Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is preeminent in its ability to harness the power of science and technology to address critical national security challenges.

Compelling Mission

Since its inception in 1952, LLNL has embraced its role as a “new ideas” laboratory, focusing on novel concepts and innovative approaches to national security science and engineering.

Its defining responsibility is stockpile stewardship, ensuring the safety, security, and reliability of the nation’s nuclear stockpile. Yet LLNL’s mission is broader than stockpile stewardship, as dangers ranging from nuclear proliferation and terrorism to energy shortages and climate change threaten national security and global stability. The Laboratory’s science and technology are being applied to achieve breakthroughs for counterterrorism and nonproliferation, defense and intelligence, energy and environmental security.

Strategic Partnerships

LLNL engages in partnerships with other laboratories, research universities, and high-technology industries to solve pressing national and global problems. Livermore has particularly strong partnerships with Sandia National Laboratories and Los Alamos National Laboratory, with shared stockpile stewardship and other national security initiatives, and with the University of California. Closer to home, the Laboratory is partnering with California’s energy providers to improve the efficiency, security and safety of the state’s utility systems.

Exceptional Science and Technology

The Laboratory’s mission requires outstanding capabilities in multiple scientific and engineering disciplines, including:

- **High-Energy-Density Science**: Provides international leadership in studying and controlling matter under extreme conditions of temperature and pressure.
- **High-Performance Computing, Simulation, and Data Science:** Leads in the development, integration and use of new computer architectures, predictive simulation capabilities, knowledge extraction tools, and analytical techniques.
- **Nuclear, Chemical, and Isotopic Science and Technology**: Advances the fundamental understanding, scientific capabilities, and technologies in nuclear and particle physics, radiochemistry, analytical chemistry, and isotopic signatures to support LLNL’s multifaceted national security mission.
- **Advanced Materials and Manufacturing**: Meets NNSA and national needs for the responsive, cost-effective development of advanced materials and manufacturing processes and systems.
- **Lasers and Optical Science and Technology**: Designs, builds, and reliably operates complex laser systems that dramatically advance the state of the art to meet strategically important applications.
- **Bioscience and Bioengineering**: Works at the interface of biology, engineering, and the physical sciences to address national challenges in biosecurity, chemical security, bioenergy, and human health.
- **Earth and Atmospheric Science**: Advances the frontier in Earth and atmospheric sciences to develop innovative capabilities that drive LLNL’s energy and national security missions.

Key Facilities

The Laboratory supports a number of unique facilities that are central to its ability to carry out its national security mission:

- **National Ignition Facility (NIF):** Largest, most-energetic laser facility in the world.
- **Livermore Computing (LC):** Home to some of the world’s fastest computers, including Sierra (125 peak petaflops) and Sequoia (20 petaflops).
- **High-Explosives Applications Facility (HEAF):** State-of-the-art research facility for formulating, characterizing, processing, and testing energetic materials.

- **National Atmospheric Release Advisory Center (NARAC):** National resource for predicting the spread of airborne releases of hazardous materials.
- **Advanced Manufacturing Laboratory (AML):** Houses some of the most capable equipment in the field of advanced manufacturing. Additional resources include material evaluation and characterization equipment, HPC modeling and simulation systems, and manufacturing capabilities from several LLNL programs.
- **Forensic Science Center (FSC):** Nationally recognized forensic analysis capabilities in support of nuclear, chemical, explosives and biological counterterrorism.
- **Center for Accelerator Mass Spectrometry (CAMS):** World's most versatile and productive accelerator mass spectrometry facility.
- **Site 300:** Remote site for high explosives and environmental testing.
- **Livermore Valley Open Campus (LVOC):** An unclassified research and development space connecting industry and academia with Laboratory expertise to advance HPC, energy and environmental security, cyber security, economic security, and non-proliferation.

Operational Excellence

Effective management, business practices, and operations provide the essential foundation for LLNL's mission activities. Safety, security, and environmental sustainability are explicitly designed into all activities. Working within a framework of performance-based management, the Laboratory strives to continually improve the quality of its business and operational performance.

Outstanding Workforce

Livermore's multidisciplinary teamwork approach is its principal strength. LLNL's diverse workforce includes roughly 4,250 scientists, engineers, and postdoctoral fellows, as well as visiting scientists and students. Below is a breakdown of our scientific workforce by highest degree discipline and highest degree level:

Engineering	32%
Math/Comp Sci	16%
Physics	15%
Physical Sci	12%
Bio/Med	6%
Other	19%

Ph. D.	1,764
Masters	836
Bachelors	1,252
Associates	399

LLNL-MI-675190
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
December 9, 2019

Lab At A Glance

Location: Livermore, California

Type: National security laboratory

Contract Operator: Lawrence Livermore National Security, LLC

Principal Sponsor: National Nuclear Security Administration, DOE

Director: William H. Goldstein

Website: http://www.llnl.gov/

Physical Assets:

- 7,700 acres (owned)
- 517 building/trailers
- 6.4 million gross square feet in active buildings
- Replacement plant value: $20.2B

Human Capital:

- 7,378 LLNS employees, including:
  - 18 joint faculty
  - 253 postdoctoral researchers
  - 184 undergraduate interns
  - 138 graduate students

FY 2019 Funding: $2.3 billion

- Weapons activities: 61%
- Department of Defense: 12%
- Department of Energy: 7%
- Nonproliferation/Counterterrorism: 6%
- DOE Integrated Contractor: 5%
- Safeguards and Security: 4%
- NNSA Construction: 1%
- Homeland Security: 1%
- Other: 3%

Stockpile Stewardship at LLNL

Ensuring confidence in the safety, security, and effectiveness of the U.S. nuclear deterrent.

Maintaining the Stockpile

Since 1992, scientists no longer confirm the performance of America's nuclear arsenal by conducting explosive tests underground at the Nevada Test Site. Instead, scientists ensure the continuing safety, security, and effectiveness of America's nuclear stockpile through the National Nuclear Security Administration's (NNSA's) science-based Stockpile Stewardship Program.

Established in 1994, this program comprises surveillance, advanced simulations, scientific and engineering experiments, materials research, and refurbishment. As part of stockpile stewardship, LLNL scientists and engineers regularly assess the health of the stockpile to inform refurbishment decisions.

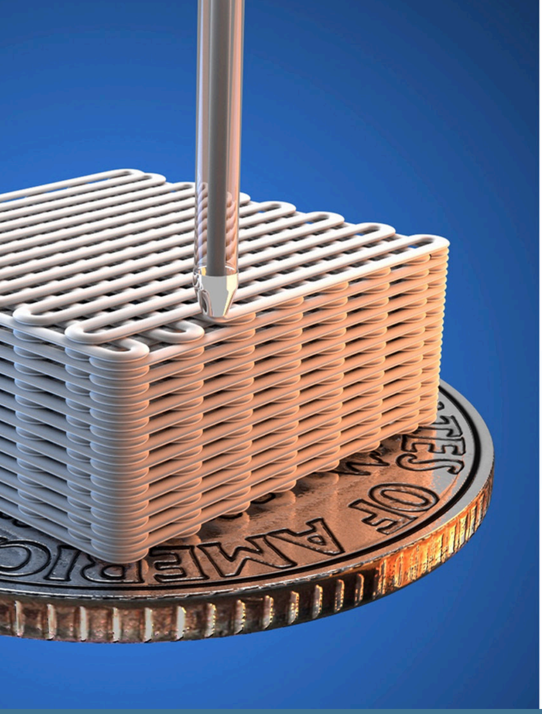
A critical part of stockpile stewardship is life extension programs (LEPs), which refurbish, replace, or redesign aging components of a warhead or bomb that require modernization. Experts design components and systems for the LEPs and certify the life-extended models when they enter the stockpile.

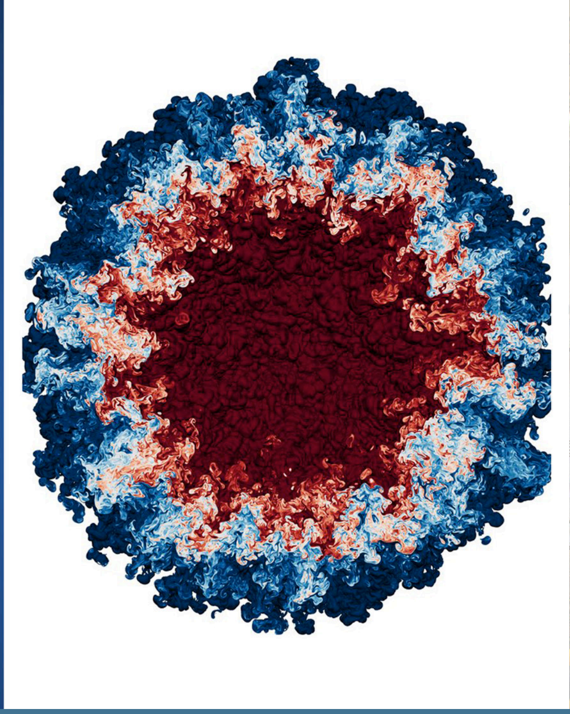
By ensuring confidence in the safety, security, and effectiveness of the U.S. nuclear deterrent, stockpile stewardship permits the nation to retain a small nuclear stockpile consistent with the need to deter adversaries and reassure allies.

Accomplishments

Despite stiff technical challenges, stockpile stewardship has worked exceedingly well, thanks to an expert workforce; advances in theory and understanding of how nuclear weapons work and the aging mechanisms that can degrade performance and safety; investments in world-class experimental facilities such as the National Ignition Facility (NIF) and the Contained Firing Facility (CFF); advances in materials and manufacturing; and development of new supercomputers, including Sierra, the second-fastest computing system in the world. LLNL's many advances and accomplishments include these:

- In 2019, LLNL completed Cycle 24 of the annual stockpile assessment.
- The W87-1 Modification Program restarted in FY19 and will field a warhead on the U.S. Air Force's new Ground-Based Strategic Deterrent by FY2030.
- LLNL is making excellent progress in the LEP for the W80-4 warhead for the Air Force Long-Range Standoff missile. Livermore experts are working closely with the Air Force, the two competing contractors for building the missile, and researchers at several NNSA facilities.
- Recent upgrades to aging facilities and infrastructure at LLNL's main campus and remote Site 300 enhance support for stockpile stewardship.
- LLNL high-explosives experts have pioneered the use of insensitive high explosives (IHEs), which greatly lessens the possibility of accidental detonation.
- Multi-physics simulations performed on cutting-edge computer platforms have delivered powerful tools for design assessment and certification of nuclear weapon weapons and their components. The next-generation supercomputer, Sierra, is playing an important role in modeling complex physical phenomena.
- Experiments conducted on NIF, the world's largest and most energetic laser, make it possible to test materials in high-energy-density regimes formerly inaccessible to scientists.
- An LLNL team hunted down 6,500 decomposing films of the nation's 210 atmospheric nuclear tests. The films are scanned to preserve content and reanalyzed to extract more precise data about nuclear weapons performance.





Scientific Underpinnings

Stockpile stewardship takes advantage of five key LLNL core competencies: high-energy-density science, lasers and optical science and technology; advanced materials and manufacturing; high-performance computing (HPC) and simulation; and nuclear, chemical, and isotopic science and technology. For example, researchers studying the aging of weapons plutonium have combined advances in nuclear theory with new types of experiments and extremely large supercomputer simulations.

A critical element in stockpile stewardship is high-performance computing and simulation. LLNL's Sierra, with a peak speed of 125-petaflops (floating-point operations per second), is a six-fold performance improvement over LLNL's previously most capable supercomputer, Sequoia. Sierra performs complex multi-physics calculations needed for the demanding requirements of stockpile stewardship.

- The National Ignition Facility (NIF) supports stockpile stewardship through a wide range of experiments. Campaigns of high-energy-density science experiments on NIF explore environments central to stockpile stewardship and critical to understanding nuclear weapons performance.
- LLNL is taking advantage of revolutionary advanced manufacturing methods to make parts with optimized properties at lower costs and shorter production schedules.
- LLNL energetic materials scientists examine the physical, chemical, detonation, and mechanical properties of high explosives used in the nuclear stockpile. Researchers are working to enable the use of new insensitive-high-explosives to further enhance safety.
- Scientists are combining data from computer simulations, past nuclear tests, non-nuclear experiments, and theoretical studies to quantify confidence factors (known as quantification of margins and uncertainties) for assessing nuclear weapon performance without nuclear testing.
- In hydrodynamic testing at the Contained Firing Facility, components are subjected to extreme pressure and shock and start to behave like liquids. These experiments—combined with results from other experiments as well as theory and HPC—ensure confidence in the nation's nuclear deterrent by providing vital data about what happens during a nuclear detonation.
- Researchers have developed advanced diagnostic techniques that gather data to validate simulation models and enhance understanding of weapon physics.

The Future

During the next few years, researchers will be focused on meeting the goals of the W80-4 Life Extension Program (LEP) and the W87-1 modification. Livermore scientists and engineers will continue to explore ways to take advantage of advanced manufacturing to improve quality while reducing costs.

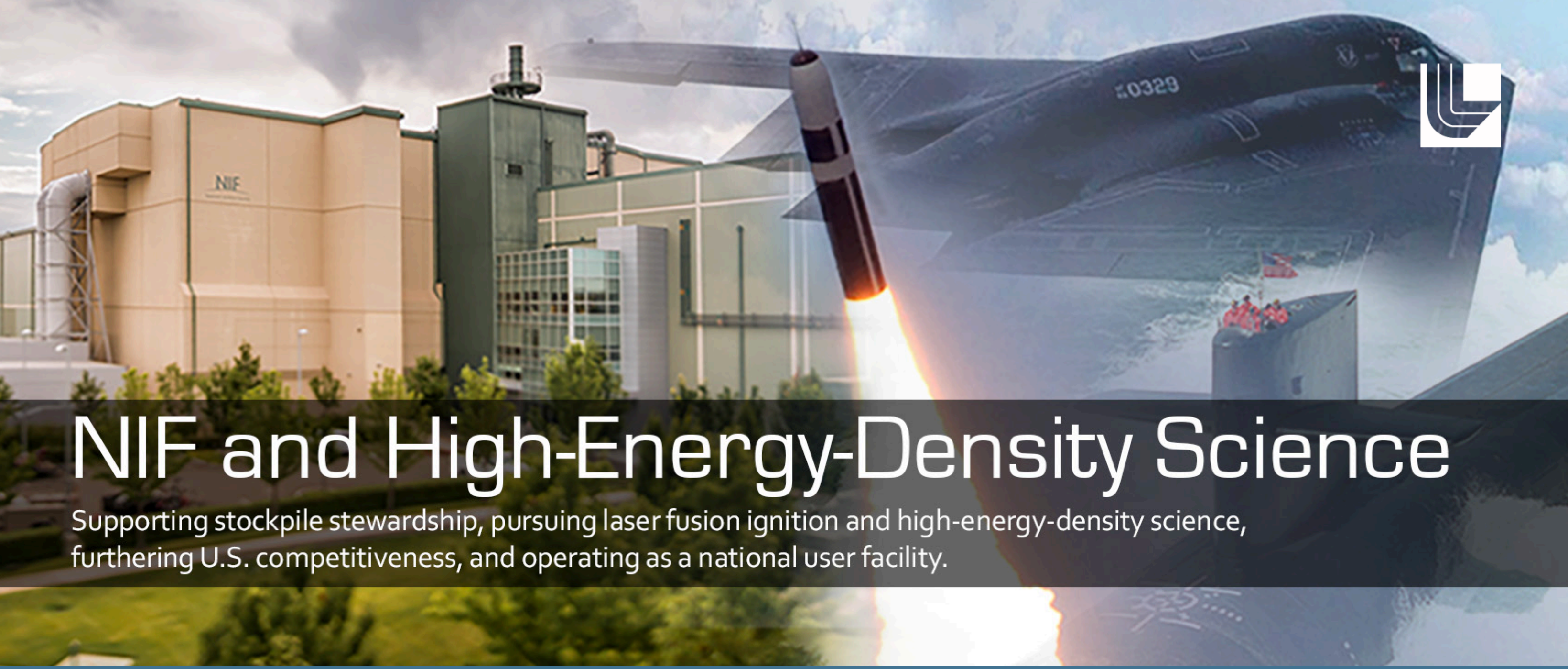
LLNL scientists will also continue to improve the physics and engineering simulation codes that support annual assessments as well as LEPs, with an emphasis on improving predictability and quantification of uncertainties. Stockpile surveillance activities, weapon subsystem tests, and flight tests will supply critical data to simulations.

Meeting Stockpile Stewardship Program goals demands outstanding scientific and engineering talent. In response to large numbers of retiring experienced researchers, LLNL is training the next generation of stockpile stewards.

Principal Sponsorship

- DOE/NNSA stockpile stewardship capabilities also support DHS, DOD, DOE/IN, and U.S. intelligence agencies.

LLNL-MI-805227
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
February 14, 2020



NIF and High-Energy-Density Science

Supporting stockpile stewardship, pursuing laser fusion ignition and high-energy-density science, furthering U.S. competitiveness, and operating as a national user facility.

World's Largest Laser

The National Ignition Facility (NIF), the world's largest and highest-energy laser system, creates the extreme temperatures and pressures necessary for advancing science-based stockpile stewardship, pursuing the prospect of laser fusion ignition, and deepening our understanding of the universe. In NIF laser shots, thousands of optics strengthen and guide light from 192 beams into a 10-meter-diameter target chamber and onto miniature, highly engineered targets.

As the premiere facility creating conditions relevant to understanding the operation of modern nuclear weapons, NIF is a crucial element of stockpile stewardship. NIF experimental data validate 3D weapon simulation codes, improve understanding of important weapon physics, and investigate questions remaining from underground nuclear tests. NIF experiments inform Life Extension Programs (LEPs), the regularly planned refurbishments of nuclear weapon systems to ensure long-term reliability. In addition, experiments devoted to studying inertial confinement fusion (ICF) aid in investigating questions remaining from underground nuclear testing.

Other experiments are devoted to studying high-energy-density (HED) science, supporting a range of national security applications, and working with other laboratory and university researchers to recreate astrophysical phenomena located light years away.

Accomplishments

Since NIF became operational in March 2009, more than 2,000 shots have been conducted by researchers from national laboratories, federal agencies, academia, and the international scientific community. NIF is proving itself a critical element of stockpile stewardship to maintain the effectiveness of America's nuclear weapons, and is the only U.S. facility designed to perform experimental studies in the pursuit of fusion ignition and thermonuclear burn, a scientific grand challenge of the stewardship program.

- Researchers achieved excellent results in material dynamic experiments examining the strength of plutonium in extreme conditions like those found in nuclear weapons. These experiments test critical theoretical predictions.

- NIF experiments have helped stockpile stewards answer questions important to the current Life Extension Program for the Air Force W80-4 warhead.

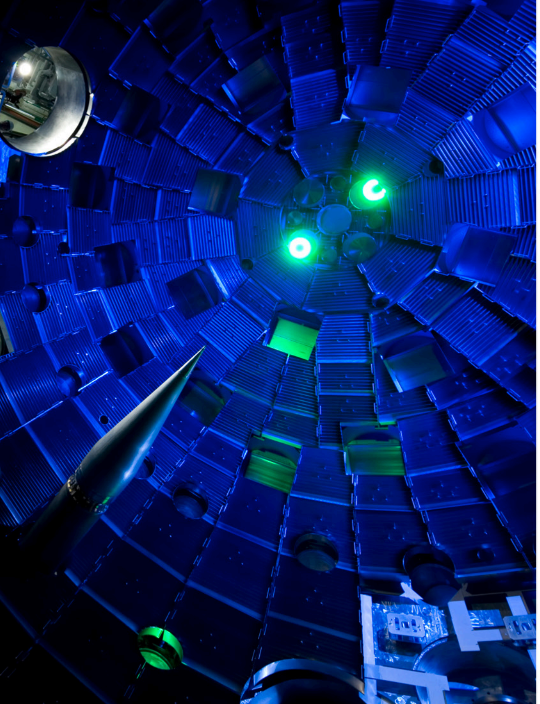
- An experimental campaign achieved a fusion yield of $1.9X 10^{16}$ (19 quadrillion) neutrons and 54 kilojoules of fusion energy output, double NIF's previous energy record. These experiments reached conditions that are 75 percent of the way to fusion ignition.

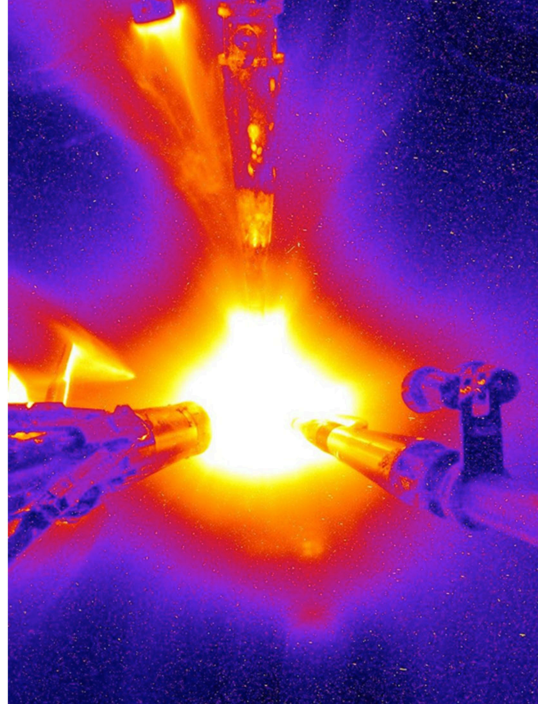
- A research team used NIF experiments to make the first observations of the metalization of hydrogen; the results were published in *Science* magazine and featured in the *New York Times*. This work was made possible by the Discovery Science Program, which provides academic users access to NIF's HED regimes and enhances collaborations between Lawrence Livermore scientists and academia.

- NIF produced a record 2.15 megajoules (MJ) of UV energy and 438 terawatts of peak power, a 15 percent improvement over NIF's design specification of 1.8 MJ.

- The Advanced Radiographic Capability (ARC), a high-energy, high-intensity laser embedded within NIF, has been used to create more penetrating x rays to reveal implosion phenomena with never-before-seen clarity for classified weapons experiments.

- The NIF shot rate has doubled over the last few years, greatly increasing the number of experiments that can be performed for stockpile stewardship.





Scientific Underpinnings

NIF embodies several LLNL core competencies, including HED science; lasers and optical science and technology; advanced materials and manufacturing; ultrafast detectors and precision diagnostics; and nuclear, chemical, and isotopic science. HED research involves examining materials under pressures and densities found in stars and the cores of giant planets—and in detonating nuclear weapons. NIF experiments are highly diagnosed to provide unprecedented insights into HED systems, and are complemented by other experimental facilities at LLNL and elsewhere. Data from experiments help inform and validate 3D weapon simulation computer codes and bring about a fuller understanding of weapon physics. Many NIF shots focus on advancing the prospect of ICF ignition for the stewardship program. NIF HED experiments also help researchers explore scientific fields including astrophysics and materials science. All of these experiments rely on miniature targets that take advantage of LLNL strengths in materials science and advanced manufacturing.

- Designing successful experiments in NIF's often unprecedented regimes draws upon LLNL's expertise in many scientific disciplines including high-pressure materials science and computational, atomic, radiation, nuclear, and plasma physics.
- LLNL scientists have made significant progress in preventing damage to optics in high-intensity laser light. Patented processes make optics' surfaces more resilient by removing impurities and absorbing micro fractures; these breakthrough extend the lifetime of optics and permit increased energy from NIF laser light.
- Experimenters rely on an array of more than 70 nuclear, optical, and x-ray diagnostic instruments, many designed and fabricated at LLNL, to record vital data from NIF shots at micrometer-length scales and picosecond (trillionths of a second) timescales. These instruments push the state of the art in diagnostic capabilities.
- NIF experiments rely on a wide variety of targets, all of which have intricate assemblies of extremely small parts. Designing, machining, and assembling these parts with micro manipulators into precisely manufactured targets requires a complex interplay among target designers, physicists, materials scientists, chemists, engineers, and technicians. Continuous improvements in NIF targets is a key to progress toward ignition.

The Future

NIF continues to be a cornerstone facility for stockpile stewardship. As the last underground tests recede into history, NIF experiments will become more critical to stockpile stewardship. The high rigor and multidisciplinary nature of NIF experiments also help LLNL attract, retain, and train stockpile stewards of the future.

NIF scientists and engineers are pushing on all fronts to increase NIF's capabilities to address stockpile stewardship challenges. This effort includes higher energy and power limits, next-generation optics, improved targets with tighter specifications, and better diagnostics. With NIF implosions already demonstrating self-heating, further improvements may lead to fusion ignition, which would create the possibility for the stewardship program to conduct experiments in new physical regimes. Symmetry control is vital for reaching ignition and will remain an important focus area for researchers. Continued research, together with improvements to NIF, will lead to better implosions and enhanced understanding of fusion ignition requirements.

Principal Sponsorship

- DOE/NNSA

LLNL-MI-767540
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
February 7, 2019

High-Performance Computing, Modeling, and Simulation

Addressing national security challenges through innovative computational solutions on world-class computer resources.

Computing at Livermore

The goal of high-performance computing (HPC), modeling, and simulation is to transform theories that explain physical phenomenon into models that can reliably predict outcomes, thereby reducing the number of expensive experiments needed to verify predictions or design new products. HPC simulations predict complex physical behavior, while experiments verify the computer simulations with real outcomes.

HPC is a linchpin of the Stockpile Stewardship Program. Scientists at Livermore use HPC to simulate the behavior of matter under extreme conditions of temperature and pressure, which are characteristic of nuclear detonations.

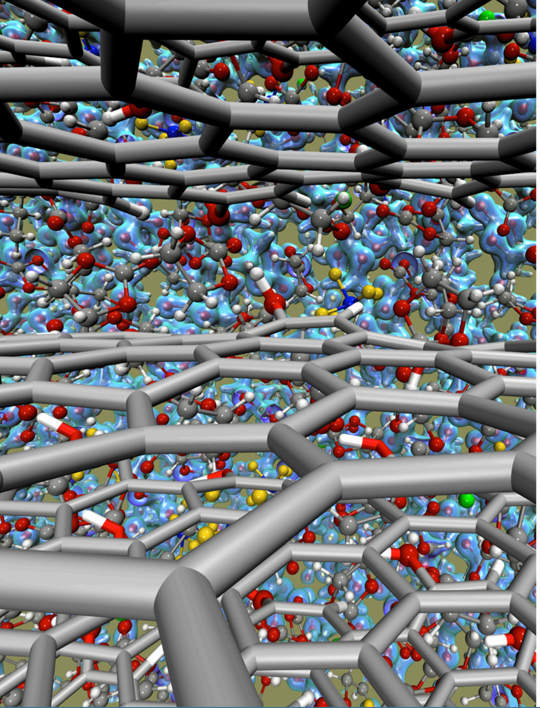
Advanced computing also supports the broader mission needs of the Departments of Energy and its National Nuclear Security Administration and other agencies such as Defense and Homeland Security.

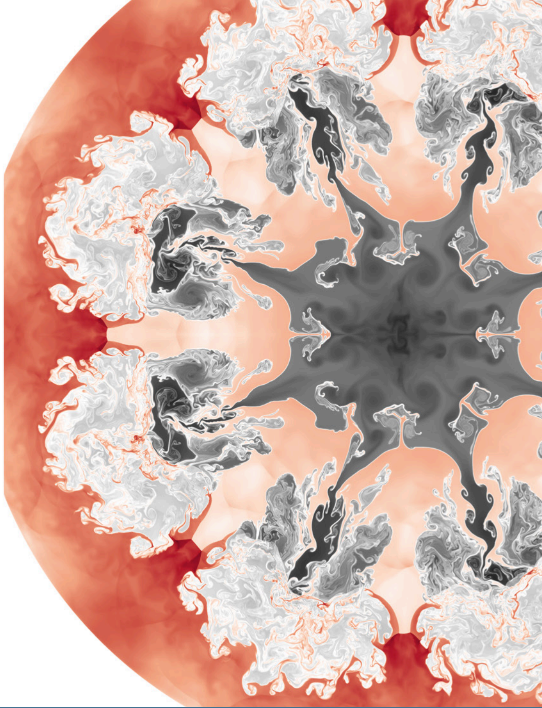
Livermore uses HPC, in cooperation with private sector partners, to solve their technological problems in such areas as semiconductors, steel and glass, and additive manufacturing. In support of its research, the Laboratory operates Livermore Computing (LC), one of the world's most prominent and successful computer centers.

Accomplishments

Lawrence Livermore is a leader in developing and using HPC to perform its missions in nuclear stockpile stewardship, national security, and basic scientific research. Among its most significant recent accomplishments:

- Annually providing the simulation capability to assure the safety, security, performance, and reliability of the nation's nuclear deterrent during the National Nuclear Security Agency's stockpile assessment process.
- Advancing the nation's progress toward the next generation of powerful computers by helping lead the Department of Energy's (DOE's) Exascale Computing Project and delivering the algorithms, libraries, and applications that are foundational to the success of those systems.
- Partnering with researchers at Livermore and elsewhere to solve science problems, such as:
  - Discerning how the iron cores of planets generate a magnetic field
  - Modeling biological processes to understand cancer tumor growth and streamline drug discovery and approval processes
  - Understanding the life and death of a neutron to provide a window into the subatomic world and gain insight into the way the universe has evolved
- Working with private sector partners to solve their technological problems, resulting in:
  - A next-generation extreme ultraviolet process for making semiconductors
  - More energy-efficient steel making and glass sheet manufacturing processes
  - Improved additive manufacturing processes that result in stronger, more uniform materials





Scientific Underpinnings

HPC at Livermore has developed over many decades in close association with the Laboratory's nuclear weapons mission. Today, HPC is a linchpin of the Stockpile Stewardship Program. Where once nuclear testing provided performance data, now Livermore scientists use HPC to simulate the behavior of matter under extreme conditions of temperature and pressure, which are characteristic of nuclear detonations, as well as the interiors of stars and giant planets.

HPC also supports the broader mission needs of the Departments of Energy and its National Nuclear Security Administration, as well as other agencies such as Defense, Homeland Security, and collaborations with the private sector. Much of the Laboratory's research depends on HPC—it touches all of Livermore's core competencies, including advanced materials, lasers, nuclear and chemical science, biosciences, and the earth and energy sciences.

In support of Livermore's research, the Laboratory operates a major computing center, Livermore Computing (LC), one of the world's most prominent and consistently successful computer centers. Among their many computational assets, LC is home to some of the most powerful computers in the world, several of which are capable of petascale computing (10^{15} floating point operations per second). These computers use tens of thousands of cores (central processing and graphics processing units) running at the same time—known as parallel processing.

Sierra, LLNL's newest and most powerful supercomputer, is an IBM-built mainframe that provides 120 petaflops (10^{15} floating point operations per second) peak performance.

The Future

Developing computing capability to fulfill the Laboratory's missions requires ever more powerful computers, and expertise in computing hardware, software, application codes, and the physical sciences to simulate these phenomena with higher fidelity and more realism.

The Laboratory is home to Sierra, an IBM-built supercomputer that provides 125 petaflops (10^{15} floating point operations per second) peak performance. Sierra is the "workhorse" for DOE classified stockpile science.

Exascale systems five times more powerful than Sierra are planned for 2023. Livermore is also pushing the frontiers:

- New simulation technologies and algorithms, especially design optimization and decision support.
- Computing beyond exascale: heterogeneous, neural, and quantum architectures.
- Novel paradigms for science enabled by large-scale data analytics, machine learning, and cognitive simulations.

Principal Sponsorship

- DOE/NNSA

LLNL-MI-761384
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 13, 2018

Energetic Materials

Strengthening the nuclear deterrent, conventional munitions, and homeland security with new energetic materials and applications.

Central to the Mission

Energetic materials (EM) such as explosives, thermites, propellants, and pyrotechnics are central to LLNL's national security mission. EM are utilized throughout a nuclear weapon and also provide the energy source for most conventional munitions.

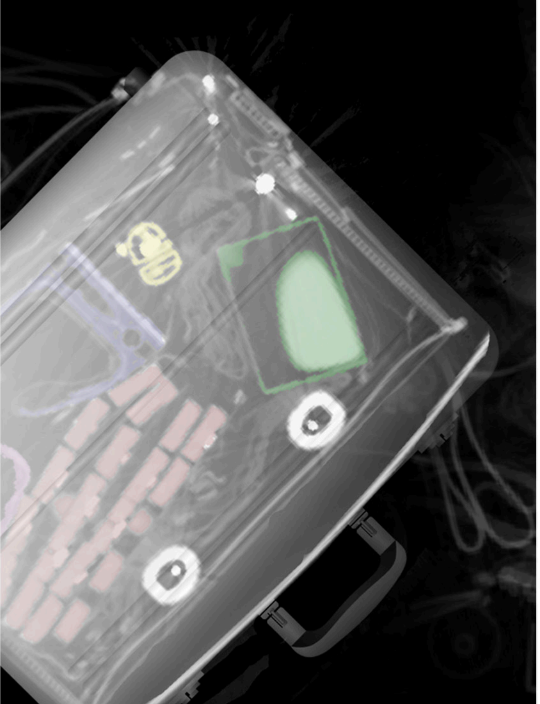
LLNL is a Department of Energy/ National Nuclear Security Administration Center of Excellence for the research, development, synthesis, formulation, and characterization of explosives. The primary mission of LLNL's EM Enterprise is to ensure the safety, security, and effectiveness of the U.S. nuclear deterrent. Researchers also apply their expertise to develop solutions for Department of Defense conventional weapons, explore new ways to detect and defeat home-made explosives for the Department of Homeland Security, and develop strategies to counter the threat of improvised explosive devices for nuclear counterterrorism.

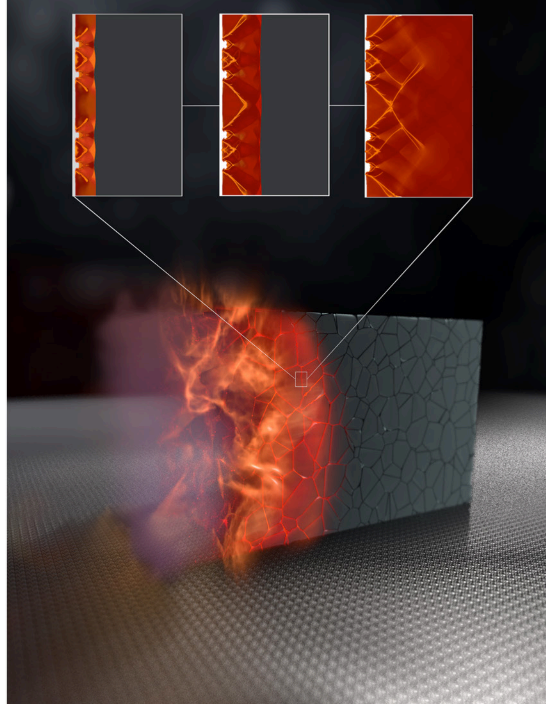
Experimental facilities at Livermore's Main Site (Site 200) and remote Site 300 together enable experimental activities that, when coupled with high-fidelity modeling and simulation, provide the basis for scientific advances in EMs.

Accomplishments

LLNL scientists have developed numerous new energetic materials (EMs),especially high explosives—HEs); experimental techniques for their characterization; and computational models (e.g., Cheetah and ALE3D) to predict their behavior. These advancements form much of the scientific basis for the modern EM R&D community. EMs developed by LLNL are used by Livermore and Los Alamos nuclear weapon programs, and the Department of Defense (DOD) uses LLNL explosives, initiation systems, and models for their unique weapon designs.

- First to design an all-insensitive-high-explosive (IHE) booster and main charge system and introduced an out-of-line detonator.
- New explosive (LLM-105) is the baseline booster material for the W80-4 and W87-1 Life Extension Programs (LEPs).
- Leading the remanufacture efforts of critical IHEs for the W80-4 and W87-1 LEPs after 30 years of inactivity. HEAF researchers defined the production parameters, and LLNL's Forensic Science Center developed chemical analysis protocols.
- Full-scale fire-safety tests provide high-fidelity data to characterize HEs and their reaction products, providing data to greatly improve simulation models.
- Groundbreaking capabilities predict the effects of material aging on explosives' performance and improve assessments of weapon service life.
- Research at DOE user facilities is obtaining never-before-captured high-resolution data in the reaction zone of a detonating HE.
- LLNL HE expertise was applied to the Source Physics Experiment (SPE) to improve physics-based models used to detect foreign nuclear explosions amidst a background of earthquakes and mining events
- New explosive threats have been characterized for homeland security using advanced x-ray, dual-energy, and computed tomography processing.
- Patented E.L.I.T.E.™ (Easy Livermore Inspection Test for Explosives) system for first-responders uses chemical reaction to quickly detect explosives.





Scientific Underpinnings

Ensuring the continued safety, security, and effectiveness of the nation's nuclear deterrent, countering threats from adversaries, and supporting DOD conventional munitions research requires outstanding inquiry performed by exceptional scientists working at world-class facilities. EM scientists explore the energy released during energetic chemical reactions, the mechanical response, and long-term aging characteristics. Taking advantage of Livermore's family of supercomputers and advanced simulation codes, scientists improve EM performance and safety. Projects are enabled by both real-time and post-test analytical diagnostics that were established with the assistance of Forensic Science Center scientists and are found only at LLNL. Science-based object views for the EM Enterprise include:

- Enhanced predictive modeling including detonation performance, chemistry, safety, mechanical properties, computed tomography, simulated radiography, and effects are coupled to LLNL's renowned high-performance computing resources to interpret, extend, and enhance EM formulations and components.
- Novel diagnostics for EM detection, detonation, and abnormal hazard response shed light on fundamental chemical reactions and properties.
- A core LLNL competency is investigating materials under extreme conditions of pressure and temperature. EM experiments are conducted on platforms ranging from OMEGA EP (at the University of Rochester's Laboratory for Laser Energetics) and the Dynamic Compression Sector (at Argonne National Laboratory's Advanced Photon Source), to firing tanks and gas guns located at HEAF.
- Responsive EM manufacturing and materials developments improve the quality of EM components and make possible new formulations with advanced geometries that can be manipulated to govern precise properties.
- Novel applications of EMs (e.g., pulsed power, energy sources, laser-matter interactions, laser initiation) strengthen national security.
- World-class facilities include HEAF for creating and detonating EMs up to 10 kg HE; Site 300 facilities for synthesizing, formulating, manufacturing, and testing HE up to 60 kg; the Contained Firing Facility and Flash X-Ray for stockpile stewardship; and the Forensic Science Center, which supports LLNL's global security counterterrorsm programs and enhances fundamental understanding of EMs.

The Future

LLNL will continue to help provide high confidence in the safety, security, reliability, and effectiveness of EMs used in the nation's nuclear deterrent. Researchers will be particularly focused on ensuring LLNL meets the goals of the W80-4 and W78-1 LEPs and enabling transition to an all-insensitive-high-explosive nuclear stockpile for enhanced safety and surety.

The breadth of EM research will include advanced conventional weapons for DOD, including increased use of insensitive technologies, new gun propellants, warheads to penetrate hard targets, and high-speed explosive projectiles. Research will also continue to include meeting the needs of the Department of Homeland Security and its Transportation Security Administration, and countering the threat of nuclear proliferation.

Principal Sponsorship

- DOE/NNSA, DOD, DHS/TSA

LLNL-MI-760827
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 1, 2018

Advanced Materials and Manufacturing

Meeting national security needs for rapid, cost-effective development of advanced materials and manufacturing processes.

A Manufacturing Revolution

Advanced manufacturing technologies such as additive manufacturing (AM) are transforming manufacturing by producing materials and components with new structural, thermal, electrical, chemical, and photonic properties. Often called 3D printing, AM uses a digital design to build three-dimensional objects by sequentially layering materials. LLNL is a national leader in AM by integrating manufacturing expertise, precision engineering, materials science, chemistry, advanced characterization, and high-performance computing (HPC) to produce innovative materials for national security missions.

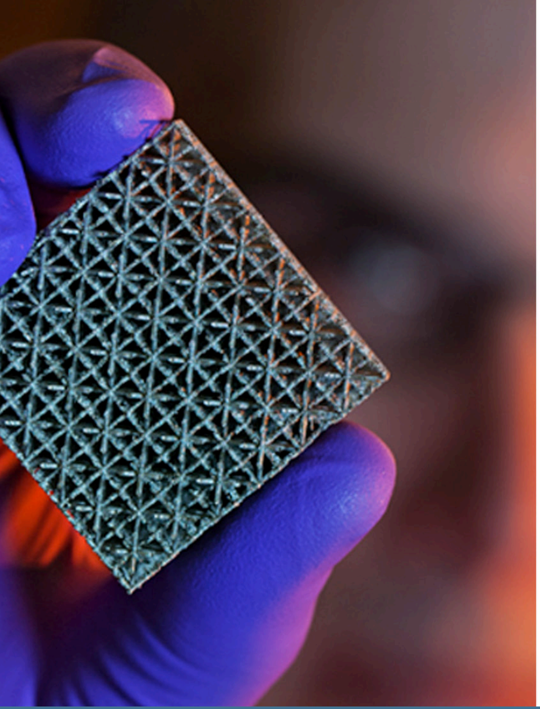
LLNL researchers are showing how AM technologies are revolutionizing the design-build-test cycle. An LLNL designer often can produce a prototype part in a few hours, immediately assess its viability, and if necessary change the design for improved performance. Finished and validated components can be produced in weeks to months instead of years using conventional approaches such as machining. or casting.

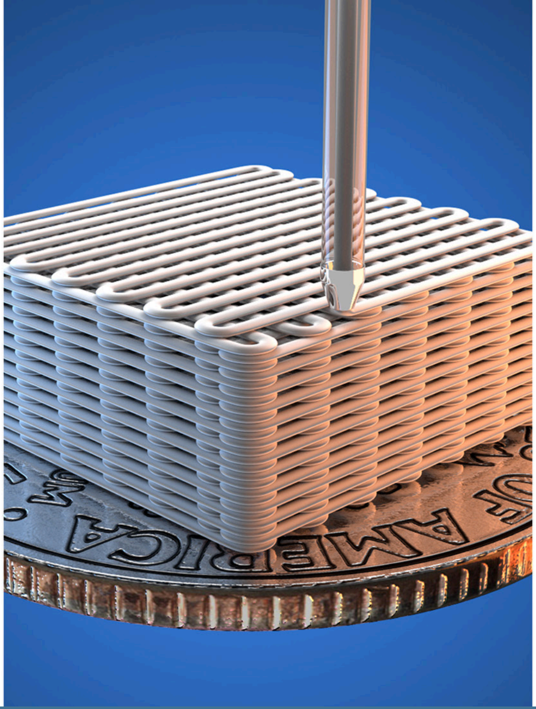
LLNL researchers have demonstrated that materials and components fabricated with AM can exhibit combinations of density, strength, thermal properties, and others that do not exist in nature. In addition, the manufacturing process requires less material than subtractive fabrication methods such as machining. In many cases the process is faster and more cost effective than standard manufacturing processes.

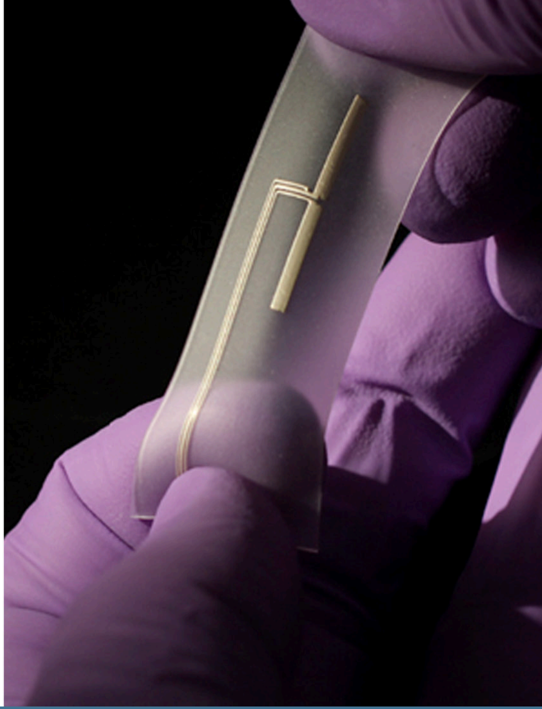
Accomplishments

As a leading materials and manufacturing research laboratory, LLNL has for decades advanced both fundamental and leading-edge materials science and engineering. Livermore materials scientists, physicists, and engineers have earned an international reputation for developing advanced manufacturing processes that produce materials and components on an accelerated schedule, at reduced cost, and often possessing properties impossible to obtain with traditional manufacturing techniques. They have also demonstrated state-of-the-art characterization technologies coupled with modeling and simulation to meet current and future national security needs. Their accomplishments include:

- LLNL's Advanced Manufacturing Laboratory premiered in 2018 to enhance partnerships between LLNL experts and colleagues in American industry to speed the development of new manufacturing technologies and materials and spur widespread interest and adoption.
- New LLNL materials and components have radically enhanced performance. Examples include catalyst-filled microcapsules to capture carbon dioxide, shape-shifting structures that fold or unfold when exposed to heat or electricity, and stainless steel with radically improved strength and ductility.
- LLNL's volumetric lithography process uses light beams to fabricate complex 3D polymer structures in their entirety instead of one layer at a time.
- Powerful design optimization algorithms, methodologies, and software enables the rapid and non-intuitive design of new objects. An example is a software package called LIDO, aimed at fundamentally transforming the design process for engineers using advanced manufacturing processes.
- LLNL experts are lending expertise in metal AM to a collaboration aimed at 3D printing and qualifying critical replacement parts for the U.S. Navy.
- More than 150 peer-reviewed papers and 20 covers have been published along with more than 130 invention disclosures, approximately 86 patents filed and pending, and 17 awarded.







Scientific Underpinnings

LLNL's deep expertise in precision engineering, materials science, and high-performance computing (HPC) continues to revolutionize advanced manufacturing technologies. LLNL researchers take a multidisciplinary approach to developing innovative new materials, manufacturing processes, and characterization methods based on firm scientific underpinnings. LLNL researchers have gained international recognition for their capabilities in developing additive manufacturing (AM) methods that produce materials with never-before-realized properties. Steady progress is being aided by reaching a fundamental understanding of the complex physics underlying AM.

- Livermore researchers are applying AM to the Laboratory's core national security mission. The effort taps modeling and simulation, another core competency, to speed certification. For example, scientists have shown that 3D-printed periodic structures perform better than standard cellular and foam materials in terms of durability and long-term mechanical performance. This attribute was proven by accelerated aging experiments, x-ray computed tomography, and finite-element analyses.
- Metal 3D printing has enormous potential to revolutionize manufacturing, but some industries have been slow to adopt the technology due to concerns over part quality and certification. Building upon research into the physics behind metal 3D printing, LLNL researchers have designed and built a portable diagnostic machine that peers into metal parts as the passing laser meets the metal powder, fusing and producing the layers that eventually become a fully formed part, to ensure the highest quality.
- LLNL researchers have unveiled many of the complex mechanisms that can drive defect formation and limit part quality in metal 3D printing. LLNL researchers teamed up with scientists at the SLAC National Accelerator Laboratory and Ames Laboratory to examine in detail what leads to defects in printed parts and how those flaws might be avoided.
- Leveraging Livermore's HPC expertise, new product designs are being modeled virtually and then optimized without having to leave the digital realm.
- Researchers are applying AM to advance other LLNL programmatic mission areas such as the National Ignition Facility and photon science, as well as global security activities, including energy programs.

The Future

LLNL researchers are working to accelerate the design, fundamental understanding, and deployment of new materials and manufacturing processes for DOE, NNSA, and U.S. industry to deliver materials and components with tailored properties on accelerated schedules and at reduced cost.

The Advanced Manufacturing Laboratory (AML) will help spark a new era of on-demand fabrication of materials and parts that until now have been impossible to make with conventional technology. Researchers will be forging partnerships with industry to spin out and spin in AM technologies.

The AML, situated in the Lab's Livermore Valley Open Campus (LVOC), increases interactions with academic and industry partners on advanced manufacturing and materials technologies.

LLNL-MI-759068
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
October 02, 2018

Civilian Cybersecurity at LLNL

LLNL's Civilian Cyber Program is focused on enhancing the security and resilience of the nation's critical infrastructure systems and networks to cyber hazards.

Countering Cyber Threats

National security depends on safe and reliable operation of information technology (IT) and operational technology (OT) systems and networks. While information theft and financial profit have been the main objectives of cyberattacks, another concerning trend has emerged in the last several years. Cyberattacks on critical infrastructure such as dams, power plants, and power grids with intent to cause physical damage are on the rise. Today, federal networks and agencies are under constant cyberattack.

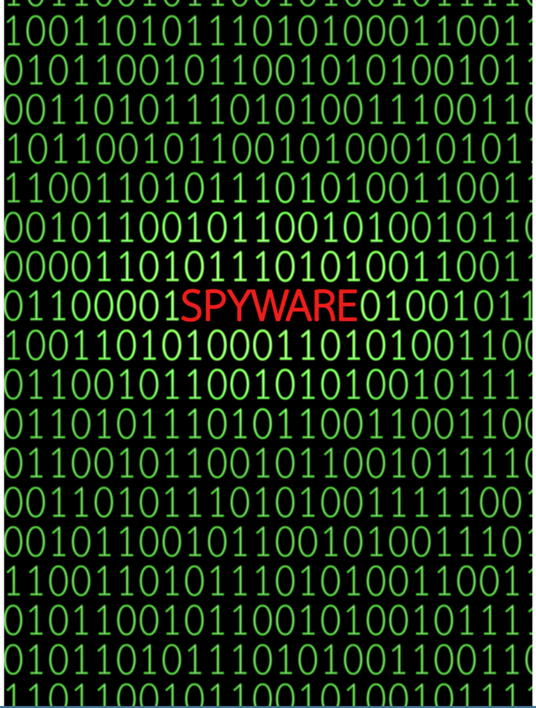
Lawrence Livermore National Laboratory (LLNL) brings its expertise in defending its own systems from cyberattack, and its knowledge and of the nature of cyber threats facing the nation through the work it has performed in a more than 20-year partnership with the intelligence community to civilian cyberdefense.

LLNL's civilian cyber program leverages our core competencies to support cyber security efforts in the Department of Homeland Security, Department of Energy, state and local governments, and industry to enhance the resiliency of government websites and that of critical infrastructure.

Accomplishments

Lawrence Livermore National Laboratory has established a research program to take on cybersecurity threats to the nation's critical infrastructure, including its energy systems and computer networks.

- As part of California Energy Systems for the 21st Century, Livermore explores next-generation cybersecurity of industrial control systems. Program focus is on machine-to-machine automated threat response (MMATR) to protect electricity grid infrastructure from cyberattacks. Livermore has developed a modeling and simulation platform, ParGrid, to evaluate consequences of cyber threats to California's transmission grid and test the performance of MMATR technologies.
- In the Grid Modernization Lab Consortium 1.4.23 project, the Laboratory's expertise in computational science and machine learning is being applied to provide smart meter data for detecting anomalies on the electricity grid. Machine learning has the potential to rapidly detect incursions.
- LLNL investigated the potential impacts of active scanning on energy delivery systems networks (EDS) and developed tools used on testbed equipment in the Safe Active Scanning for Energy Delivery Systems project. These tools allow users to test active scans from common, benign scans to extremely aggressive scans in realistic, production-like environments that impose significant burdens on EDS devices.
- Skyfall is a Livermore-developed EDS testbed representative of a common utility substation to test for vulnerability and grid-level impact analysis, firmware analysis, and malware analysis. Skyfall is connected to ParGrid, LLNL's coupled power transmission and communication model.
- Researchers in the Robust DERMS Control Verification project are working to enable distributed energy resource management systems (DERMS) for verifying that commands sent by a central authority will not damage the distribution system. The verification protects them from adversaries who gain control of the central command system's communications channel.
- QIARA (Quantitative Intelligent Adversary Risk Assessment) develops methods to quantify risk of cyberattack and understand the value of mitigation options.
- The CyTRICS project uses Livermore's automated software assurance tool ROSE to examine the software and firmware of devices on the grid to ensure their integrity against cyberattack.



Scientific Underpinnings

LLNL applies its skills, facilities, and computational tools developed for its national security work to address cyberthreats to the security and resiliency of civilian networks, operational systems, and critical infrastructure. LLNL's Civilian Cyber Program uses core competencies in high-performance computing (HPC), data analytics to handle the output from HPC simulations, and threat awareness (based on the Laboratory's longstanding relationship with the intelligence community). The Laboratory draws on the following key capabilities enabled by our core competencies:

- **Modeling and Simulation of Cyber-Physical Systems:** HPC enables development of high-fidelity, large-scale coupled, physics-based models of cyber and cyber-physical systems to understand effects, vulnerabilities, large-scale impacts, and mitigations.
- **Machine Learning and Data Analytics for Cyber Threat Detection:** The Laboratory uses its capabilities in machine learning and data analytics to develop systems that discern the difference between normal and off-normal behavior in physical systems and network traffic.
- **Collaborative Autonomy for Cyber Systems Resilience:** Collaborative autonomy entails the use of autonomous computing devices with algorithms that can communicate, pool data, operate through compromise, and make decisions collaboratively based on objective criteria about how to respond. Livermore is pioneering this technology, using systems as autonomous agents to search for, detect and counter cyberattacks in such infrastructure as computer network, power grids, transportation systems and industrial facilities.
- **Software Assurance:** Livermore's researchers develop automated tools to deconstruct software and trace execution pathways to identify intentional and unintentional vulnerabilities and inefficiencies in code. Using machine learning and Livermore-developed software, researchers can ensure the validity of software updates, and understand the origin of code, across software libraries.
- **Network Characterization and Security:** LLNL scientists combine active and passive techniques to gather and interpret network information to identify components, enumerate assets, and understand their configuration and network topology.
- **Cyber Risk and Resilience:** The Laboratory's experts provide quantitative estimates of risk from intelligent adversary threats and develop appropriate mitigation options using science-based, threat-informed methods.

The Future

LLNL's Civilian Cyber Program supports a wide range of customers—including the Department of Homeland Security, Department of Energy, state and local governments, and industry—to enhance cyber security and resiliency of .gov domain and critical infrastructure.

The program is expanding to address threats to the nation's network and IT infrastructure from hackers, organized criminal agents, and nation-state actors. The program is pushing toward a layered defense with three significant thrusts:

1) build hardware systems as securely as possible to defend against low-capability actors

2) develop technology to detect and respond to cyberattack in real time

3) develop technologies for resilient systems that can continue to operate while under cyberattack. This three-level defensive strategy is designed to counter a wide spectrum of credible threats from actors with varying levels of capability.

Principal Sponsorship

- DOE/NNSA, DHS, DOD, DOE/IN, and U.S. intelligence agencies

LLNL-MI-768187
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
February 21, 2019

Energy Security

Advancing the security of the nation through science and technology innovation that ensures U.S. energy supplies are abundant and delivery systems are secure and resilient with reduced environmental impacts.

A Need for Secure Energy

Energy security is based on developing secure sources of energy, protecting the reliable flow of energy from natural and human disruption, and understanding the environmental impacts of energy use. Energy is essential to the economic well-being of the United States. Livermore's energy security mission is to deliver innovative energy technologies that utilize national resources and reduce the environmental effects of energy use. The Laboratory delivers solutions that assure abundant, low-cost, reliable, and sustainable energy resources and energy/water systems while protecting energy infrastructure from cyber threats, physical attack, and natural disasters.

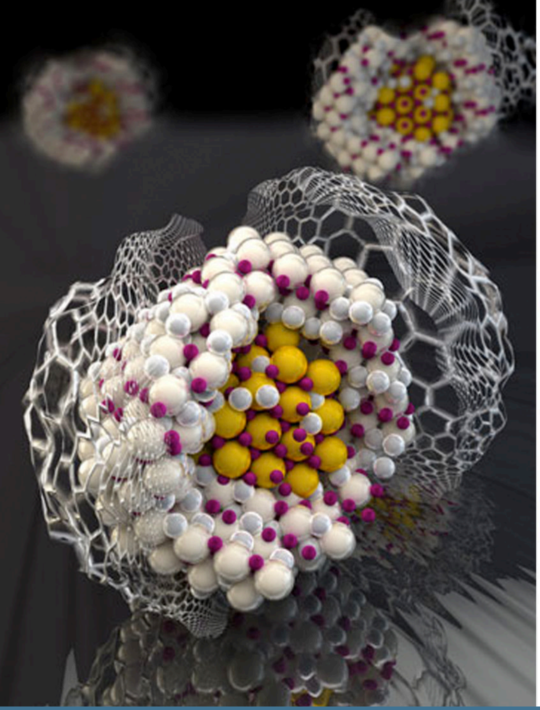
The Laboratory uses high-performance computing to model energy systems, resilience, and cybersecurity; new material discovery for renewable power applications, light-weighting, energy storage, and water purification; and advanced manufacturing and catalysis for carbon capture, and energy- and material-efficient industrial processes.

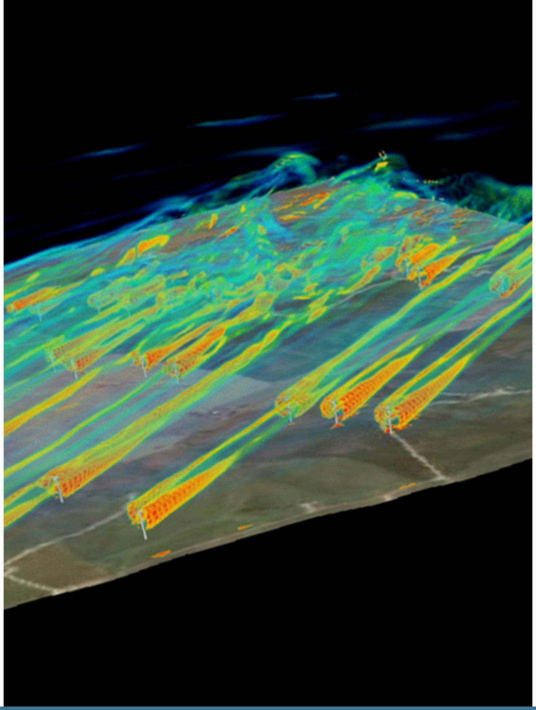
Through core competencies in the biosciences and earth and atmospheric science, the Laboratory studies the biogeochemical cycle, its microbiome, carbon storage in biologic systems, and Earth's changing climate and hydrological cycle to predict changes in resource availability and the environmental impacts of energy use.

Accomplishments

Throughout the Laboratory's history, the development of new energy technologies has been a continuing concern. Early on Livermore researchers studied nuclear energy, including ways of harnessing nuclear fusion as a clean, abundant source of power. Today, energy security has assumed a broader meaning, including not only developing technologies to generate and transform energy, but energy-efficient industrial processes that save energy; processes and technologies to sequester carbon underground; technologies to extract minerals less energy-intensively and to generate and store hydrogen; inexpensive technologies to desalinate and detoxify water; and the means to secure critical energy infrastructure like the electricity grid. Livermore researchers have:

- Developed inexpensive phosphors without rare earth elements for more efficient fluorescent lighting.
- Elucidated basic chemistry of hydrogen absorption and transfer to develop better processes and materials for generating and storing hydrogen.
- Developed computing tools for sequestering carbon and adaptively managing the subsurface.
- Developed microcapsules made of inexpensive materials to capture and remove carbon dioxide emissions from industrial sources.
- Discovered new lightweight aluminum alloys that are structurally stable up to the melting point for improved energy efficiency in cars and trucks.
- Bioengineered a bacteria that has ability to harvest rare earth elements used heavily in energy technology, but are difficult to mine and separate.
- Created powerful magnets that require smaller amounts of rare earth elements and improve renewable power performance and energy-efficient transportation.
- Assisted American companies in improving the energy efficiency and profitability of manufacturing in such areas as steel production, paper manufacturing, semiconductor production, and new clean energy technologies.
- Received an R&D 100 Award for computational methods that model the behavior of chemical systems that will enable next-generation clean engines and fuels.
- Created a high-fidelity model of the electric grid and tested grid control systems in the laboratory to evaluate cyber threats.





Scientific Underpinnings

To advance energy security, Lawrence Livermore applies a broad range of its core competencies to develop new materials for energy applications such as energy storage and alloys for energy production; improve the security and resilience of the electricity grid to natural and human-caused disasters; develop new technologies to desalinate and purify water; improve the efficiency of energy extraction, production, and byproduct disposal; and reduce the energy used in energy-intensive industrial processes.

- Using its high-performance computing capabilities, the Laboratory works with industry through the High Performance Computing for Manufacturing and High Performance Computing for Energy programs to optimize the energy efficiency of their production processes.
- Advanced materials science and additive manufacturing research is demonstrating new ways to produce products with less material and energy waste.
- Earth and atmospheric science expertise is used to improve the detection and extraction of energy resources and the use of renewable power sources.
- Experts in the biosciences, and in nuclear and chemical science are developing biological processes, and catalysts and storage materials for generating biofuels and hydrogen as fuel and materials feedstock.
- High-energy-density science research and laser physics at the National Ignition Facility advance the quest for clean energy through inertial confinement fusion.

The Future

The Laboratory is focusing its future work in energy and climate security on several major thrusts:

- The carbon economy: developing technologies to extract carbon dioxide and convert it into value-added products and feedstocks in manufacturing.
- Producing fuels from carbon dioxide.
- Developing advanced materials for new energy and storage technologies.
- Working toward an intelligent, self-healing, self-protecting electricity grid to withstand terrorist attack, natural or accidental disruptions, and climate-induced stresses.
- Improving water security by developing technologies to desalinate water inexpensively and to selectively remove minerals and toxic chemicals as well as modeling the impacts of climate change on water supplies.
- Revitalizing American manufacturing by reducing the cost of manufacturing through energy and materials efficiency using high-performance computing.

LLNL-MI-761502
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 13, 2018

Space Science and Security

Support of national security and science space missions.

Securing the Heavens

Space science has a rich tradition at Livermore, where scientists study the origin of the solar system, the astrophysical dynamics at play in the Milky Way, and the cosmological evolution of our universe. This research is enabled by combining observational astrophysics, cosmochemistry analyses, novel instrumentation, physics-based modeling and simulation, and multi-disciplinary teams formed from experts in the physical sciences and engineering disciplines. We are applying these capabilities, along with all-source intelligence analysis, to address emerging challenges for the U.S. in the national security space domain.

The urgency of this new mission for LLNL stems from: increasing commercial competition from internal firms; aggressive behavior from countries developing counter-space capabilities; and a more complex global security environment that requires more data to keep decision-makers informed.

LLNL's expertise, infrastructure, and tools created for fundamental space science and core Laboratory missions are delivering new national security space solutions. Innovations include new designs for imaging payloads, optimizing satellite architectures, demonstrating affordable space-based space situational awareness, and developing a government-owned architecture for nanosatellites ("CubeSats").

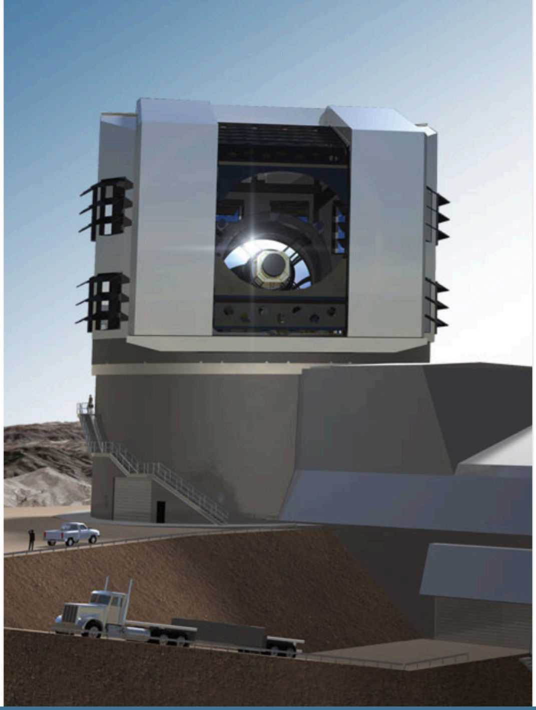
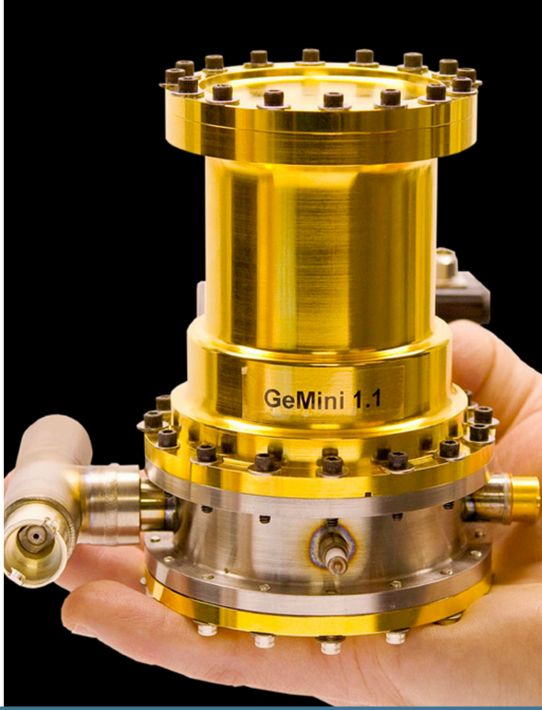
Accomplishments

Livermore has made seminal contributions to space science, including:

- Using the Electron Beam Ion Trap and pioneering laboratory-based astrophysics measurements to support several missions for NASA, the European Space Agency, and the Japanese Space Agency.
- A gamma-ray spectrometer for MESSENGER, a NASA mission launched in 2004, that resulted in the first spacecraft to orbit Mercury.
- Starting in the mid-2000's, providing scientific leadership and enabling technologies for the CERN Axion Solar Telescope, a leading particle astrophysics experiment searching for Dark Matter.
- The first images of an extrasolar planetary system in 2008.
- X-ray optics for NASA missions, including the Solar Dynamics Observatory (SDO, 2010) and the Nuclear Spectroscopic Telescope Array (NuSTAR, 2012).
- The Gemini Planet Imager, a powerful ground-based adaptive optics instrument that enables direct imaging and spectroscopy of planets around nearby stars.
- Developing and refining all known isotopic chronometers that yield ages of planetary materials ranging from the first condensates to form in the solar nebula, to rocks from the Moon, and rocks from Martian meteorites.

Expanded efforts include technology development for potential space security missions, including:

- Nano-engineered foils and diffractive optical elements for large lightweight optics.
- Compact, robust optical imaging systems based on a "monolithic" optics concept that combine multiple mirror surfaces into a single structure.
- The creation of a government-owned architecture for nanosatellites, sometimes referred to as "CubeSats."
- Livermore scientists helped develop optical design, lenses and mirror fabrication, and computational methods to analyze the expected 20-terabyte/night flow of data from the Large Synoptic Survey Telescope (LSST) under construction in Chile, which will perform the most comprehensive astronomical survey ever starting in 2021.

Scientific Underpinnings

The Laboratory's growing national security program relies on three symbiotic elements:

1. All-source intelligence analysis—employed to anticipate and respond to emerging threats. Laboratory analysts work in multidisciplinary teams to assess and evaluate technologies using physics-based modeling and simulation and to understand their impact on the security environment.

2. Advanced modeling and simulation tools—used to quickly study and improve potential mission concepts. The Laboratory's scientists and engineers use commercially available, open-source and custom-written codes to understand and optimize the performance of sensors, satellites, and constellations of satellites.

3. Novel instruments—developed to meet mission requirements tailored to small satellite platforms and distributed space operations. Small satellite platforms have multiple virtues, including resiliency, faster technology refresh, and lower risk. In addition, constellations of small satellites offer a pathway towards high-cadence observations, which represents a potential game-changing capability for both space situational awareness (SSA) and intelligence, surveillance, and reconnaissance (ISR) missions.

Many of Livermore's core competencies are used across the entire portfolio of space science and space security projects.

- High resolution x-ray spectroscopy, atomic and nuclear physics, as well as chemical and isotopic science. These disciplines provide the experimental basis to help scientists better understand astrophysical observations and to analyze sample returns from space missions.
- High-performance computing plays an important role in modeling the performance of instrumentation during the design phase, and the basics physics of astrophysical phenomena. Key to our success in this area is applying methods and techniques from Stockpile Stewardship to the broadest set of challenges.
- Advanced manufacturing helps Livermore researchers develop new ways of making essential parts.
- Laboratory expertise required for the nuclear non-proliferation mission are also used to develop technologies to sense and measure x rays, gamma rays, and other radiation.

The Future

LLNL will demonstrate new data analytics and instruments for improved space situational awareness. Building on the successful operation of monolithic optics from space we will explore new form factors and design principles, as well as how such technologies can deliver affordable, persistent, space-based imagery.

The Laboratory will address fundamental questions in planetary science, astrophysics, and cosmology, delivering gamma-ray spectrometers for two upcoming deep-space planetary missions (Psyche and Mars Moon Exploration). We will characterize non-traditional stable isotopes to determine the nucleosynthetic sources that combine to form planets. We will develop x-ray optics and detectors for future satellite missions and provide scientific leadership for the X-Ray Imaging and Spectroscopy Mission. As we lead LSST scientific investigations to elucidate the nature of Dark Energy, we will also apply LSST technologies to the Wide-Field Infrared Survey Telescope.

Principal Sponsorship

- DOD, the U.S. intelligence community, NASA, DOE/NNSA, and DOE/SC

LLNL-MI-761500
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 13, 2018

Biosciences and Biotechnology

Protecting the nation by countering current and future biological and environmental threats

Security: Health and Energy

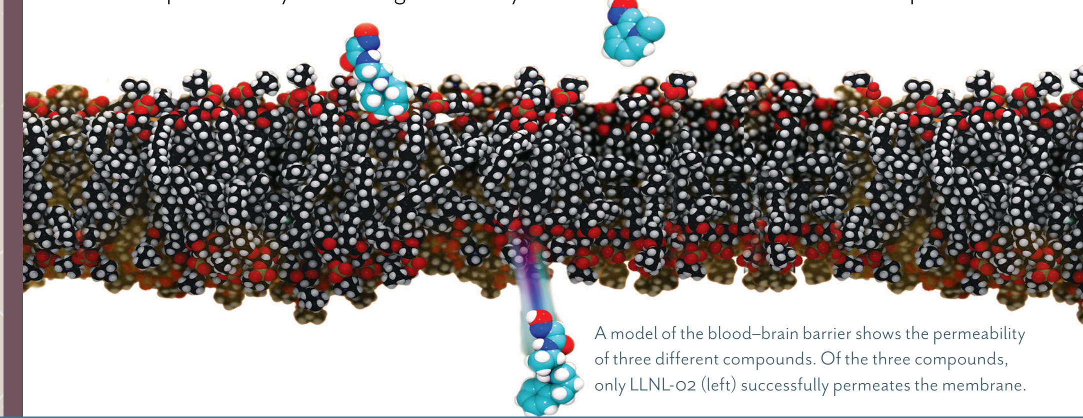
Biosciences and biotechnology research at Lawrence Livermore anticipate the health and environmental security needs of the nation. Working at the intersection of biological, physical, and engineering sciences, the Laboratory uses highly integrated, multidisciplinary biologically focused teams to translate fundamental science to innovative solutions. The explosion of biological advances over the past decades has enabled new biothreats to emerge that range from increasingly resistant strains of disease-causing organisms, and the geographic spread of known pathogens, to new technologies that might be used to weaponize biohazardous organisms.

Using its capabilities in biological science and technology (S&T), the Laboratory develops tools to characterize biology quantitatively, which allows for a deeper understanding of the complexity of biological systems and communities relevant for health and environmental security.

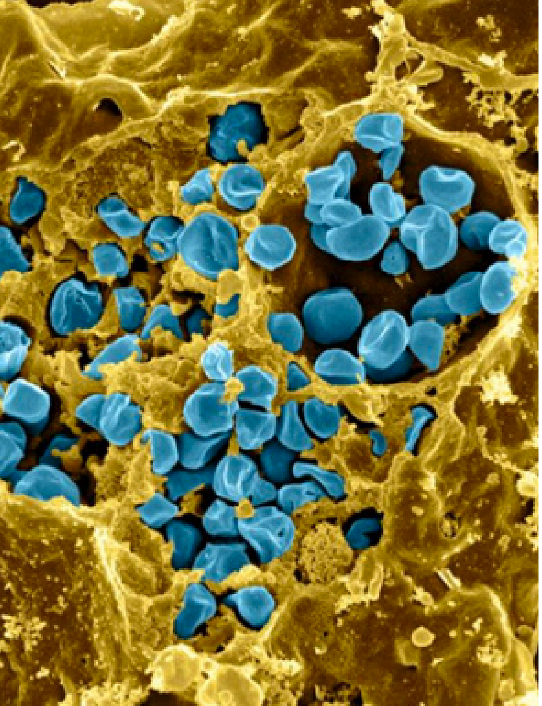
Laboratory staff develop computational tools, create three-dimensional (3D) experimental models, and use them to predict the therapeutic outcomes of various approaches. Through experimentation, Laboratory researchers evaluate the mechanisms of disease, engineer microbial communities for health- and environmental-related objectives, and develop biological production methods for such applications as sustainable energy sources and resource extraction.

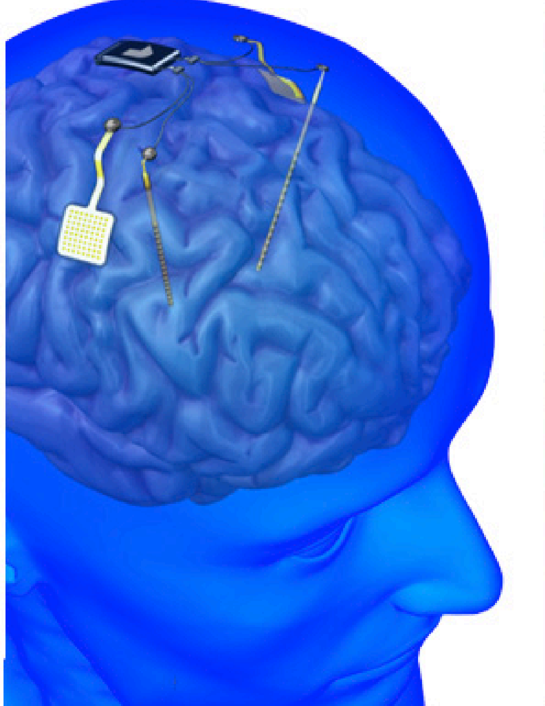
Accomplishments

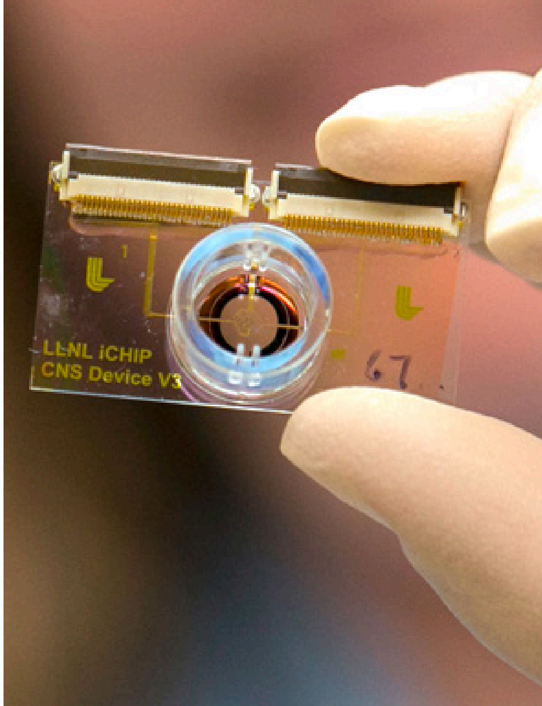
- The Lawrence Livermore Microbial Detection Array (LLMDA) is a pangenomic platform for rapid microorganism detection (within 24 hours). Its 400,000 probes challenge the limits to bioinformatics while continuing to push data analytics to new heights.
- Livermore researchers have developed an in vitro chip-based investigational platform (iCHIP) designed to replicate important aspects of human physiology. The iCHIP combines human cells, tissue engineering, and microfluidics to reproduce the body's physiological response under various conditions. Four iCHIP platforms have been developed, representing the peripheral nervous system, central nervous system, cardiac, and blood–brain barrier.
- A novel nanoparticle-based vaccine delivery platform developed at Livermore offers a potentially transformative approach to preventing infectious diseases. The delivery platform can be modified for targeted delivery of therapeutics for other diseases, including cancer treatment.
- The Laboratory's Forensic Science Center (FSC) has developed a method of using human hair proteins to identify people. It supplements DNA methods, which are not reliable when DNA evidence has degraded over time.
- LLNL researchers study the structure and function of biological agents such as anthrax-causing Bacillus anthracis and Yersinia pestis, which causes plague, to develop field tests and countermeasures.
- Livermore has identified a class of oximes (organic chemicals) that have high blood–brain barrier permeability, enhancing their ability to counter the effects of chemical weapons.



A model of the blood–brain barrier shows the permeability of three different compounds. Of the three compounds, only LLNL-02 (left) successfully permeates the membrane.







Scientific Underpinning

Bioscience researchers at LLNL create interrogable, human-relevant experimental models that can be modified in a systematically controlled manner to observe and measure responses to differing experimental conditions. This approach takes advantage of the fastest supercomputers in the world, enabling faster data processing and the creation of more accurate computational representations of biological systems. These models, both experimental and computational, provide the basis for engineering cells and communities to combat disease and develop bioproduction methods to support a robust bioeconomy.

Bioscience and biotechnology researchers utilize a wide, multidisciplinary set of Laboratory capabilities. These include:

- Fundamental expertise in:
  - Genomics, synthetic biology, biochemistry, biophysics, microbiology, immunology, pharmacology and toxicology, environmental biology, and human health science.
  - Bioengineering, bionanotechnology and biological nanomaterials, and neural technology.
- High-performance computing to simulate biological systems at many scales, including atomistic and coarse-grained molecular dynamics, quantum simulations, constraint-based genome-scale simulations, reaction-transport dynamic simulations, and agent-based, whole-organ, and pharmacokinetics/pharmacodynamics models.
- Advanced materials and additive manufacturing to develop new materials for such applications as (1) bioreactors to produce pharmaceuticals, biofuels, and other products; fabrics for protecting humans against biothreats; (2) detectors capable of analyzing pathogens and other biologics; (3) materials for environmental remediation.
- Accelerator mass spectrometry to detect small quantities of biologically relevant chemicals in living systems.
- Threat analysis and counterproliferation expertise.
- Forensic sciences capabilities at the Laboratory's Forensic Science Center.
- The establishment of the Select Agent Center (SAC), the only Biosafety Level-3 laboratory in the U.S. Department of Energy national laboratory complex.

The Future

The future focus of bioscience and biotechnology research at Livermore targets the following challenges:

- Integrate experimental and computational tools to create human-relevant models usable for large-scale comparative biology.
- Expand our understanding of cellular mechanisms so that we can engineer microbes and microbial communities for health and energy challenges, develop methods for bioproduction, and enhance our knowledge of cellular and molecular pathways of disease.
- Produce solutions to counter emerging challenges, including detector systems, next-generation sensing and protection materials, and novel therapeutics and vaccine development.

Principal Sponsorship

- DOE, DARPA, DHS, DTRA, NIH, and EPA

LLNL-MI-796398
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 7, 2019

Climate Science Research

Providing scientific tools for assessing climate change and quantitatively understanding influences that human activities have on our climate.

An Issue of National Security

Understanding how the Earth system evolves is one of the most difficult of science's many grand challenges. The problem requires billions of data points from the surface, sea, air, and space-based observations. These data points are used to model the system on the most powerful computers through the application of physical sciences and applied mathematics and computational science.

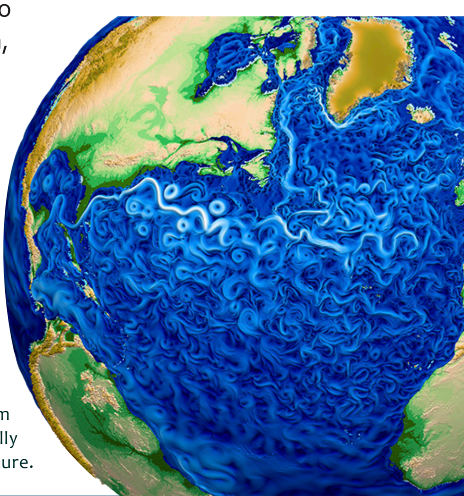
Unexpected rapid environmental change poses risk to national security, the economy, and public health. Livermore has been studying the climate and Earth system since the beginning of computer simulation. Its codes, developed to understand the complex dynamics of nuclear detonations, were adapted to study their impacts on the atmosphere, and eventually, the atmosphere itself.

Today, Livermore contributes to Earth system and climate research on several fronts: modeling the climate to understand the impacts of climate change, adapting models to study regional effects, for example, on the Western U.S. watershed, and testing the many existing climate models to understand how well they perform at predicting the atmosphere's actual behavior.

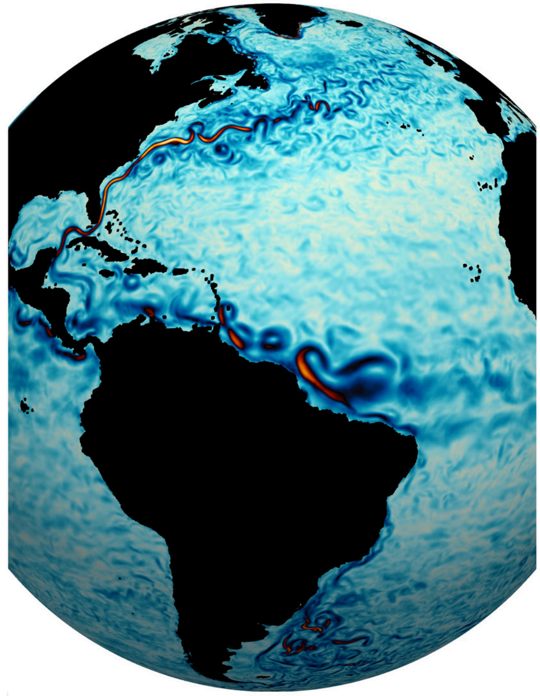
Accomplishments

Lawrence Livermore's climate research began in 1960 with developing the world's first atmospheric general circulation model, and continues through the present day with research areas addressing the performance of climate models, regional climate effects, and their impacts on national security and Earth's living systems. The computational intensity of these models helps drive the development of more and more powerful computers, software, and data management, which in turn benefits Livermore's stockpile stewardship and other security missions.

- In the 1960s, Livermore created the world's first atmospheric general circulation model (the Livermore Atmospheric Model). It calculated temperature, winds, humidity, clouds, precipitation, the day-and-night cycle, and weather systems around the globe.
- In 1989, the Laboratory took the lead in the Program for Climate Model Diagnosis and Intercomparison (PCMDI), an international program designed to evaluate the many climate models developed by leading scientific organizations.
- Livermore scientists participate in the assessments (five to date) of the Nobel-prize-winning Intergovernmental Panel on Climate Change (IPCC), established in 1988 to provide the scientific basis for the understanding of climate change.
- The Laboratory leads the Earth System Grid Federation (ESGF), an R&D 100 award-winning international high-volume data-management system that allows researchers from all over the world to securely store and share observational data, models, analyses, and results.
- Livermore leads the Energy Exascale Earth System Model (E3SM) program. E3SM links Earth system and energy models into a single system that can assess how changes in energy use impact Earth's ecosystems, water availability, snowpack, sea levels, and other factors.



The E3SM project will reliably simulate aspects of Earth system variability and project decadal changes that will critically impact the U.S. energy sector in the near future.



Scientific Underpinnings

Earth system science research at Livermore applies expertise in basic sciences such as meteorology, climatology, applied mathematics and computational science, and high-performance computing to the problem of understanding and predicting how the Earth system evolves on time scales from a few years to several centuries. Scientists compare detailed and rigorous observations from surface, atmosphere, satellite, and oceanographic measurements with outputs from computer models. These results are used to improve the models as well as to search for patterns in climate, and their causes.

Livermore scientists work to understand both the natural variability of the climate, and detect changes that are unlikely to be caused solely by natural variations. Through modeling and research, "detection" demonstrates that an observed change is unlikely to be caused by natural variation, and "attribution" demonstrates that an observed signal is consistent with a given combination of human and natural forcing.

Scientists at the Laboratory also study the regional effects of climate change, those limited to a geographical area rather than to the Earth as a whole. Running models at high spatial resolution produces more realistic models at this scale because they can better represent physical processes. Livermore has contributed substantially to the study of regional effects on water availability, snowpack, and irrigation in the western U.S.

To gain confidence that models are correctly representing climate and atmospheric processes, Livermore practices model assessment through intercomparisons of results from different models with one another and with real data. It uses other techniques as well, such as uncertainty quantification. The Program for Climate Model Diagnosis and Intercomparison has coordinated many projects to compare and evaluate model results.

The Future

The evidence that human influences affect the climate builds steadily from research conducted by the scientific community worldwide. To fulfill its national security mission, Livermore continues to study how Earth system changes might affect and pose security threats to the U.S. and its economy, improving climate models through high-performance computing and model assessment.

Livermore scientists are participating in the next assessment of the IPCC, to provide the scientific research that can inform responses to climate change. Its researchers are also examining the impacts of clouds and aerosols on regional climate changes, such as how climate change may affect the headwaters of rivers that provide irrigation in the western U.S.

Principal Sponsorship

- DOE/SC

LLNL-MI-761497
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 13, 2018

24/7 Emergency Response

Providing around-the-clock expertise and technical capabilities in support of civil emergencies and military and intelligence operations.

Scientific Expertise on Call

LLNL maintains capabilities in areas that are relevant to emergency preparedness and operations. In particular, LLNL is a long-established partner with DOE/NNSA and the interagency nuclear/radiological emergency preparedness and response community. These efforts encompass assessment, planning, exercises, and post-disaster response. Our capabilities include assessment and scenario planning for potential threats against the U.S.; support to governmental emergency response capabilities; and support during and after incidents of national concern.

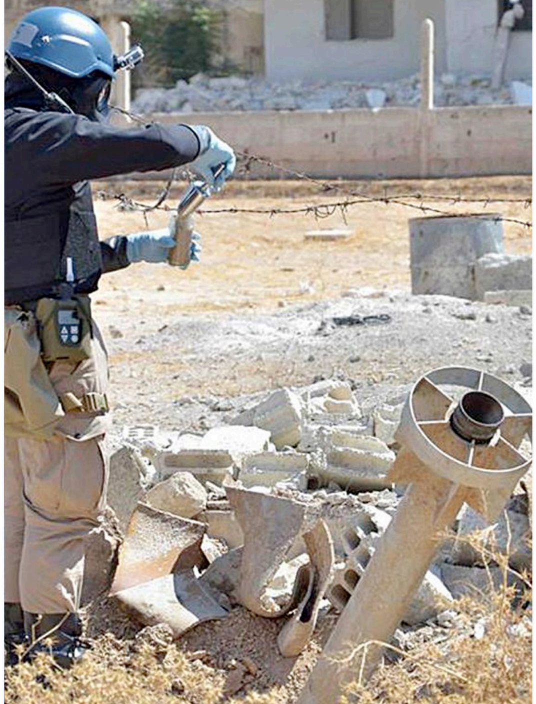
LLNL marshals multidisciplinary science, engineering, and computational resources to help the national response to emergencies that have the potential for massive casualties and damage. LLNL has expertise in chemical, biological, radiological, nuclear, and explosive (CBRNE) threats, as well as sophisticated facilities and laboratory-analysis capabilities.

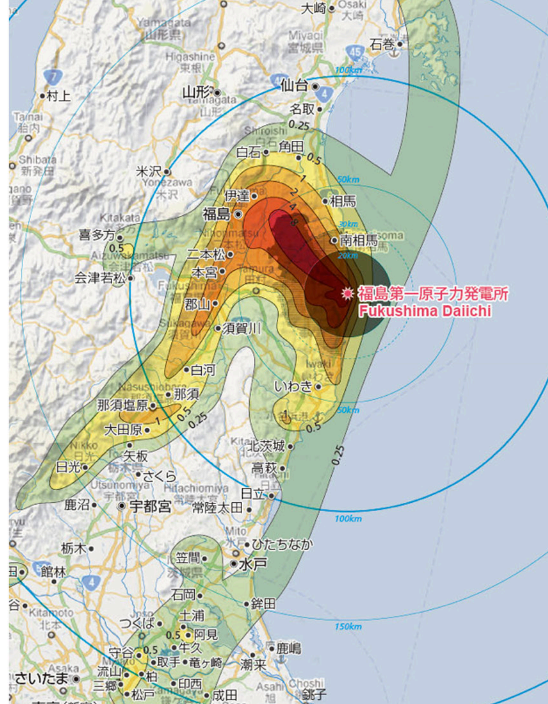
The Laboratory's trained and certified personnel can be deployed 24/7, on- or offsite, and are supported by equipment and logistics that can be deployed within minutes to hours in response to potential and actual incidents.

Accomplishments

LLNL's strong record of emergency response and preparedness relies on a clear understanding of the risks and threats; preparation of policies, plans, and procedures to respond to incidents and emergencies; and development of technologies to enable prevention, mitigation, and response. LLNL supported the U.S. government in major emergencies, providing technical expertise to address the full range of CBRNE threats, including:

- **Hanford (2018):** NARAC provided assessment of contamination during Hanford Plutonium Finish Plant Demolition.
- **Apex Gold (2016):** LLNL hosted the first-ever minister-level gathering to identify national and international actions to address a nuclear crisis and help advise heads of government during a nuclear security crisis or emergency.
- **PG&E Substation Sniping (2013):** Conducted after-action analysis, assessed security vulnerabilities, and recommended security enhancements.
- **Fukushima Daiichi Nuclear Disaster (2011):** Deployed Radiological Assessment Program team, developed plume modeling predictions, analyzed Japanese environmental samples, and analyzed radionuclides.
- **Deepwater Horizon Oil Spill (2010):** Predicted smoke plumes, provided engineering red team support, and estimated the amount of released oil.
- **Cerro Grande Fire (2010):** NARAC developed wind forecasts and estimates of potential radiological hazards when the fire swept through parts of Los Alamos National Laboratory.
- **Libyan WMD (2003):** Assisted in dismantlement, removal, and inspection of the nuclear weapons program in Libya.
- **9/11 Attacks (2001):** Provided hyperspectral data gathering and analysis, microimpulse radar for survivor search and rescue, and continued intelligence reachback through 2012.
- **Anthrax Letters (2001):** Provided sampling equipment, assays to inform the response, and forensic analysis. Helped set engineering parameters to optimize facility decontamination and cleanup.





Scientific Underpinnings

LLNL draws on the following centers and programs, as well as core basic and applied science expertise, to provide timely and critical operations support and response:

- **National Atmospheric Release Advisory Center (NARAC):** NARAC provides plume modeling predictions and analyses for hazardous atmospheric releases. NARAC is the DOE modeling center for nuclear/radiological incidents and provides National Response Plan capabilities for national and international emergencies.
- **Nuclear Incident Response Programs:** This DOE-funded emergency response capability is ready for potential and actual nuclear/radiological incidents. Trained and certified personnel can be accessed 24/7 along with deployable equipment and logistics support that can be rapidly marshaled.
- **Forensic Science Center (FSC):** This all-CBRNE Weapons of Mass Destruction laboratory provides microsampling and analysis capabilities. FSC is also the lead Environmental Protection Agency Environmental Response Laboratory Network Laboratory for chemical and biological weapons and is certified by the Organisation for the Prohibition of Chemical Weapons and ISO.
- **Biodefense Knowledge Center (BKC):** This DHS-funded, 24/7 center provides analysis and recommendations regarding biological emergencies and incidents.
- **Counterproliferation, Analysis, and and Planning System (CAPS):** Provides reachback support to combatant commands/warfighters in CBRNE mission areas.
- **Critical Infrastructure Protection and Security:** LLNL experts evaluate the physical and cyber security of electrical grids, oil refineries, natural gas transmission networks, rails, ports, and waterways.
- **International Nuclear and Radiological Security:** LLNL works worldwide to secure nuclear and rediological material to detect and deter trafficking of this material. Experts advise on how to protect, control, and train security staff to protect against theft, sabotage, and terrorism.
- **Intelligence Analysis (Z Program):** LLNL provides all-source intelligence support with emphasis on WMD and emerging S&T threats, including detailed analytical with rapid reachback, as requested.
- **Nuclear Forensics:** LLNL is an ISO 17025 accredited partner laboratory in DHS's Bulk Special Nuclear Material Analysis Program that provides and maintains laboratory analysis capabilities commensurate with specific interagency requirements.

The Future

LLNL has an ongoing responsibility to provide 24/7 emergency operations and response capabilities. To satisfy this mission, the Laboratory must continue to improve technical capabilities and help shape a credible national response posture.

LLNL is investigating ways to apply advances in high-performance computing to better interpret gathered intelligence and to anticipate and assess which threats are most credible. Whether planning a response to a natural disaster or terrorist event, it is vital that federal decision makers are provided with the best possible science-based and intelligence-informed conclusions, recommendations, supporting rationale, and other relevant observations—which LLNL can provide.

Our researchers seek innovative technology breakthroughs to improve emergency response capabilities, which need to be effective and broadly applicable in many potential CBRNE scenarios. LLNL also closely interacts with the first-responder community.

Principal Sponsorship

- DOE/NNSA, DHS, DOD, DOE/IN, and U.S. intelligence agencies

LLNL-MI-762278
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
November 26, 2018

Fueling California's Economy

Through business and community partnerships, LLNL's science, technology, and engineering strengthens the state's economy by providing jobs and economic opportunities.

LLNL's Economic Impact

Lawrence Livermore National Laboratory (LLNL), located in Livermore, California, is a research and development facility for science and technology solutions to some of our nation's greatest challenges. Managed by Lawrence Livermore National Security, LLC, (LLNS), LLNL has an annual budget of nearly $2.3 billion, and has almost 7,400 LLNS employees. It is largely funded by the Department of Energy's National Nuclear Security Administration.

LLNL's economic impact in California manifests itself directly through its payroll to its employees, and through procurements awarded to companies operating within the state. The Laboratory stimulates commercial activity through the transfer of its technologies to licensees ranging from startups to established companies. LLNL also develops research-based public-private partnerships to improve business access to world-class scientific capabilities to help them improve their technologies.

In Fiscal Year 2019, LLNL awarded more than $753 million in procurements to businesses, both in California and across the nation, for a broad range of products and services that support the Laboratory's overall mission. Over $1.3 billion of products with LLNL technology inside were sold worldwide in the past 5 years. In addition, the Laboratory workforce's more than $947 million payroll base directly contributes to the regional economy.

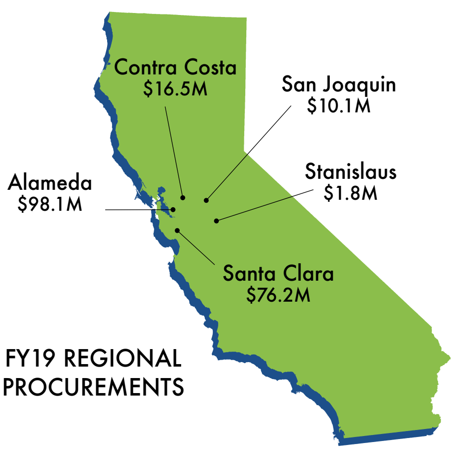
California Success Stories

Dyna-3D: Developed at LLNL by John Hallquist, this software analyzes and visually portrays the effects of stresses on computer-generated 3-dimensional objects. Hallquist launched Livermore Software Technology Corporation (LSTC) in Livermore, CA and matured the original software into LS-DYNA. The automobile industry, among others, uses LS-DYNA to simulate crashes and conduct safety testing. LSTC was sold to ANSYS Inc. in 2019 for $780 million.

Micro Impulse Radar (MIR): Pioneered at LLNL, MIR single-handedly revolutionized radar technology. Its compact form, low power, low cost, short range radar system is used around the world in a wide range of applications. For example, MIR operates automatic doors or gates, motion detectors for alarm systems, and automobile blind-spot detection and anti-crashing systems. MIR can also be used to non-destructively analyze vehicle roadways and bridges. MIR has been LLNL's most successful technology transfer to date.

DNA-TRAX: Foodborne diseases cost the U.S. an estimated $150 billion annually. SafeTraces, Inc. licensed an LLNL-developed spray-on DNA-based barcode technology that can track the source of contaminated food in the supply chain in just minutes rather than days or weeks. SafeTraces aims to reduce food safety concerns such as contaminated and counterfeit food.

LLNL FY19 Fueling California's Economy

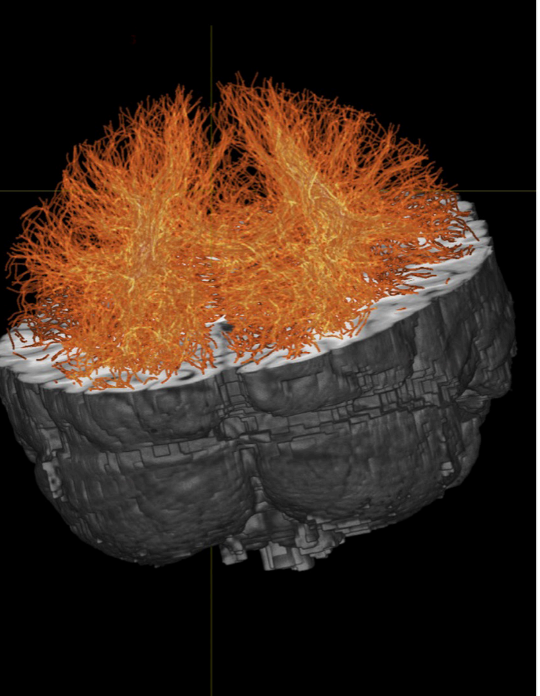


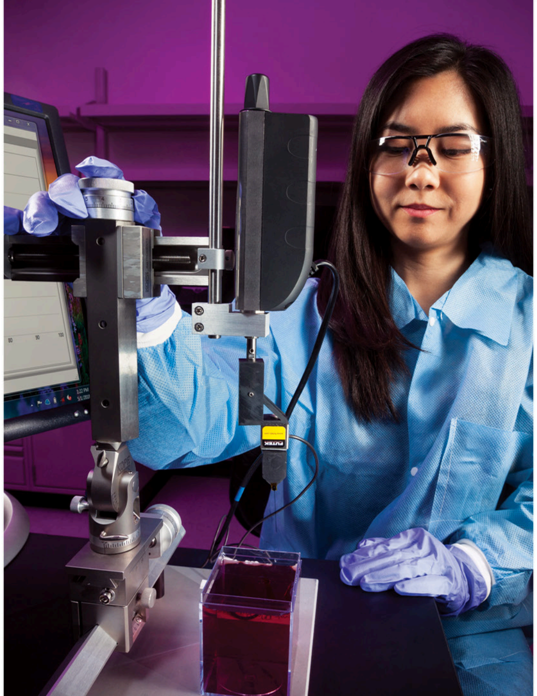
FY19 REGIONAL PROCUREMENTS

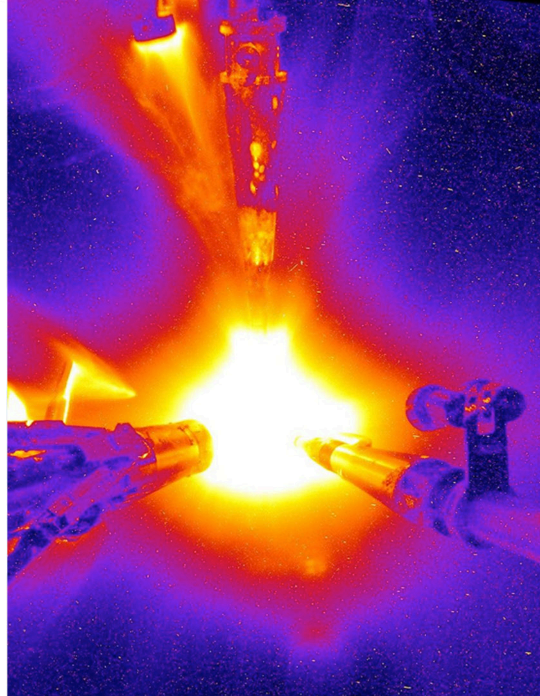
$303 M
CA PROCUREMENTS AWARDS

$753 M
TOTAL PROCUREMENTS AWARDS

- **91** companies with active commercial licenses, **44** based in California
- **$947** million total California payroll







LLNL as a Business Partner

The Laboratory focuses on innovation initiatives that will develop public/private partnerships and grow high-technology business opportunities in the Tri-Valley and greater San Francisco Bay region. Furthering these goals are LLNL's relationships with regional organizations such as the California Clean Energy Fund, the Bay Area Council, East Bay Economic Development Alliance, Silicon Valley Leadership Group, and the Innovation Tri-Valley Leadership Group.

LLNL's Innovation and Partnerships Office (IPO) spearheads the Laboratory's engagement with industry. Whether through technology commercialization, encouraging entrepreneurship, or business development activities, the primary mission is to grow the economy by advancing the development and commercialization of scientific discoveries.

IPO has active commercial licenses with 91 companies as well as dozens of cooperative research and development agreements (CRADAs). Licensing and royalty income in 2019 topped $5.7 million, while over the previous five years there were more than $1.3 billion in sales of products based on LLNL technology. LLNL-licensed technologies have enabled the launch of numerous new businesses that are helping to drive economic growth locally, regionally, and beyond. Additionally, the Laboratory participates in events and organizations that support technology innovation and business development. Here are some examples:

- **University Partnerships:** LLNL and Stanford University collaborate to create multi-scale models and prototype devices for the electromechanical production of chemicals from CO_2. The project aims to improve carbon capture, storage, and utilization technologies, which will reduce CO_2 and reliance on fossil fuels and chemicals.
- **Industry/Non-Governmental Organizations:** The High Performance Computing for Energy Innovation program (HPC4EI) offers U.S. industry access to LLNL's superior computing power to improve their global competitiveness. One example: LLNL works with semiconductor chip manufacturer Applied Materials to improve a process for depositing thin-film materials on wafers used in LED lights.
- **Community Partnerships:** LLNL supports the i-Gate innovation hub, located in the city of Livermore, California, for regional entrepreneurs. Since 2015, the value of mergers, acquisitions and IPOs of Tri Valley companies has totaled $28.5 billion.
- **State Government Partnerships:** The California Energy Commission funded an LLNL effort to reduce the cost of water desalination and increase water reuse to help California through future droughts.

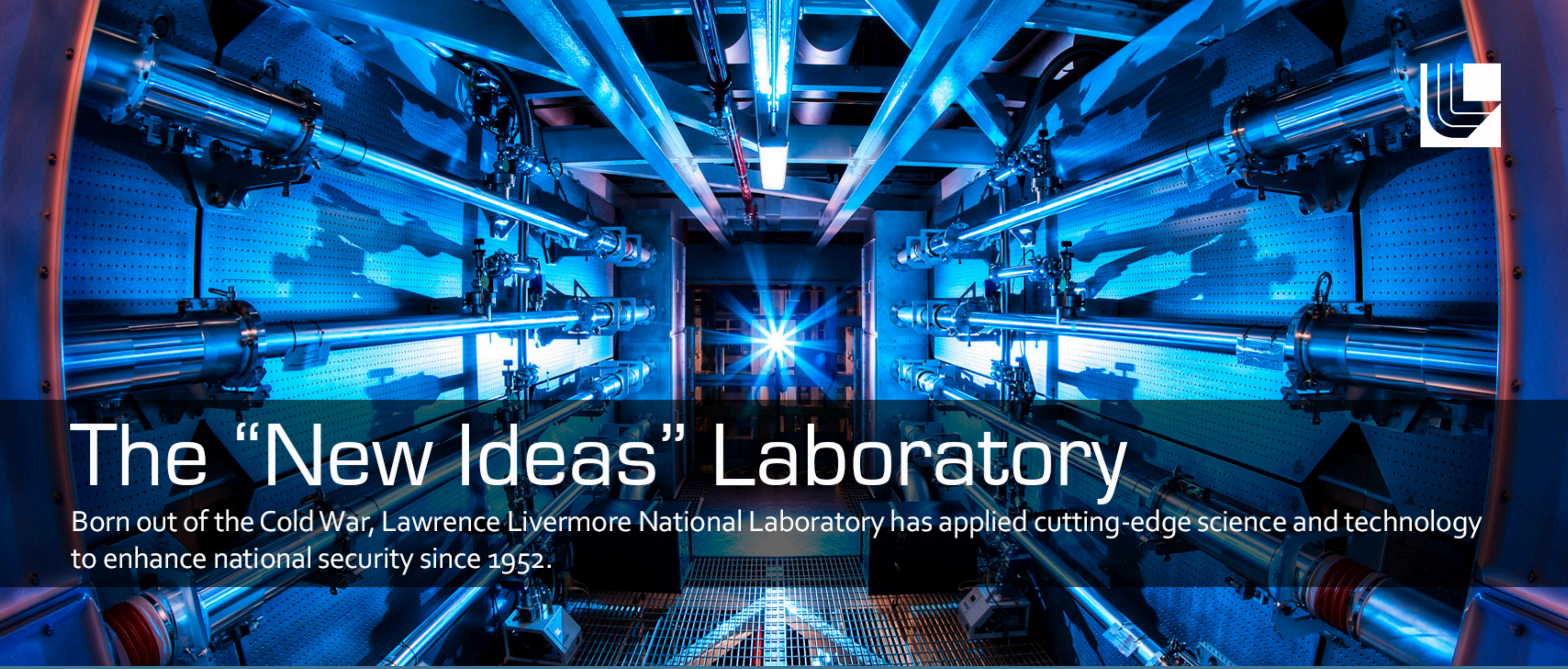
Expanding Partnerships

The Advanced Manufacturing Lab (AML) is a new collaborative hub for developing next-generation materials and manufacturing technologies. The 13,000-square-foot facility is located in LLNL's growing Livermore Valley Open Campus, and features two laboratories (a reconfigurable "wet" chemistry lab and a "dry" instrument lab), a collaboration space, conference area and support rooms with a potential for future expansion.

Expanding on LLNL's existing infrastructure and expertise in materials science, engineering, and additive manufacturing, the AML combines high-performance computing, modeling, and simulation to rapidly advance research into emerging manufacturing technologies.

The AML enables two-way learning and transfer of technology and capabilities between industry and LLNL.

LLNL-MI-768155
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
February 10, 2020



The "New Ideas" Laboratory

Born out of the Cold War, Lawrence Livermore National Laboratory has applied cutting-edge science and technology to enhance national security since 1952.

Seven Decades of Cutting-Edge Science

Lawrence Livermore National Laboratory (LLNL) was established in 1952 at the height of the Cold War to meet urgent national security needs by advancing nuclear weapons science and technology.

Renowned physicists E.O. Lawrence and Edward Teller argued for the creation of a second laboratory to augment the efforts of the laboratory at Los Alamos. Activities began at Livermore under the aegis of the University of California with a commitment by its first director, Herbert York, to be a "new ideas" laboratory and follow a multidisciplinary, team-science approach to research that Lawrence had pioneered on the Berkeley campus of the University of California.

Since then, LLNL researchers have conducted seven decades of cutting-edge science to meet national security needs.

1950s

Livermore made its first major breakthrough with the design of a thermonuclear warhead for missiles that could be launched from highly survivable submarines. For decades, the Laboratory led the development of high-yield warheads compact enough that several could be carried on each ballistic missile.

Livermore aggressively pursued advances in computer simulations to support nuclear weapons and other research activities, including fusion energy. After acquiring one of the first UNIVAC computers, the Laboratory subsequently drove industry's development of and put to use increasingly powerful machines.

1960s

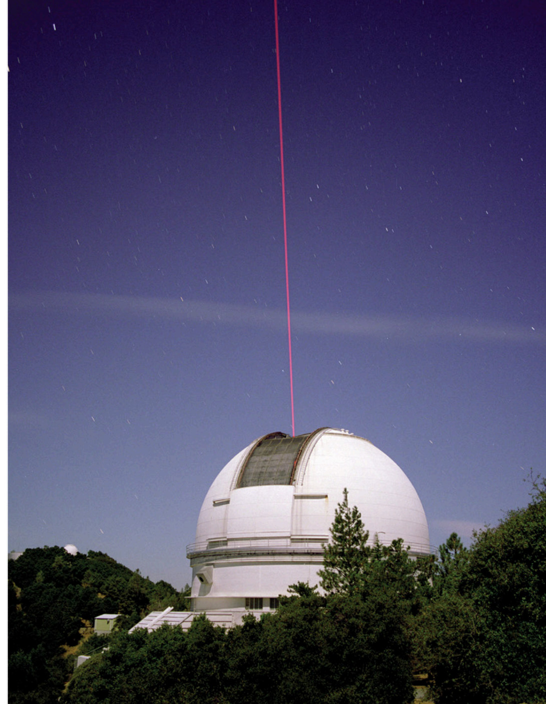
In addition to supporting nuclear deterrence, the Laboratory explored the peaceful use of nuclear explosives and made significant advances in magnetic fusion research. Strong research efforts in atmospheric sciences and a new bioscience program addressed concerns about fallout and the effects of ionizing radiation on human health. They later led to successes in genomic sequencing and sensors for biosecurity as well as capabilities for modeling atmospheric releases and global climate change.

Livermore also established a formal working relationship with the Intelligence Community (IC) to analyze Soviet nuclear test activities and develop technologies for the IC. That effort has continued to grow together with the IC's need for all-source analyses of the nuclear programs in an expanding list of countries of concern.

1970s

The decade began with Livermore's most ambitious nuclear test, the design of a high-yield warhead for ballistic missile defense. Keen interest arose in a new technology, lasers, as means for achieving fusion in a laboratory setting. LLNL's Laser program has flourished and interest has remained high in ballistic missile defense. Scientists designed new weapons to enhance deterrence of aggression in Europe and they developed new explosives to improve the safety of nuclear weapons.

The energy crisis in the 1970s invigorated energy research programs, which continue to seek long-term reliable, affordable, clean sources of energy. Notably, Livermore scientists conducted important studies on the effects of human activities on Earth's ozone layer and the newly developed Atmospheric Release Advisory Capability helped manage crisis response to the Three Mile Island reactor accident in 1979.



1980s

To help win the Cold War, Livermore developed a new strategic bomb and a new ballistic missile warhead for the U.S. Air Force. One of the needed computer simulation tools, DYNA3D, was transferred to industry and has been widely used to crash test vehicles. In support of the Strategic Defense Initiative, LLNL created the first x-ray lasers and developed small-satellite technologies that were deployed on the Clementine mission in 1994 to map the Moon. Laser science and engineering in support of national security and fusion energy applications advanced with the development and use of the 10-beam Nova laser system.

In 1987, Livermore bioscience researchers spearheaded DOE's launch of an initiative that would determine the entire sequence of DNA that makes up the human genome. LLNL had developed key chromosome-sorting capabilities to make genome sequencing possible, and DOE's effort evolved into the world-wide Human Genome Initiative.

1990s

The Berlin Wall fell in 1989, and LLNL helped DOE define the Stockpile Stewardship Program, which is ensuring the safety, security, and performance of the nation's nuclear deterrent in the absence of nuclear testing. Livermore provided leadership in achieving a million-fold improvement computing capability over a decade and began construction of the National Ignition Facility (NIF) to perform physics experiments at weapon-like temperatures and pressures. LLNL also pursued the development of analytical and detection capabilities to address the threat posed by weapons of mass destruction.

New world-class capabilities established at Livermore included the High Explosives Applications Facility, the Forensics Science Center, the Center for Accelerator Mass Spectrometry, and the Program for Climate Model Diagnosis and Intercomparison.

2000s

LLNL successfully completed a life-extension program for the nation's most modern ICBM warhead that will enable it to remain in the U.S. strategic arsenal well into the 21st century. Studies conducted at Livermore and Los Alamos concluded that the plutonium in weapons is aging gracefully. In addition, a new facility was constructed to house successive generations of powerful supercomputers, and NIF was dedicated in 2009.

LLNL programs in counterterrorism and counterproliferation gained impetus after the 9/11 attacks. Innovative technologies were developed to detect biological and chemical threats, explosives, and nuclear materials. Livermore researchers also contributed to the discovery of the first extrasolar planet and began work on the Gemini Planet Imager.

2010s and into the Future

Precision experiments and advances toward exaflop-scale computing are enabling the development of more predictive simulation models for stockpile stewardship. NIF is proving to be a remarkably flexible and valuable tool for creating conditions that exist in giant planets, providing data needed for stockpile stewardship, and progressing toward fusion ignition.

Innovations, based on advances in material science, range from plastic scintillators for radiation detection to biocompatible microelectronics and sensors for myriad healthcare applications. Livermore researchers' advances in additive manufacturing are creating materials with previously unimaginable properties and are providing a path toward more cost-effective production processes within the nuclear weapons complex, and more broadly, U.S. industry.

Images (left to right): delivery of Livermore's first supercomputer; development test of the Polaris missile; and laser guide star and adaptive optics to view exoplanets.

LLNL-MI-769586
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
March 13, 2019

Veteran and Military Education Outreach at LLNL

LLNL is committed to helping veterans, active duty members, and future officers acquire critical job-related skills needed for today's workforce and to fulfill the Laboratory's mission.

Vets Make a Difference

Since its founding in 1952 at the site of an old U.S. Navy air station, Lawrence Livermore National Laboratory has enjoyed strong ties to the nation's armed forces. Through the decades, LLNL scientists, engineers, and technicians have worked closely with all four military branches. LLNL researchers (many of them veterans) have developed innovative, advanced technologies to identify and address threats to national security and enhance the capabilities of today's warfighters.

The Laboratory is helping returning veterans as well as student military program participants acquire the science, engineering, technology, and math (STEM) skills required by LLNL and other Bay Area high-tech employers. At the same time, LLNL is actively recruiting veterans to fill critical workforce needs. Nearly 500 veterans currently work at LLNL in virtually every discipline, and more are being recruited every day. LLNL veterans have established a strong reputation for technical excellence as well as intangible skills like leadership, problem solving, and a solid work ethic.

LLNL, as well as other high-tech Bay Area employers, has a need for talented people in numerous technical fields. In particular, LLNL managers estimate they will need to hire 300 technicians over the next few years for assignments ranging from operating the world's largest laser to developing advanced new materials.

Veteran and Military Education Programs at LLNL

- **Veteran Internship Program (VIP)**
  In partnership with California community colleges and the Alameda County Workforce Investment Board, LLNL annually hosts 10 to 15 vets for 10 weeks of hands-on training in information technology, computer science, engineering, and other fields.

- **Engineering Technology Program (Vets2Tech)**
  Provides veterans with education and hands-on training. (See more on reverse.)

- **Military Academic Research Associates Program**
  An average of 25 to 30 cadets, midshipmen, and faculty from the military academies complete a four- to six-week summer assignment at LLNL every year.

- **ROTC Internship Program**
  LLNL hosts 20 to 25 cadets and midshipmen from universities across the country for 12 weeks during the summer to support Laboratory research efforts, and an annual ROTC Day for regional students and faculty to learn more about LLNL.

- **Air Force Fellows Program**
  Assigns two to four active duty majors and civilians to LLNL for a one-year period to become familiar with Stockpile Stewardship and defense-related activities.

- **Army Training with Industry Program**
  Assigns one Army Environmental Science and Engineering Officer to the Laboratory's Environmental, Science, and Health office for best business practices and R&D efforts.

- **Air Force Academy Outreach Program**
  Provides lectures to cadets on nuclear deterrence and associated weapons, technical, and policy issues.

- **Newly Commissioned Officer Program**
  Newly Commissioned Officers participate in Livermore research programs prior to their service appointment. Fourteen have participated to date.

- **Career Skills Program**
  Military service members can intern at LLNL in their last four to six months of service

Engineering Technology Program (Vets2Tech)

Established by LLNL in 2014, the Engineering Technology Program (Vets2Tech) at Las Positas College helps veterans and minority students acquire industry-standard skills needed to enter the fast-growing field of mechanical engineering technology. The program recognizes that many veterans, despite strong leadership and problem-solving skills, lack the required math skills to enter high-paying tech jobs. Participating community colleges provide accelerated math curicula, priority registration for veterans, a tight-knit student community, and a student support specialist that provides tutoring, soft skill development, and employer engagement.

> "The program has allowed me to acquire a new set of skills and see a career path I would have never considered before."
>
> – Jeremy Taylor, former Army staff sergeant working at NIF

Upon completing the first-year, students are provided an opportunity to work in paid internships at local employers. During their 10-week summer internship, ETP participants have hands-on opportunities to apply their knowledge and connect with traditional students. The internship covers a variety of manufacturing and research positions including semiconductors, industrial instrumentation, bioengineering, additive manufacturing, and lasers and optics. In addition, the students receive personal coaching during their internship to ensure their successful transition into the civilian world of work. Students completing the curriculum are well positioned to work toward their Associate of Science (A.S.) degree and employment as STEM technologists. On average, 20% of graduating students go on to Bachelor of Science (B.S.) degree.

Curently, about 60% of ETP participants are veterans, and the program maintains a more than 80% retention rate. Since the first graduating class in 2016, LLNL has hired more than 23 veterans and retains an average of 6 students throughout the year. To ensure that all students are placed, LLNL leads a local employer group known as Vets2Tech that hires students and graduates. The program is currently expanding to two additional community colleges in Northern California.

The Engineering Technology Program won an Award for Innovation in 2017 from the East Bay Economic Development Alliance.

Veteran and Military Outreach Contacts

Beth McCormick
Engineering Recruitment and Diversity
mccormick11@llnl.gov

George Sakaldasis
Deputy Director for Military and Nuclear Affairs, National Security Office
sakaldasis1@llnl.gov

Barry Goldman
Student Military Programs
goldman1@llnl.gov

LLNL-MI-704760
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
July 19, 2018

STEM Day at the Lab

Description

STEM Day at the Lab was established to emphasize the importance of expanding access to high-quality science, technology, engineering, and mathematics (STEM) and computer science education, particularly among historically underserved youth.

The event's goal is to instill an awareness and passion for STEM by exposing students (grades 5–8) to science and technology in an organizational setting, and to provide them with access to seeing and experiencing STEM-related careers.

Lawrence Livermore National Laboratory (LLNL) views this event as a supportive contribution to our education system, community, government, and industry. It is a strategic investment in building the future STEM workforce for the Laboratory and the nation.

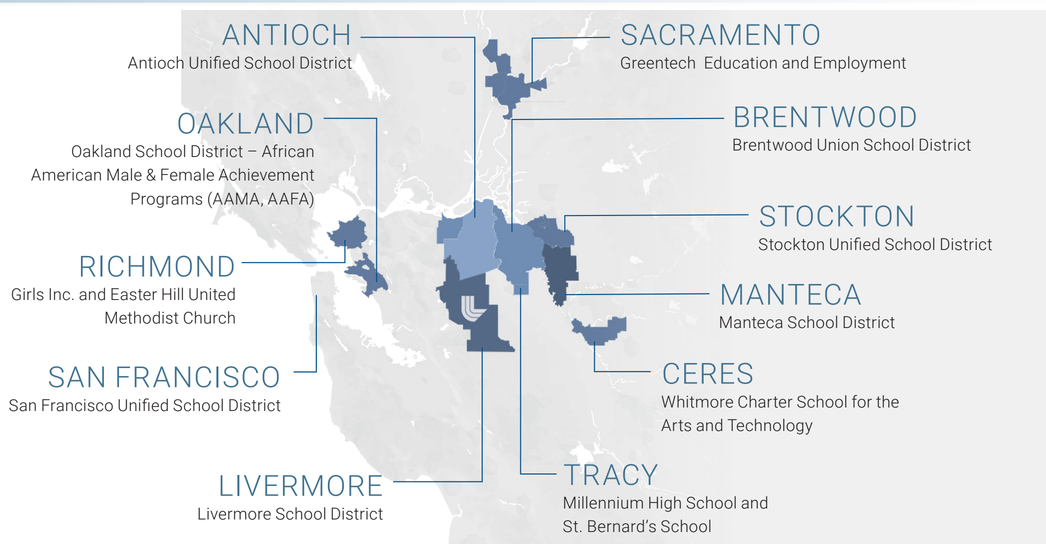
Events to Date

- 2015 – 2019 – 7 events
- Overall Attendance ~ 1155 students
- 2015 – Over 60 students (1 event)
- 2016 – Over 180 students (1 event)
- 2017 – Over 250 students (1 event)
- 2018 – Over 340 students (2 events)
- 2019 – Over 325 students (2 events)

Significance

- The Department of Energy (DOE) chose LLNL as the first government entity to pilot the program. DOE values the importance of teaching science and demonstrating how it can improve educational outcomes for children from economically challenged backgrounds and communities who are underrepresented in scientific and technical professions.
- Nine of DOE's national science laboratories, along with eight federal agencies (including NASA, the Department of Defense, and the National Institutes of Health) participated in expanding the program across government contractors and agencies.
- The event continues to inspire and motivate youth by building awareness of STEM and showcasing career opportunities within science and technology.
- The event has helped build strong relationships with key school districts and organizations in Central and Northern California.
- The event is now a part of LLNL's diversity and inclusion outreach initiatives.

Northern California school districts participating in STEM Day at the Lab



Accomplishments

- The event has grown each year, and multiple organizations and schools have partnered with LLNL to bring students to the Laboratory.
- From 2015 to 2019, over 1155 students participated in the program.
- The number of schools and organizations that participated increased significantly in 2017.
- Scientific activities and demonstrations have doubled in the past four years.
- Employee engagement has increased to over 100 volunteers participating in the event.

Activities and Demonstrations

- Several activities and demonstrations featured during STEM Day at the Lab provide students access to and participation in a variety of scientific and other career fields.
- LLNL science disciplines and operational areas such as computation; engineering; technical information; physical and life sciences; environment, safety, and health; and security create interactive learning activities for all students to enjoy and learn.
- In 2019, more than 21 activities and demonstrations were on display. These included 3D manufacturing, animation techniques, computer coding, groundwater demonstrations, laser-light concepts and properties, on-campus tours (e.g., National Ignition Facility – NIF), security demos, videos, wildlife at the Lab, and several other important STEM-learning experiences.

The Future

The Office of Strategic Diversity and Inclusion Programs (OSDIP) plans to enhance the event by:

- Strengthening the relationships with current STEM Day at the Lab schools and organizations to ensure ongoing participation beyond a yearly one-time event.
- Reaching out to more communities and organizations in multiple regions of Northern California.
- Creating additional STEM-related activities and demonstrations to further inspire students.
- Recruiting more staff volunteers to support year-round communication and activities with schools and organizations.

Contact Information

Tony Baylis
Director, Office of Strategic Diversity and Inclusion Programs
Tel: 925-424-4954
Email: baylis3@llnl.gov
Website: diversity.llnl.gov

LLNL-POST-749039
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.
October 30, 2019