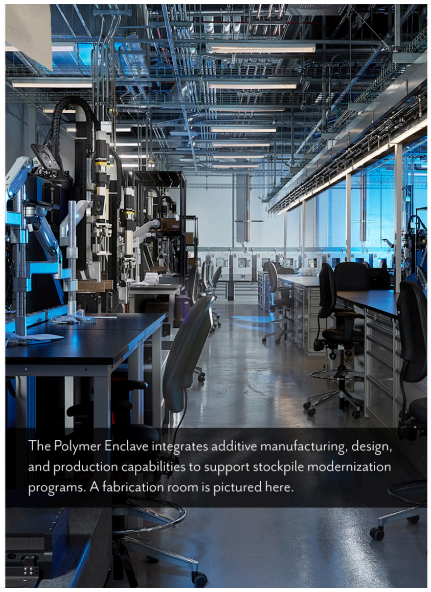
Accomplishments:

- Harnessed AI to discover interatomic potentials in new materials for applications in solid-state batteries, hydrogen storage, and CO_2 electrolysis.

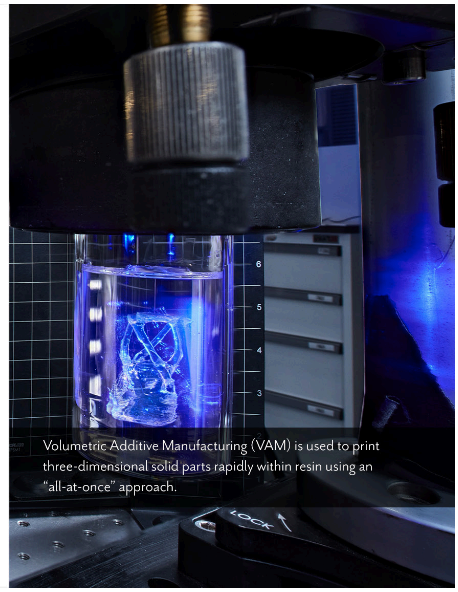
Advanced Materials and Manufacturing



A 3D-printed metal lattice with variable strut size demonstrates the ability to manufacture lightweight, graded-density parts based on topology optimization algorithms.



The Polymer Enclave integrates additive manufacturing, design, and production capabilities to support stockpile modernization programs. A fabrication room is pictured here.



Volumetric Additive Manufacturing (VAM) is used to print three-dimensional solid parts rapidly within resin using an "all-at-once" approach.

- Advanced additive manufacturing by constructing a workflow to design, fabricate, characterize, and field fully 3D-printed fuel capsules for use in ignition experiments at NIF.
- Invented Volumetric Additive Manufacturing (VAM) technique, which can fabricate complex 3D objects in seconds to minutes by projecting a combination of tomographic images into a photosensitive resin.
- Designed customized alloys for extreme environments with thermally stable microstructures that are lightweight and corrosion-resistant, leveraging both experiments and predictive models to identify aging-resistant materials.
- Discovered a method to 3D print microbes in controlled patterns, expanding the potential for using engineered bacteria to recover rare-earth metals, clean wastewater, and detect actinides.

3–5-Year Vision

The long-term vision for LLNL's Advanced Materials and Manufacturing Core Competency includes increased integration of automation, machine learning, and artificial intelligence to further accelerate materials discovery, design, development, and deployment. Build-out of capabilities will include collaborative spaces for materials synthesis, characterization, and testing, including flagship enclaves for energetic materials, polymers, ceramics, alloys, and rapid prototyping. Further emphasis on multi-material and graded-interface fabrications, including compatibility and aging analysis, will leverage current and future capabilities. Issues of feedstock development, availability, recycling, and reuse—in light of mineral and material criticality in the supply chain—will increasingly drive innovations. LLNL will continue to take a leadership role in DOE-sponsored research activities involving materials for a secure energy future.

To view a list of LLNL AMM publications, please visit: https://engineering.llnl.gov/centers/cemm/projects-publications

Core Competencies

Description

Bioscience, bioresilience, and bioengineering research at LLNL delivers transformative solutions to the nation's health and energy security needs. Scientists and engineers converge their expertise in biological science, high-performance computing, precision measurement, and engineering to understand, predict, and engineer the behaviors of complex biological systems. This integrated approach enables the exploration of underlying mechanisms of disease and engineer microbial communities, addressing biosecurity and health risks.

Mission Applications

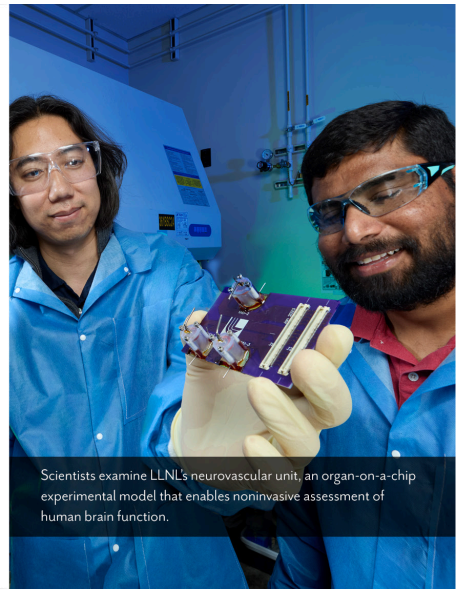
Across the Laboratory, bioscience and bioengineering research is highly collaborative and provides innovative solutions for national security challenges. Livermore scientists and engineers couple quantitative experiments with high-performance computing resources to model and understand biological systems across scales. LLNL's expanding bioscience research portfolio focuses on early biothreat detection, accelerated countermeasures, and sustainable biomanufacturing and biomaterials. Engineered experimental models and testbeds of biosystems provide physiologically and environmentally relevant data for neurovascular disease diagnosis. By combining strengths in quantitative biology, computing, and precision measurement, bioscientists and engineers apply the design–build–test–learn cycle to tailor biological molecules, microbes, and microbial communities to accelerate broad-target antibodies and sustainable biomanufacturing of low-carbon materials. Biological models are also integrated into ecology research to provide innovative solutions for the bioeconomy and energy security.

Accomplishments

- Carried out a preemptive optimization of a clinical antibody for neutralization of SARS-CoV-2 variants.
- Developed sustainable biomining approaches for purifying rare-earth elements to safeguard the domestic supply of critical minerals for U.S. energy security.
- Discovered a promising treatment for opioid overdoses that offers a more rapid recovery than current treatments.

LLNL researchers are using advanced tools to show how subetadex binds and neutralizes fentanyl—a breakthrough step toward new treatments for the opioid crisis.

LLNL researchers are engineering microbes to sustainably recover rare-earth elements—critical for clean energy, electronics, and national security.



Scientists examine LLNL's neurovascular unit, an organ-on-a-chip experimental model that enables noninvasive assessment of human brain function.

- Designed a small molecule blocking RAS-PI3Kα interaction inhibiting tumor growth with fewer side effects.
- Developed real-time affinity measurements of proteins synthesized in cell-free lysates.
- Advanced novel nanoparticle-based vaccine delivery formulations to new testing phase to evaluate efficacy against infections caused by chlamydia and other pathogens.
- Coupled a 3D brain-on-a-chip with a blood–brain barrier model to create a neurovascular unit that provides physiologically relevant data for disease diagnosis and treatments.

3–5-Year Vision

Looking ahead, Laboratory teams will continue to be at the forefront of advanced diagnostics, therapeutics, and sustainable biomanufacturing through innovative, multidisciplinary research. Areas of emphasis include: 1) employing a comprehensive strategy for early biological threat assessment and developing broad-spectrum antibodies, novel therapeutics, or vaccines to counter these threats; 2) integrating big-data analytics and computational modeling to enhance genotype-to-phenotype predictions, thereby improving our understanding of complex biological systems; 3) understanding biomolecules, microbes, and microbial communities to address challenges in biomanufacturing, energy security, and supply chain resilience; and 4) developing advanced instrumented experimental systems and testbeds that provide mechanistic understanding and quantitative measurements for predictive models and technology scale-up.

Earth and Atmospheric Science

Understanding the critical role Earth processes play in energy, environmental, and national security missions.

Description

Researchers in the Earth and atmospheric sciences continually innovate to make the world safer, the environment cleaner, and our energy resources more sustainable. Key areas of research include seismology, geophysics, geomechanics, geochemistry, hydrology, atmospheric turbulence and dispersion, Earth system modeling and model intercomparison, climate sensitivity and feedbacks, energy systems, and geochemical cycles.

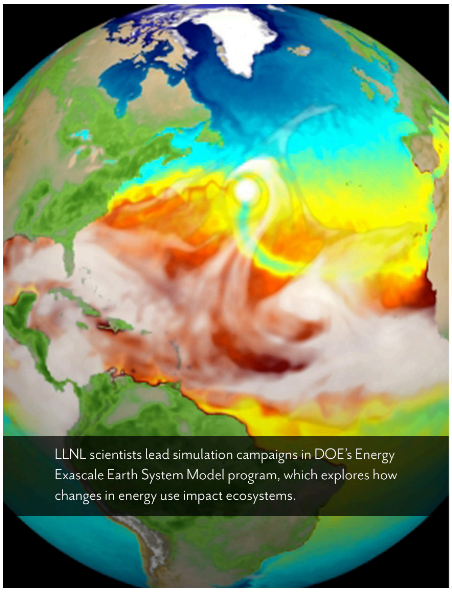
Mission Applications

Earth and atmospheric sciences play a central role in LLNL's mission-driven work. LLNL scientists bring unique expertise and capabilities to advance engineering applications above, on, and below the Earth's surface. From refining space-based observations to analyzing seismic signals under the Earth's crust, LLNL's research teams use their expertise to help build a safer and more resilient future. For decades, LLNL scientists have been at the leading edge of Earth system science, improving our understanding of natural systems and supporting resilience planning for infrastructure development and national security operations. In parallel, Laboratory staff develop innovative energy technologies and waste management techniques to support energy independence and environmental stewardship. In the national security arena, LLNL advances global-scale monitoring techniques for detecting, locating, and characterizing underground nuclear testing. Decades of innovations leveraging state-of-the-art computational methods validated with unique laboratory capabilities and large-scale field experiments have strengthened response efforts for nuclear emergencies and hazardous material releases.

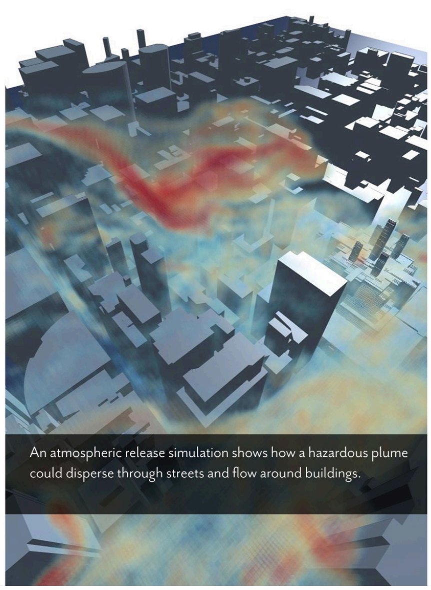
Accomplishments

- Since 1979, the National Atmospheric Release Advisory Center (NARAC) at LLNL has been on call 24/7 to respond to hazardous release emergencies around the world. NARAC monitored data from radiation detection sensors in Ukraine (2022), responded to nuclear power plant failures at Chernobyl (1986) and Fukushima (2011), and assessed airborne hazards in the wake of Hurricane Katrina (2005), the Deepwater Horizon oil spill fire (2010), and the spread of ruthenium across central Europe (2017).

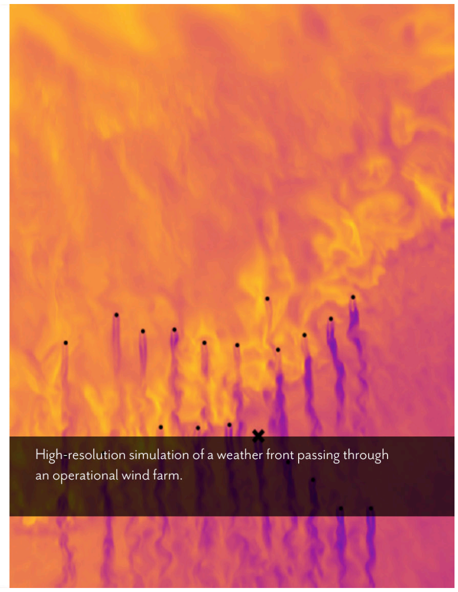
- LLNL maintains one of the most complete geomaterial modeling libraries available for national security applications. The library incorporates complex phenomena related to impact and explosions in hard rock and similar materials.



LLNL scientists lead simulation campaigns in DOE's Energy Exascale Earth System Model program, which explores how changes in energy use impact ecosystems.



An atmospheric release simulation shows how a hazardous plume could disperse through streets and flow around buildings.



High-resolution simulation of a weather front passing through an operational wind farm.

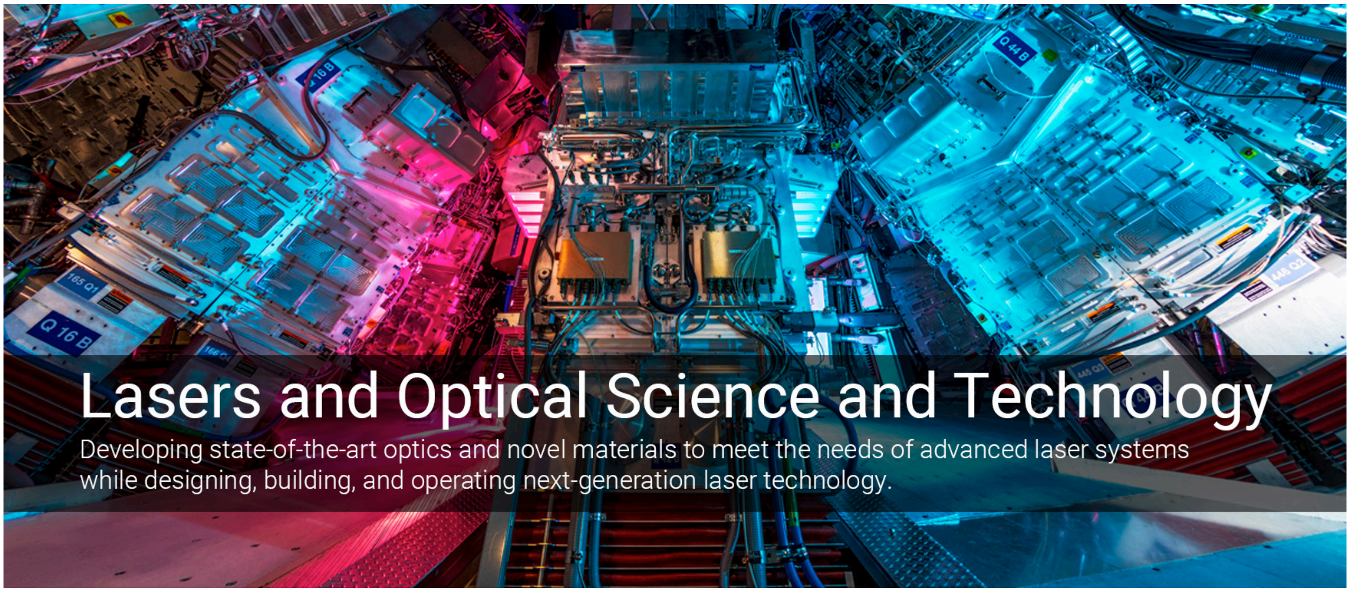
- The Gordon Bell Prize, recognizing outstanding achievements in high-performance computing, was awarded to LLNL researchers in 2023 for their work on an exascale-capable atmospheric modeling code that is paving the way towards unprecedented resolutions in Earth system simulations.
- LLNL leads development of GEOS, an open-source reservoir simulator for subsurface energy systems. This exascale capability, developed by a community of energy industry and academic partners, has been used in numerous studies to support reservoir management, hydraulic stimulation for oil and gas extraction, geothermal energy, and hydrogen storage projects.

3–5-Year Vision

Over the next few years, LLNL is prioritizing several investments in Earth and atmospheric sciences to prepare for future challenges. These include enhancing regional-to-local seismic, climate, and nuclear event characterization through investments in novel methods that leverage machine learning and artificial intelligence, data fusion, big-data analysis, and exascale computing. These efforts will expand research related to emerging technologies like hydrogen storage and enhanced geothermal energy, eliminating bottlenecks on the path to large-scale deployment; and providing decision-makers, including U.S. agencies tasked with ensuring our national security, with actionable data on natural hazards and their impact on global security.

To view a list of NARAC related publications, please visit: https://narac.llnl.gov/about/publications

Core Competencies



Description

The Laboratory's leadership in lasers and optical science and technology reflects longstanding expertise in systems engineering, laser construction and operation, and collaboration with commercial partners. LLNL scientists have a record of high-impact innovations advancing state-of-the-art lasers, optical systems, imaging, and spectroscopy in traditional laboratory and extreme environments. This is complemented by leadership in photonics, HED science, optical materials, the physics of laser–material interaction, and laser system modeling and simulations.

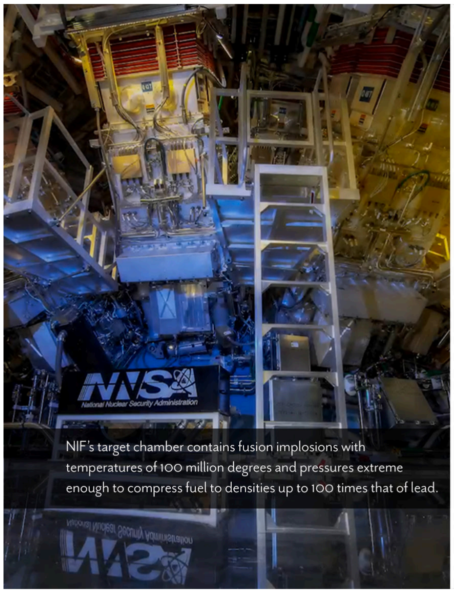
Mission Applications

The National Ignition Facility (NIF) is an essential tool in pursuing LLNL's core mission of safeguarding America's nuclear weapon stockpile while exploring high energy density (HED) regimes. NIF provides key insights and data for simulation codes used in weapon-performance assessments and certification and is an important resource for weapons effects studies and nuclear forensics analysis. As LLNL's scientists and engineers use, maintain, and improve NIF, they are also developing next-generation laser and optical systems and technologies. Such advances are informing the key performance specifications and approaches for a high yield fusion facility for stockpile management and modernization while laying the groundwork for inertial fusion energy (IFE) and delivering directed energy capabilities for national security missions.

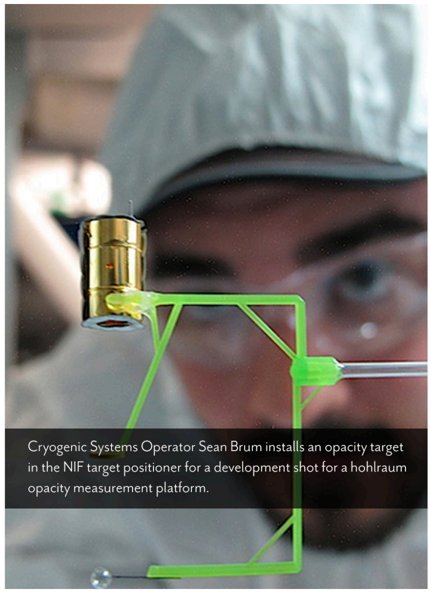
Space science and security is also a prominent application area. LLNL research and development of adaptive optics systems has led to image quality improvements by compensating for blurring due to atmospheric turbulence in large optical telescope systems. Thin film multilayer and interference coating modeling and fabrication capabilities at LLNL have delivered unique optical components with tailored properties needed for satellite payload systems.

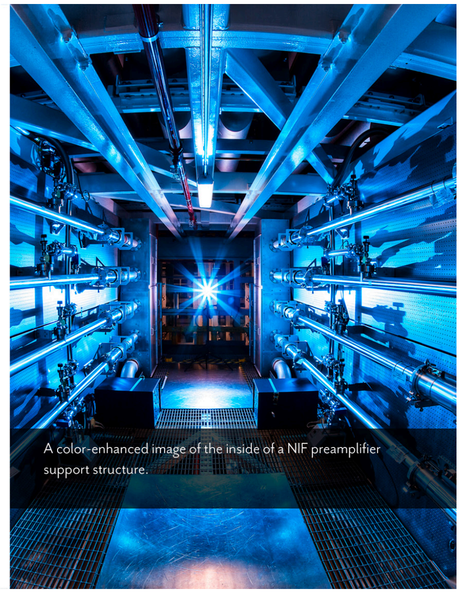
Accomplishments:

- Achieving ignition and beyond: on December 5, 2022, the NIF laser precisely delivered 2.05 megajoules (MJ) of energy to its target to produce 3.15 MJ of fusion energy, achieving the first demonstration of fusion ignition in a laboratory. This historic achievement has since been repeated at higher energy levels—a record yield of 8.6 MJ was achieved in April 2025.



NIF's target chamber contains fusion implosions with temperatures of 100 million degrees and pressures extreme enough to compress fuel to densities up to 100 times that of lead.


Cryogenic Systems Operator Sean Brum installs an opacity target in the NIF target positioner for a development shot for a hohlraum opacity measurement platform.


A color-enhanced image of the inside of a NIF preamplifier support structure.

- Delivering a successful Conceptual Design Review for the NIF Enhanced Yield Capability with the promise to boost NIF's laser energy up to 2.6 MJ and unlock new fusion regimes.
- Applying fusion ignition conditions to assess weapons-grade plutonium for survivability data.
- Facilitating public-private partnerships with fusion energy companies to apply LLNL's deep knowledge of laser technology to inertial fusion energy approaches.
- Using lasers to produce muons, subatomic particles that can pass through dense materials more easily than x-rays. These experiments have opened a range of potential imaging capabilities with national security applications.
- Standing up a DOE-funded effort to revolutionize extreme ultraviolet lithography, laying the groundwork for the next generation of semiconductors.
- Strengthening partnerships with LLNL's Jupiter Laser Facility to support LaserNetUS experiments and introduce an advanced laser pulse-shaping technology called STILETTO (Space Time Induced Linearly Encoded Transcription for Temporal Optimization).

3–5-Year Vision

The next generation of laser systems will continue expanding capabilities in energy, pulse width, and repetition rate. Optics damage mitigations and new coating technologies will continue to increase functionality, lifetime, and yield of optical components to enable improved performance of high energy lasers. Improving precision and control over all laser properties (including time-dependent waveforms and spectra, beam intensity, and wavefront profiles) while tailoring polarization states will enable novel modalities for optimizing laser interactions with matter and mitigating instabilities. Development of high-dynamic range metrology capabilities will enable improved detection and mitigation of defects and damage in optics exposed to ultra-high laser powers and energies. LLNL will further advance state-of-the-art lasers and optics over the next five years. Its scientists and engineers will design, develop, build, and optimize laser systems for high yield stockpile management and modernization applications, IFE drivers, and directed energy. They will also introduce optical technologies that improve imaging and enable new optical systems, including space science applications.

To view a list of LLNL laser and photon science publications, please visit: https://lasers.llnl.gov/science/journal-articles

Core Competencies

Nuclear, Chemical, and Isotopic Science and Technology

Studying reaction pathways of chemical and nuclear systems for national security and scientific discovery.

Description

Nuclear, chemical, and isotopic research advances our scientific understanding, capabilities, and technologies in nuclear and particle physics, environmental radiochemistry, cosmochemistry, high explosives research, and forensic science to support LLNL's national security mission. Leveraging unique experimental and computational tools, we study nuclear reactions, the limits of nuclear stability, actinide behavior, chemical reactions of energetic compounds and chemical warfare agents, and heavy-element chemistry. We also explore the evolution of our planet, our solar system, and our universe, from the origin of matter to the formation of all the nuclei in the periodic table. Our scientific research efforts provide the foundation for addressing these challenges. Our overarching strategy is to position LLNL at the nexus between fundamental nuclear and chemical science research and global security applications. This approach supports efforts to recruit, train, and retain top-flight scientists and engineers who are key to executing the Laboratory's core security missions, while also enhancing LLNL's reputation as a world-leading center for innovative scientific research.

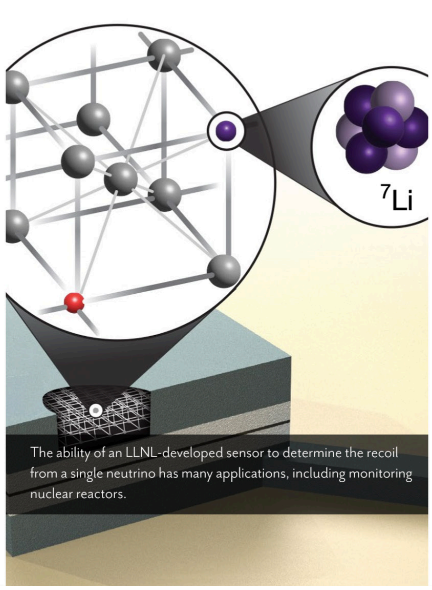
Mission Applications

Chemical, nuclear, and isotopic science research directly benefits our national security mission by improving the safety and reliability of our strategic deterrent and enhancing our detection and attribution capabilities for materials associated with weapons of mass destruction and detonations. LLNL's unique tools enable our scientists to be at the forefront of a wide range of topics, including nuclear and particle physics, nuclear structure and reaction data, radiochemistry, nuclear detection technology and algorithms, nuclear and chemical forensic science, cosmochemistry, and environmental isotope systems. Advancement in these areas of research helps answer far-reaching questions in fundamental science.

Accomplishments

- Analyzing samples from asteroid Bennu and learning about building blocks of our solar system.
- Making new reference materials for high-precision actinide radiochronometry and isotopic analysis, and surrogate debris for post-detonation exercises.

LLNL codeveloped a high-throughput, automated mass spectrometry platform to discover medical countermeasures against chemical warfare agents.



The ability of an LLNL-developed sensor to determine the recoil from a single neutrino has many applications, including monitoring nuclear reactors.

LLNL scientists analyzed samples from the carbon-rich asteroid Bennu, illuminating the formation of asteroids and the solar system.

- Installing and employing a one-of-a-kind NanoSIMS instrument with specialized sample handling capabilities that captures images at unprecedented resolution.
- Measuring the first cross sections using National Ignition Facility (NIF) capsules doped with radionuclides.
- Accelerating discovery of medical countermeasures for emerging chemical threats and opioid overdose.
- Developing experimental techniques to constrain the properties of the neutrino and the weak nuclear force.
- Developing predictive theory that revises scientists' understanding of alpha processes during the Big Bang.
- Making the first measurements using the Mobile Antineutrino Demonstrator.

3–5-Year Vision

Prioritized research areas in nuclear, chemical, and isotopic science and technology include development of novel neutron sources, targets, and techniques for future nuclear data measurements for national security programs, preparation for NASA sample return missions that will use state-of-the-art new instrumentation for isotopic and spatial analysis, and investigations into the use of quantum systems for detectors and sensors as well as artificial intelligence and quantum computing for nuclear theory and data applications. LLNL scientists will also respond to long-range planning needs recently released by the Office of Science in Nuclear Physics (NP) and High Energy Physics (HEP), including the searches for sterile neutrinos and dark matter, experimental and theoretical research on nucleosynthesis and the properties of exotic nuclei, and probing the quark and gluonic structure of nuclear matter. Efforts will also include incorporating ultrahigh throughput and automated detection workflows into LLNL's chemical research endeavors.

Section 3.6: S&T Mobilizers—Facilities, Centers, and Institutes

LLNL's facilities, centers, and institutes promote collaboration in focused scientific domains and/or in important experimental regimes to magnify our impact on national security and global challenges. As incubators of innovation, they drive science, technology, and engineering breakthroughs by engaging staff from multiple directorates to carry out research, partner with external research communities, and build a pipeline of talented students and collaborators.

Mission Applications

Centers and institutes link complementary resources to continue our mission-driven work while remaining accessible to external collaborators. Some focus on the research frontiers in a particular discipline, and others are built on the shared perspectives of researchers aligned for a common application. The Laboratory's facilities house the most energetic laser in the world, powerful supercomputers, and other premier tools that support a depth and breadth of research activities. Detailed information is available on the websites of each of the items on the list below:

Key Facilities

- Advanced Manufacturing Laboratory
- Aerosol Inhalation Research Laboratory
- Center for Micro- and Nanotechnology
- Contained Firing Facility
- Electron Beam Ion Trap
- Forensic Science Center
- High Explosives Applications Facility
- Jupiter Laser Facility
- Livermore Computing Complex
- Manufacturing Complex
- National Atmospheric Release Advisory Center
- National Ignition Facility
- Optical Fabrication and Processing
- Polymer Enclave
- Select Agent Center
- Site 300
- SKYFALL

Discipline-Oriented Institutes and Centers

- Center for Accelerator Mass Spectrometry
- Center for Applied Scientific Computing
- Center for Bioengineering
- Center for Design Optimization
- Center for Engineered Materials and Manufacturing
- Center for Global Security Research
- Data Science Institute
- Energetic Materials Center
- Glenn T. Seaborg Institute
- High Energy Density Science Center
- High Performance Computing Innovation Center
- Laboratory for Energy Applications for the Future
- Livermore Center for Quantum Science
- Livermore Institute for Fusion Technology
- Nondestructive Characterization Institute
- Space Science Institute

Section 4: Support of Science and Technology

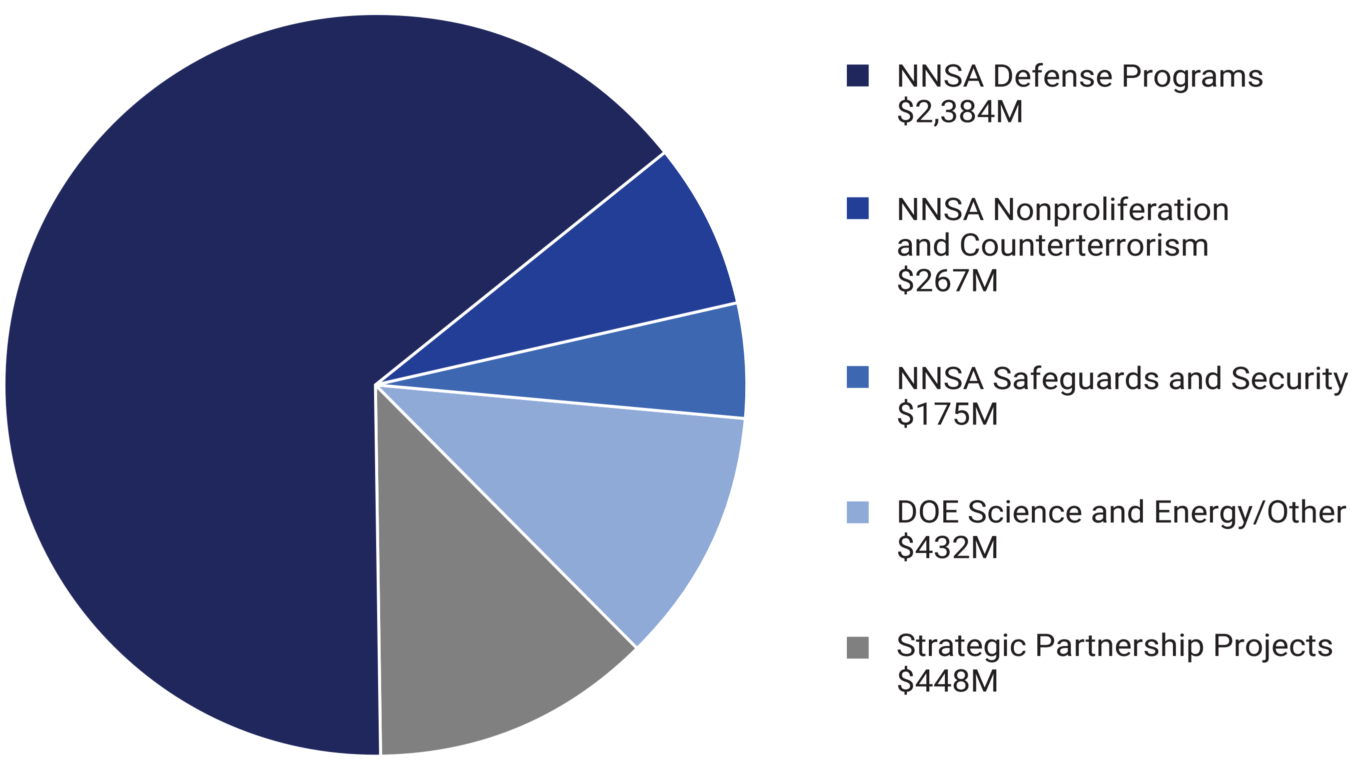
Financial support of LLNL's science and technology enterprise comes from a range of funding sources. The largest and most important sponsor is NNSA Defense Programs, which provides the majority of support for and enables synergy among our S&T Mobilizers. LLNL also conducts significant research and development for NNSA Defense Nuclear Nonproliferation, NNSA Office of Counter-Terrorism & Counter-Proliferation, DOE Office of Science and other DOE offices. This broad and diverse sponsor portfolio allows LLNL to apply its technical competencies to the full suite of DOE missions and Departmental priorities, while providing synergistic benefits to our core NNSA mission.

Many non-NNSA mission areas also benefit from the Laboratory's expertise, unique capabilities, and facilities. Strategic Partnership Projects (SPPs), often conducted in collaboration with other organizations, serve to strengthen and broaden the science and technology expertise necessary for NNSA work. The non-NNSA DOE projects can be sponsored by other U.S. government agencies, industry, or academia, and spin back new ideas and knowledge into NNSA programs. They also attract and support outstanding researchers that contribute to a healthy, vibrant Laboratory.

In addition to externally funded work guided by sponsors, LLNL makes significant internal investments to create new capabilities, pursue leading-edge R&D, and ensure our S&T Mobilizers can address NNSA's mission imperatives and respond to emerging challenges.

Section 4 outlines sources of funding and their internal investment as detailed in the chart below.

Total FY25 Laboratory Funding ($M)



Section 4.1: NNSA and Sponsored Science

NNSA Defense Programs and Defense Nuclear Nonproliferation

Aided by the Laboratory's efforts in stockpile management and modernization, NNSA's Office of Defense Programs and Office of Counter-Terrorism & Counter-Proliferation have made dramatic advances in experimental and computational capabilities to gain tremendous insights into the science and engineering of operational nuclear weapons. LLNL's Director signs an Annual Assessment letter, addressed to the Secretaries of Energy and Defense/War, attesting to the safety and security of the nation's nuclear stockpile as part of the Annual Stockpile Assessment Process. These technical capabilities deliver tangible impacts on developing programs and are a signal to our adversaries that we are innovative and agile in response to new challenges. The mission of NNSA's Office of Defense Nuclear Nonproliferation (DNN) is to prevent the proliferation of nuclear weapons and reduce the threat of nuclear and radiological terrorism. LLNL's innovative science and technology is required to forestall nations and non-state actors from making nuclear weapons or obtaining weapons-enabling materials, knowledge, and equipment. LLNL's longstanding support of these important national priorities draws upon our Core Competencies, while an ever-evolving security environment spurs innovation and creates new technologies. LLNL currently leads multiple national efforts to advance capabilities for the nonproliferation mission, including new methods for arms control treaty verification and the use of machine learning to discover evidence of potential nuclear proliferation on a global scale. DNN funding also allows LLNL staff to develop hierarchical, multimodal detection approaches to characterize threats and create sophisticated physics-based modeling capabilities to optimize mitigation strategies.

DOE Office of Science

The DOE Office of Science (SC) is an enduring partner and a major source of funding for fundamental scientific research at LLNL. LLNL's SC program is formulated around a diverse portfolio of research that seeks to address major scientific challenges while contributing to the vitality of the Laboratory's Core Competencies. LLNL's current SC portfolio includes funding from six program offices: Advanced Scientific Computing Research (ASCR), Basic Energy Sciences (BES), Biological and Environmental Research (BER), High Energy Physics (HEP), Nuclear Physics (NP), and the Accelerator R&D and Production (ARDAP) program.

DOE Applied Energy and Environmental Management Offices

LLNL also conducts a broad range of research activities for additional DOE Program Offices that leverage Core Competencies and provide opportunities for LLNL staff to make important contributions to national priorities. This portfolio includes funding from: Advanced Research Projects Agency-Energy (ARPA-E), the Office of Critical Minerals and Energy Innovation (CMEI, formerly the Office of Energy Efficiency and Renewable Energy), the Office of Electricity (OE), the Office of Environmental Management (EM), the Office of Hydrocarbons and Geothermal Energy (HGEO), the Office of Nuclear Energy (NE), the Office of Energy Dominance Financing (EDF), and the Office of Cybersecurity, Energy Security, and Emergency Response (CESER).

Strategic Partnership Projects (SPP)

Developing and sustaining interagency and industrial national security work enhances scientific capabilities, and National Laboratories are encouraged to take on SPPs to serve U.S. government goals. These efforts feed new technology into our mission while solving challenging national security problems for a variety of sponsors. The optimal SPP portfolio for LLNL is one that leverages and augments the Laboratory's Core Competencies, unique scientific and technical infrastructure, and

Section 4.1: NNSA and Sponsored Science (cont.)

integrated problem-solving skills. Approximately 75% of the SPP funding results from successful proposals to a wide variety of organizations that reside within the Department of Defense/War (DOD), including the Defense Advanced Research Projects Agency (DARPA), each of the six branches of the U.S. Armed Forces, and the U.S. Intelligence Community (IC). Other government agencies such as National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), Department of Homeland Security (DHS), and related agencies also provide funding for research ideas on a range of topics.

SPP also extends beyond the federal government, since opportunities arise regularly to transfer technology originating at DOE/NNSA facilities to industry for further development or commercialization. This entire portfolio of diverse research includes developing and implementing cutting-edge solutions and is a major factor in recruiting and retaining the Laboratory's talented workforce.

Section 4.2: Internal Investments

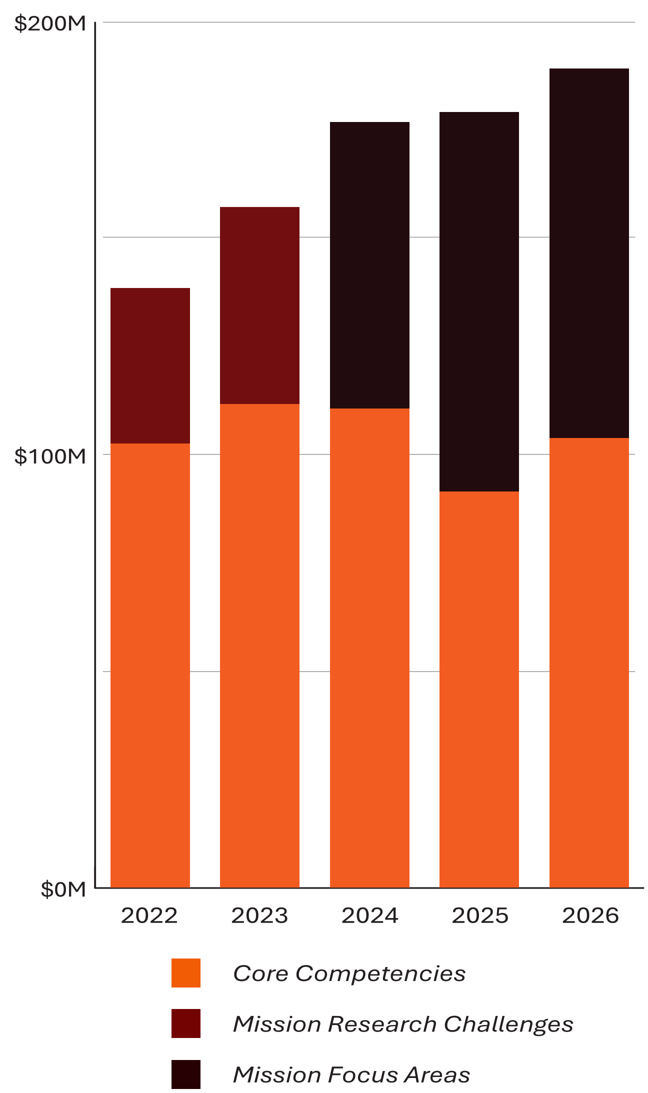
Our internal investments—in particular, our LDRD program—support the exploration of new ideas that anticipate future needs within our national security missions. The Laboratory uses funding from LDRD, ISCP, and L&R to achieve specific goals in the most important areas of attention of the Laboratory: infrastructure, research capabilities, and people.

Laboratory Directed Research and Development (LDRD)
Internally funded high-risk, potentially high-value research and development

The LDRD program is a congressionally authorized component in the NNSA's S&T investment strategy that provides investments in cutting edge science and technology that enable the Laboratory to attract and retain the world's most talented scientists and engineers and enables them to expand the frontiers of knowledge and anticipate emerging national security challenges. Funded with approximately six percent of the Laboratory's budget, LDRD is awarded through a rigorous and highly competitive review and selection process. To meet the Laboratory's evolving mission needs, the LDRD process is designed to be flexible and forward-looking to achieve our national security goals.

The LDRD program is also a powerful means to hire outstanding staff, postdocs, and students; foster collaborations with other prominent

LDRD Funding FY22 through FY26



Section 4.2: Internal Investments (cont.)

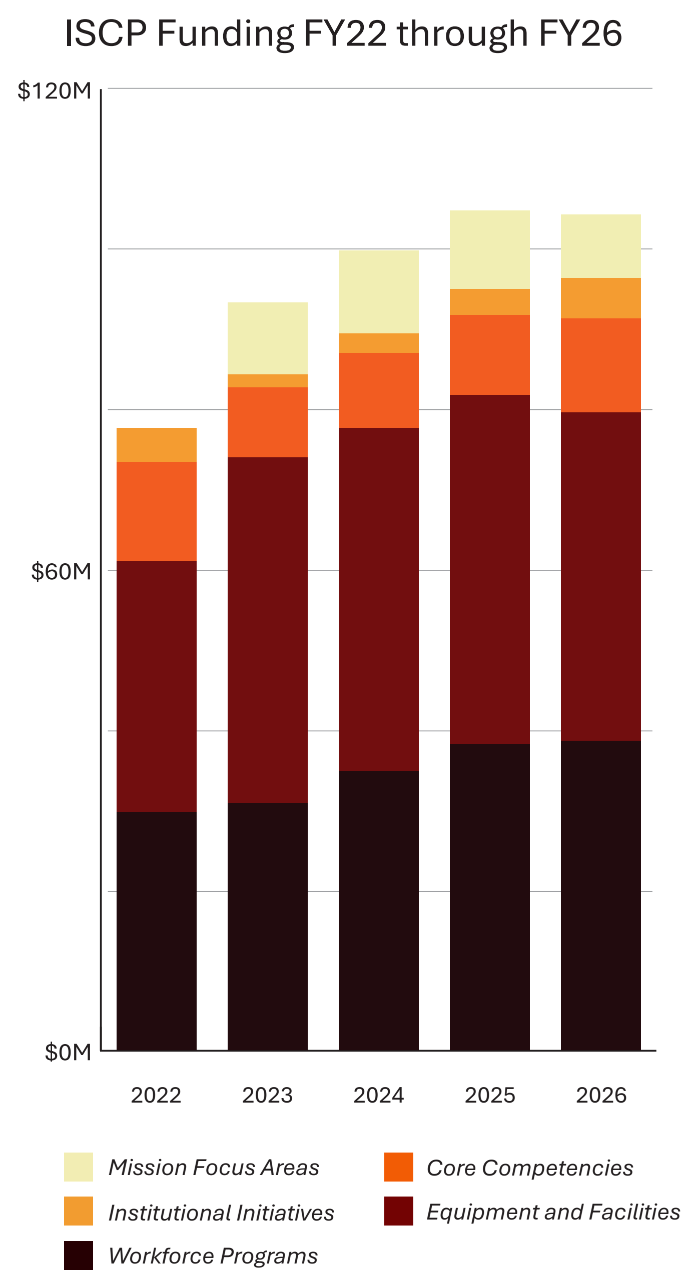
scientific and technological institutions; leverage some of the world's most technologically advanced assets; and publish innovative science and technology achievements in high-impact journals and meeting proceedings. LDRD enables LLNL to invest in high-risk, potentially high-value research and development that creates innovative technical solutions applicable to current and emerging difficult national security challenges. LDRD investments into Core Capabilities ensure LLNL science, technology, and engineering stays at the cutting edge.

Institutional Scientific Capability Portfolio (ISCP)
Funding to maintain the Laboratory's core and mission competencies

ISCP is an important component of LLNL's strategic investment program that supports capability sustainment projects, institutional equipment, multi-programmatic facilities, and program development associated with LLNL initiatives and priorities that have cross-directorate benefits in workforce programs and scientific infrastructure. ISCP projects are non-R&D activities funded by indirect resources that maintain or improve the Laboratory's Core Competencies and must be applicable to current and future mission and S&T capabilities.

Licensing and Royalties (L&R)
Funding scientific collaboration

L&R funds are generated by licensed Intellectual Property invented by Livermore researchers. Activities must meet the criteria defined by the Stevenson-Wydler Act. Recent uses of this funding include supporting LLNL's participation in the Accelerating Therapeutics for Opportunities in Medicine consortium, supporting the research of Early- and Mid-Career Award winners, and developing the Stellar Occultation Hyper-temporal Imaging Payload (SOHIP), an instrument deployed on the International Space Station in 2023. FY25 included funding Commercial Clementine, supporting the assembly, integration, and test (AI&T) of an LLNL Argus Mk-II payload.



Section 4.2: Internal Investments (cont.)

Institutional Equipment
Internally funded, multi-programmatic needs

The Multi-Programmatic Instrumentation Committee (MPIC) collects and prioritizes requests for internally funded instrumentation purchases and enhancements. Institutional equipment purchased with this funding must support multiple projects for capability sustainment and research activities—internally (indirect) and externally (direct) funded. This pathway provides an excellent opportunity to upgrade or replace critical capabilities, such as decades-old instruments that no single program or experiment can replace in a single year, or to add a new capability where there is currently a gap.

FY25 Institutional Equipment Purchases

600 MHz NMR Spectrometer Upgrade
The 600 MHz NMR spectrometer serves multiple programs across LLNL by enabling chemical analysis of solution and solid state materials. Upgrading this end-of-life instrument will ensure continued capability to support the diverse user base. In addition, the upgrade will expand current capabilities to be able to detect every NMR active nuclei as well as being triple resonance which enables detection of any nuclear spin pair for heteronuclear experiments.

Containerized N_2 generation for EMIT Wind Tunnel
The Energy Matter Interaction Tunnel (EMIT) is building a N_2 generation capability to be able to run the wind tunnel off custom mixtures of N_2 and O_2 instead of just compressed air. This will expand the testing capabilities to better understand oxidation behavior in material degradation by allowing for adjustable O_2 concentrations, all the way down to no oxidation (pure N_2). Due to the high volume of gas required, the facility adds on-demand N_2 generation through on-site atmospheric gas separation. Air compression, nitrogen filtration, and a blending system are being installed outside the building in containerized storage and plumbed into the existing wind tunnel hardware to allow for this expanded tool. When operational, the capability will allow researchers to adjust the working fluid composition on a per-day basis, which gives unique capability to maintain identical test conditions while solely varying the atmospheric composition, in order to mimic different flight altitudes or understand degradation mechanisms via gas-surface interactions.

Sigray Eclipse XRM X-ray CT instrument
The system provides 3D x-ray tomography structural and composition information on NIF targets, advanced manufactured components, and other complex objects required by LLNL programs. It uses a large-format 26 MP detector with nano-focus x-ray tube to produce micron resolution over 3-4 mm field of view. This new instrument enables full characterization of a NIF ICF shell in the same amount of time that the previous x-ray CT instrument acquired approximately 5-10% of the shell volume, without giving up spatial resolution. The geometric magnification can be selected by the user to optimize resolution and field of view for specific samples, ranging from approximately 2x to over 150x, depending on the sample size. Features down to approximately 0.5 micro-meters can be resolved in the 2D radiography images. The instrument includes an x-ray tube that has four selectable anode materials, and hence characteristic x-ray wavelengths to provide better material identification. The instrument is operated and maintained by the Engineering Non-Destructive Evaluation group.

Section 5: Metrics and Reviews

We have a mandate for excellence and effectiveness

Lawrence Livermore National Security (LLNS) takes a multifaceted approach to fostering, pursuing, and achieving excellence. This includes every part of our work, from recruitment and staff development, to establishing multidisciplinary teams for innovative solutions, to developing unparalleled facilities and cutting-edge equipment, all guided by a vision that connects innovative science and engineering to our mission. All of these measures tend to lead to excellence, but excellence is not taken for granted. To ensure that our science and technology are healthy and innovative, we use a series of metrics and reviews to evaluate our internal portfolio of investments.

Overall, we evaluate how well the Laboratory's science and technology support our mission, their impact, recognition, research value, levels of collaboration, and program sustainability. We seek to track how well our investments in LDRD and ISCP yield future accomplishments, capability, and support for mission areas.

For the multiple dimensions of performance in the science and technology domain, the Laboratory uses a variety of metrics. Some metrics may be applied to each element of the portfolio, while others are tailored more specifically to each program.

Current metrics include: the size, quality, and disciplinary diversity of our postdoctoral cohort; conversion efficiency of postdocs to research staff; the number and quality of our publications; the impact of our research, as measured by how well we transition innovations to mission programs, industry, and other partners; and the expertise of our staff, as recognized by awards, fellowships, and other external recognition from their peers. The Research Library utilizes its subscriptions to scientific publication databases not only to help our researchers better connect with their communities, but also to provide bibliometric data. Continued sponsor support is its own metric, but we seek to go beyond satisfaction: The Laboratory fulfills its promise when it not only delivers on what is requested by sponsors but also tells sponsors what they did not know they could request.

Metrics are imperfect and incomplete in several ways. For a publication, the impact may not be apparent through metrics for years. Many of the Laboratory's programs do not publish in open literature. We use internal reviews to support our efforts to recognize merit with staff awards, which we consider to be an important part of our staff development and a way to incentivize great work.

Reviews by independent experts are the most valuable way to evaluate the quality of the research, the application of science and technology to key mission areas, the composition of the investment portfolio, and how investments have translated to impact. The Laboratory utilizes External Review Committees (ERCs) composed of independent experts to provide feedback to the programs. The LLNS Board of Governors (BOG) Science and Technology Committee reviews across the programs, looking at the big picture and doing selected deep dives to report back to the LLNS BOG on the health of the Laboratory's science and technology.

To view recent LLNL awards and recognition, please visit: https://st.llnl.gov/news/recognition

Section 6: Emerging Opportunities

We are striving to make the nuclear security enterprise agile, resilient, sustainable, and responsive to emerging national needs.

This forward-looking section of the *Investment Strategy for Science and Technology* outlines urgent national priorities and needed scientific capabilities. Section 6.1 highlights areas of growth within three Core Competencies, while 6.2 highlights the facilities, centers, and institutes that focus on specific scientific capabilities. Section 6.3 outlines how our internal investments are chosen to fulfill the Laboratory's mission-driven work in multiple ways to reflect a swiftly changing geopolitical environment. Each element considered in this section ensures the Laboratory can support new mission requirements, meet long-term mission needs, and rise to new challenges. The Laboratory's many successes are the result of our dedicated staff members' efforts to strengthen national security and global stability through world-class science, technology, and engineering.

Section 6.1: Focus Areas for Investment

New applications of mission-critical science and technology are continually emerging.

Our seven Core Competencies are foundational; we continually work to enhance their quality and breadth. The science and engineering that support these competencies is strengthened by our LDRD program and our institutional support, and their quality is assessed via measures of output, external reviews, honors awarded to LLNL staff, and the success of external partnerships. Our engagement in the external research community and our ability to anticipate and respond to our sponsors' vision and strategic plans demonstrate our expertise in these areas of scientific strength. Excellence is an element of strategic deterrence.

Core Competencies are a key priority for our LDRD research portfolio. Looking ahead, three areas of focus in LDRD will be emphasized in FY27: advances in HED Science, including two avenues of exploration, one in high yield facility (HYF) definition and the other, inertial fusion energy (IFE); advanced materials and manufacturing (AMM); and artificial intelligence (AI). These three areas were prioritized by the Senior Leadership Team and are further described below:

Advanced Materials and Manufacturing

New breakthroughs in AMM will accelerate the discovery, design, and deployment of novel materials with tailored properties for extreme environments and/or challenging design requirements. Integrating AI and machine learning with experimental workflows will dramatically reduce the design-to-deployment timeline for new alloys, energetic materials, and advanced components. These efforts not only support modernization of the nuclear stockpile and the broader security enterprise but also drive innovation in energy, aerospace, and industrial applications, ensuring LLNL continues to work at the forefront of materials science and manufacturing technologies.

AMM Relevant Facility, Center, or Institute

LLNL's advanced materials and manufacturing capabilities help researchers turn design concepts into reality, from testing early prototypes to pilot-scale demonstrations. LLNL's Prototyping Enclave, sited for the Livermore Valley Open Campus, will offer additional resources to support collaborative design and scale-up activities, including device and system demonstrations that validate the technology's potential for commercial deployment. The Prototyping Enclave will help next-generation engineers and materials scientists demonstrate technology maturation in advanced materials and manufacturing, fusion, and defense for the rapid scale-up of great ideas.

AMM LDRD Highlight
Project Title: Virtual Inspection of Advanced Manufacturing via Process-Scale Digital Twins
Principal Investigator: Brian Giera

Inspection presents the largest bottleneck in NNSA's manufacturing enterprise and is as much as four times more costly than fabrication itself. Furthermore, there are no known methods to connect machine instructions to the final performance of a part, limiting the ability to ensure part quality and mission assurance. This LDRD project addressed these limitations using process- and part-scale digital twins: a framework that combines in situ process monitoring, data-driven measurements, virtual inspection, and virtual reality (VR) visualization.

This holistic approach alleviates the bottleneck of manufactured part certification for critical applications across the NNSA mission space by enabling more efficient, data-driven certification pathways. Through digital twin software pipelines, researchers demonstrated the ability to analyze process data, construct part-level meshes for simulation, measure parts from sensor data in previously unrealizable ways, and visualize data collaboratively among teams not colocated. Using Direct Ink Write as a demonstrator, scientists showed that the framework can reduce inspection time by a factor of 120,000 while improving traceability and confidence in structural analysis of a part. Ultimately, results established a digital twin framework applicable to advanced manufacturing processes of programmatic interest, directly supporting the NNSA mission by maintaining and enhancing the safety, security, and effectiveness of the U.S. nuclear weapons stockpile, providing an agile, flexible, and effective nuclear deterrent, and enabling NNSA to create new ways of responding to national security challenges.

AMM Mission Support
The Laboratory's AMM expertise is crucial in accelerating delivery of solutions supporting the reliability of the nation's nuclear deterrent. The ability to manufacture customized alloys for extreme environments while using predictive models to identify designs resistant to aging have mission-critical applications in hypersonic vehicles, space science, high-power lasers, and nuclear reactors.

AMM Multidisciplinary Approach
A wide range of multidisciplinary skills contribute to the rapid development of AMM processes. A recent collaboration studied neodymium, a rare-earth element essential for producing the strongest permanent magnets used in defense technologies, hard drives, medical imaging devices, electric vehicle motors, wind turbines, and more. Despite its designation in the U.S. as a critical material, neodymium is primarily mined and refined overseas. China controls much of the supply chain, and the country recently threatened to expand restrictions on the exports of rare-earth elements. A domestic capability to produce critical materials like neodymium would address supply chain vulnerabilities in the U.S. To this end, researchers at LLNL, Case Western Reserve University (CWRU) and Ames National Laboratory developed a new process for neodymium magnet fabrication that generates high-purity material at high efficiency. This work represents a strong collaboration; CWRU led electrochemical design and process modeling, LLNL contributed materials characterization and anode fabrication, and Ames used the material produced to fabricate magnets that were comparable to industry standards. CWRU is currently working to scale up the electrolysis setup design, while LLNL tests new deposition approaches to further stabilize the anode.

Section 6.1: Focus Areas for Investment (cont.)

HED Science

Within HED science, two complementary avenues of exploration are underway: one in the definition of a high yield facility (HYF) and the other, inertial fusion energy (IFE). While funding sources and key stakeholders differ between these realms, they both require an interwoven set of technical strengths: laser performance, advanced materials, and target design. Deep understanding and experimental investigation of HYF elements are essential for addressing key questions in nuclear deterrence and for making advances toward the potential of fusion energy. The DOE released its Fusion Science and Technology Roadmap in October 2025, outlining a national strategy to accelerate the development and commercialization of fusion energy. A HYF is a critical next step needed to support stockpile science. Further research in IFE science will advance the foundational S&T required to realize fusion as a practical energy source. IFE research not only strengthens LLNL's efforts in stockpile management and modernization but also positions the Laboratory as a key contributor in the national and international fusion energy community. LLNL is building on a legacy of HED science and contributions from industry partners to enable new exploration for a HYF and IFE.

HED Relevant Facility, Center, or Institute

Planning is underway for a HYF capable of producing more than four times the current energy delivered by NIF lasers. This facility would enable experiments with drastically higher yields, allowing access to new experimental regimes. LLNL researchers are exploring innovative laser technologies, such as compact, efficient laser drivers, to reduce the size and cost of the facility. A national discussion on driver technologies is underway, including laser and pulsed power options. Technology maturation efforts will help ensure readiness for a design down select in the early 2030s.

HED LDRD Highlight

Project Title: Advancing Atomic Physics at Extreme Pressures
Principal Investigator: Tilo Doeppner

Recent radiography measurements of National Ignition Facility (NIF) capsule-implosion experiments have revealed a discrepancy between predicted and experimentally measured shell absorption that translates to a difference in carbon K-shell occupation on the order of half an electron per atom. A similar trend was observed in x-ray Thomson scattering (XRTS) measurements where the K-shell occupation is determined with high precision from the ratio of elastic to inelastic scattering. This project aims at bringing these two observations together by fielding simultaneous precision radiography and XRTS measurements at the NIF. It will also develop a new framework for analyzing XRTS spectra, including model-independent temperature inference based purely on detailed balance, which is crucial for interpreting the ionization measurements. This project will advance our understanding of atomic physics at pressures of 100 Mbar and beyond, which affects important plasma properties like opacity, radiation transport, heat capacity, and compressibility. An accurate understanding of these plasma properties in dense plasmas is of direct relevance to stockpile management and modernization applications and inertial confinement fusion (ICF), where such plasma conditions are encountered in the ablator in flight and close to stagnation.

HED Mission Support

Experiments in HED science are directly applicable to the Laboratory's mission. The LDRD experiment outlined above develops advanced approaches to interpret x-ray Thomson-scattering spectra obtained

Section 6.1: Focus Areas for Investment (cont.)

from high-density plasmas at the NIF. An accurate knowledge of the ionization balance in ultra-dense plasmas is crucial to improving equation of state tables, since it affects many thermodynamic and transport properties like opacity, heat capacity, compressibility, etc. These studies will advance the understanding of ionization and opacity at these conditions, which is crucial to improve predictive capabilities for fusion experiments and stockpile management and modernization. An in-depth discussion on the interpretation of NIF XRTS results will have high visibility in the HED community and highlight LLNL's leadership in HED science—specifically, the unique advantages of the NIF.

HED Multidisciplinary Approach

The achievement of fusion ignition at the NIF demonstrated the fundamental basis of IFE and is a pivotal first step towards a fusion energy future. The IFE initiative is enabling the U.S. national, technical, and community leadership needed to build the foundational science and technology for IFE and to support the DOE's vision for accelerating the commercialization of fusion energy.

Artificial Intelligence

Artificial Intelligence continues to be a focus for LLNL's research portfolio; AI is fundamentally reshaping scientific discovery, mission delivery, and operational efficiency. Previous LDRD support has helped develop advanced machine learning algorithms, trustworthy and safe AI systems, and automation for experimental and manufacturing platforms. By harnessing AI in a variety of scientific domains, from biology and drug design to manufacturing and energy dominance, researchers can achieve rapid data analysis and adaptive experimental design, while accelerating hypothesis generation and testing. Partnering with industrial and academic colleagues and revamping internal processes ensures that LLNL's research supports U.S. leadership in the global AI landscape.

AI Relevant Facility, Center, or Institute

Ranked No. 1 on the TOP500 List of the world's most powerful supercomputers, El Capitan was built primarily for NNSA stockpile management and modernization simulations but has demonstrated its ability to deliver world-class scientific AI capabilities that serve the nation in both national security and in advancing scientific understanding. Scientists at LLNL and collaborators at Advanced Micro Devices (AMD) and Columbia University have achieved a milestone in biological computing: completing the largest and fastest protein structure prediction workflow ever run, using the full power of El Capitan. The effort, dubbed ElMerFold, produced high-quality 3D structure predictions for more than 41 million proteins—a scale and speed previously thought impossible. The record-breaking run hit a sustained rate of 2,400 structures per second and peaked at ~720 petaflops of performance using 43,200 AMD Instinct MI300A accelerated processing units and 10,800 nodes of El Capitan. The success of ElMerFold demonstrates how the architecture can accelerate AI-driven life sciences and highlights the importance of high-performance computing in biology, where AI models and massive datasets are becoming standard tools for discovery. Additional projects, including ICECap (Inertial Confinement on El Capitan), showcase a transformative approach to inertial confinement fusion (ICF) design optimization targeted primarily for El Capitan. At the core of ICECap is discovering the next generation of robust, high yield ICF designs, expanding the possibilities of computational science and shaping the future of plasma science through emerging technologies. ICF has implications for NNSA's stockpile management and modernization efforts, as well as future viable fusion power plants. Exemplar applications such as these demonstrate the capabilities of El Capitan for world-class AI applications and the strength of working with both multidisciplinary and multi-institutional teams.

Section 6.1: Focus Areas for Investment (cont.)

AI LDRD Highlight
Project Title: FLASK: Foundation Learning AI for Synthesis Knowledge
Principal Investigator: Brian Van Essen

The FLASK project is developing a foundation model and agentic workflow for molecular discovery, with a particular focus on energetic molecules and routes for synthesis. This project heavily leverages HPC resources to train AI models from scratch or to retrain open-source models. This is necessary because current state-of-the-art models are unable to adequately serve the needs of the synthetic chemistry community and have guardrails that prevent productive use of the models for mission-critical programs. Knowing that the ability to efficiently execute AI workloads is critical to the future of work at LLNL. One of the thrusts within FLASK has been to develop the capability to deploy trained AI models on all of El Capitan (LLNL's flagship supercomputer) and accelerate the training of large language models (LLMs) as well as other scientific AI models. Under this thrust area, the FLASK team has made significant contributions to the AMD AI software stack and is a key contributor to the overall AI readiness of El Capitan and Tuolumne. While private industry has developed several cutting-edge AI models and methods, they inevitably require translation when used for LLNL's mission-driven work and researchers require the ability to adapt, fine-tune, or retrain these models when working on national security-relevant projects. This would not be possible without the HPC resources at the Laboratory and the efforts of LDRD projects, such as FLASK, that enable AI to meet mission demands.

AI Mission Support
LLNL is tapping AI to revolutionize inertial confinement fusion experiments, which recreate the power of the sun by using 192 lasers to compress a tiny hydrogen fuel pellet from all directions. These pellets, known as fusion targets, are central to experiments that mimic the extreme conditions of a nuclear blast without detonation. LLNL's new tool, the Multi-Agent Design Assistant (MADA), uses AI agents running on two supercomputers, El Capitan and Tuolumne, to automate the complex design of fusion targets and accelerate breakthroughs in nuclear research. MADA unites natural-language interaction, automated testing, and real-time feedback into a single mission-critical workflow relevant for advanced materials, technology development, and nuclear weapons certification.

AI Multidisciplinary Approach
As HPC, AI, and machine learning become increasingly important to mission-critical applications, multidisciplinary teams can draw on research launched by institutional initiatives in emerging scientific realms. The Cognitive Simulation institutional initiative aimed to accelerate the integration of AI, high-performance computing, and empirical data for a range of scientific applications. As the DOE considers significant large-scale AI investments, Cognitive Simulation research ensures LLNL upholds a deliberate, focused vision on AI development and execution for national security priorities. The Decision Superiority initiative was created to build on mathematical advances in complex systems and AI capabilities to foster scalable, stable, and robust modeling and forecasting capabilities that can resolve decisions with limited information. The impact of biotech at LLNL is also growing, with new uses for AI in medical countermeasures and national security applications in threat recognition and reduction.

LLNL expertise is needed to understand the challenges of data governance within the field of AI, including issues related to collection, storage, access, governance, and metadata. Hundreds of scientists, engineers, computer scientists, data scientists, statisticians, and mathematicians are needed to develop and deploy the simulations and AI tools used to support nuclear deterrence, national security, and basic scientific research.

Section 6.1: Focus Areas for Investment (cont.)

DOE Initiative: Genesis Mission
The DOE's Genesis Mission is a sweeping new federal initiative aimed at accelerating AI innovation, strengthening the nation's technological leadership and global competitiveness, and enhancing national security. The program seeks to deliver innovation overmatch—the ability to outpace global adversaries by rapidly developing AI-driven solutions for nuclear deterrence, energy, and science. A unified Genesis Platform for DOE's National Laboratories, universities, and private industry partners will combine frontier-scale AI models with the world's best supercomputers, AI systems, and next-generation quantum computers to aid discovery and decisionmaking across DOE and NNSA missions.

To view a list of LLNL AI and ML publications, please visit: https://data-science.llnl.gov/ai-ml-spotlight

Section 6.2: Next-Generation Facilities, Centers, and Institutes

In addition to the facilities, centers, and institutes highlighted in the previous section, new construction, building improvements, and upgrades support cutting-edge research activities at LLNL. LLNL will continue to provide essential support to facilities and capabilities to enable impactful basic and applied research and development and to support mission- and sponsor-driven work. Four near-term key projects to achieve the goals outlined above are highlighted below:

Livermore Institute for Fusion Technology (LIFT)
Realizing fusion energy at scale will ensure energy security, drive economic prosperity, and provide a sustainable power source for generations to come. The U.S. holds a unique advantage in fusion science, demonstrated by the repeated achievement of fusion ignition at LLNL's National Ignition Facility. LLNL is committed to expanding this lead by de-risking fusion technology and accelerating its path to market. The newly established Livermore Institute for Fusion Technology (LIFT) promotes public-private partnerships, drives innovation in science and technology, and supports fusion commercialization. LIFT is structured to enable new types of partnerships that help de-risk and scale innovations while overcoming cross-cutting technical barriers.

Vertically Integrated Prototype Realization Enclave (VIPRE)
VIPRE is a complex of three line-item advanced materials and manufacturing facilities intended to enable our vision of discovery to deployment of critical national security systems in less than a year. The three modules are:

- **VIPRE-Discovery** which will house accelerated materials discovery and characterization, as well as new manufacturing process invention and development.
- **VIPRE-Techmat** is for new process and material scale-up and maturation, component realization, and rapid inspection.
- **VIPRE-Impact** is being designed for testing, evaluation, and deployment of integrated system assemblies.

The VIPRE campus will allow LLNL to become the premier materials and manufacturing ecosystem, uniquely able to anticipate, innovate, and deliver national security solutions.

Section 6.2: Next-Generation Facilities, Centers, and Institutes (cont.)

B177 Wet Chemistry Laboratory
The B177 Wet Chemistry Laboratory at LLNL is a new state-of-the-art facility supporting ultra-trace chemical and isotopic analysis for scientific and national security applications. Integral to the Center for Accelerator Mass Spectrometry (CAMS), it enables precise analysis for nuclear forensics, proliferation monitoring, cosmochemistry, carbon cycle studies, and environmental health. The building features an advanced design to minimize sample contamination and interference, ensuring the highest sensitivity and reliability in analytical measurements. B177 positions the Laboratory at the forefront of scientific discovery, enabling collaboration, training of future experts, and the development of solutions to global challenges in energy security and environmental science.

Center for Predictive Bioresilience (CPB)
The Center for Predictive Bioresilience (CPB) serves as LLNL's main hub for collaboration between computational and experimental biology. The center combines high-performance computing and experimental platforms to accelerate the design of medical countermeasures and develop advanced predictive models for early warning systems to help prevent future pandemics.

Section 6.3: Investing in People and Innovation

It's a privilege to invest in the capabilities that keep LLNL's science and technology at the cutting edge. Here are the areas in which DDST anticipates increased investment in FY2026.

People
Whether it's sparking scientific interest in K-12 students or recruiting the next generation of nuclear physicists, developing our workforce pipeline continues to be a strategic priority. Our workforce is at the heart of everything we do, as we strive to live our values in a culture of growth opportunities. From helping postdocs transition to independent scientists, to developing thought leaders by providing opportunities for early career staff to lead a Center or Institute and advance Core Competencies, LLNL supports a workforce able to meet mission objectives. It is vital that the Laboratory continues to invest in what allows our workforce—no matter their role—to be productive, innovative, and successful. Across the Laboratory, effective team science is enabled through a healthy research culture of respect, openness, interdisciplinary teaming, workforce diversity, and collaborative approaches. Each year, we participate in hundreds of recruiting and conference events as we continue to develop talent pipelines for succession planning to meet the Laboratory's future needs. Three marquee activities include:

Science on Saturday
The popular Science on Saturday lecture series is presented by leading LLNL scientists alongside local high school science teachers. Geared towards middle and high school students, the hour-long talks highlight ongoing Laboratory research areas. 2025 lectures highlighted space-based x-ray observatories, the challenges of capturing images of planets orbiting distant stars, and how drones can help address significant scientific challenges.

Faculty Mini-Sabbatical Program
Our Faculty Mini-Sabbatical Program is designed to bring top academic talent from colleges

Section 6.3: Investing in People and Innovation (cont.)

and universities across the world to the Laboratory for one- to three-month visits to exchange knowledge and build partnerships. Targeted collaborations with academic faculty strengthen LLNL's pipeline of new ideas, people, and engagement with the larger academic community.

Research SLAM
This annual contest awards the best three-minute research presentation given by an LLNL postdoc, amplifying the importance of effective science communication. Postdocs learn to clearly explain the motivation, results, and significance of their research to a non-specialty audience and a panel of judges. The top three LLNL winners move on to the Bay Area Research SLAM to compete against colleagues at Bay Area laboratories. LLNL's first-place winner represents Livermore at the National Lab Research SLAM in Washington D.C., heightening competition and collaboration while raising visibility of the National Laboratory system and federal research priorities.

Innovation
Best practices in innovation are deployed for scientific excellence at LLNL. We work to strengthen the way we carry out purposeful partnerships throughout the scientific ecosystem. Research outreach must be accompanied by efforts to identify new economic opportunities, protect LLNL intellectual property, and transfer it to the private sector through licensing and partnerships. An engaged posture for the Laboratory helps researchers respond rapidly to the security challenges of a deeply connected world. The Innovation and Partnerships Office (IPO) serves as a focal point for LLNL engagement with industry and is a key member of a larger innovation ecosystem that stimulates regional economies in the Tri-Valley and greater San Francisco Bay Region. IPO's network of innovation-focused partners amplifies technology commercialization programs, trains staff on industry practices, and provides S&T-focused results.

In FY24, IPO made significant strides in enhancing access to LLNL's innovative technologies with the launch of a new Software Licensing Portal. This portal streamlines the process for external organizations to license LLNL-developed software, making it easier than ever to leverage our cutting-edge solutions for real-world applications. Designed with user experience in mind, the portal offers a centralized, efficient platform for exploring available technologies and software and initiating licensing agreements. This initiative reflects LLNL's commitment to fostering impactful partnerships and accelerating technology transfer.

LLNL and Amazon Web Services (AWS) are partnering to integrate AI into the NIF to create a system for troubleshooting and enhancing reliability. The first phase has successfully implemented semantic search across decades of NIF operational logs using AWS generative AI; this project is intended to set a new standard for AI use in scientific facilities.

The Laboratory's partnership and open innovation initiatives are purposefully oriented to ensure excellence and to understand the dissemination of information related to critical and emerging technologies. These connections with industry, government agencies, universities, and international counterparts cultivate entrepreneurship, grow the U.S. economy, and meet national and global security needs.

Appendix A: Acronym List

AEO: Academic Engagement Office

AI: Artificial Intelligence

AMD: Advanced Micro Devices

AMM: Advanced Materials and Manufacturing

ARPA-E: Advanced Research Projects Agency-Energy

ASCR: Advanced Scientific Computing Research

AWS: Amazon Web Services

BOG: Board of Governors

CAMS: Center for Accelerator Mass Spectrometry

DARPA: Defense Advanced Research Projects Agency

DDST: Deputy Director for Science and Technology

DHS: Department of Homeland Security

DOD: Department of Defense

DOE: Department of Energy

DNN: Office of Defense Nuclear Nonproliferation

EOS: Equation of State

ERC: External Review Committee

FFRDC: Federally Funded Research and Development Center

FY: Fiscal Year

FSC: Forensic Science Center

HEAF: High Explosives Applications Facility

HED: High Energy Density

HPC: High-Performance Computing

HYF: High Yield Facility

ICF: Inertial Confinement Fusion

IFE: Inertial Fusion Energy

IPO: Innovation and Partnerships Office

ISCP: Institutional Scientific Capability Portfolio

JLF: Jupiter Laser Facility

L&R: licensing and royalties

LDRD: Laboratory Directed Research and Development

LIFT: Livermore Institute for Fusion Technology

LLNL: Lawrence Livermore National Laboratory

LLNS: Lawrence Livermore National Security

LVOC: Livermore Valley Open Campus

MJ: Megajoule

ML: Machine Learning

NASA: National Aeronautics and Space Administration

NARAC: National Atmospheric Release Advisory Center

NIF: National Ignition Facility

NIH: National Institutes of Health

NNSA: National Nuclear Security Administration

R&D: Research and Development

S&T: Science and Technology

S&TR: *Science and Technology Review*

SC: Office of Science

ST&E: Science, Technology, and Engineering

SLCM-N: Sea-Launched Cruise Missile-Nuclear

SOHIP: Stellar Occultation Hyper-temporal Imaging Payload

SPP: Strategic Partnership Project

VIPRE: Vertically Integrated Prototype Realization Enclave

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Cover image: A team from Lawrence Livermore National Laboratory, Stanford University and the University of Pennsylvania introduced a novel wet chemical etching process that modifies the surface of conventional metal powders used in 3D printing. By creating nanoscale grooves and textures, the researchers reportedly increased the absorptivity of these powders by up to 70%, allowing for more effective energy transfer during the laser melting 3D printing process.

Image Source: Brendan Thompson/LLNL