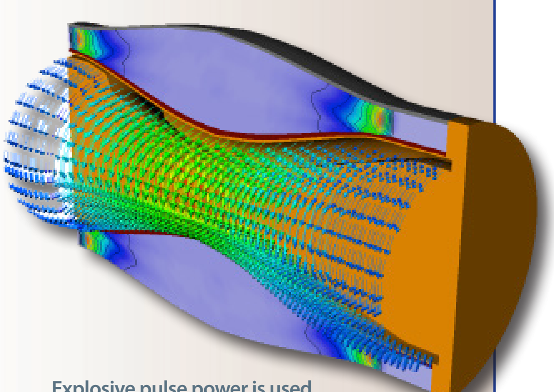
ENGINEERING

Lawrence Livermore National Laboratory

“We want to push the envelope on science and technology…offering up solutions for the future that nobody else can.”

— *Anantha Krishnan, Associate Director for Engineering at LLNL*

A rocket motor 3D printed in a single piece, complete with internal cooling passages. This stainless steel component was fabricated using a laser powder melting additive manufacturing machine.



Explosive pulse power is used to generate million-amp current pulses.

Who We Are

The Engineering Directorate has been developing, building, and applying cutting-edge technology innovations for national security missions for over 60 years. Our staff of nearly 1600 world-class engineers, scientists, and technicians, organized into five divisions, is the foundation for most of our core programs in stockpile stewardship, advanced laser systems, global security, and science and technology. We are meeting our nation’s needs to enhance national security, reduce global threats, and tackle scientific and engineering challenges of national importance.

Core Competencies

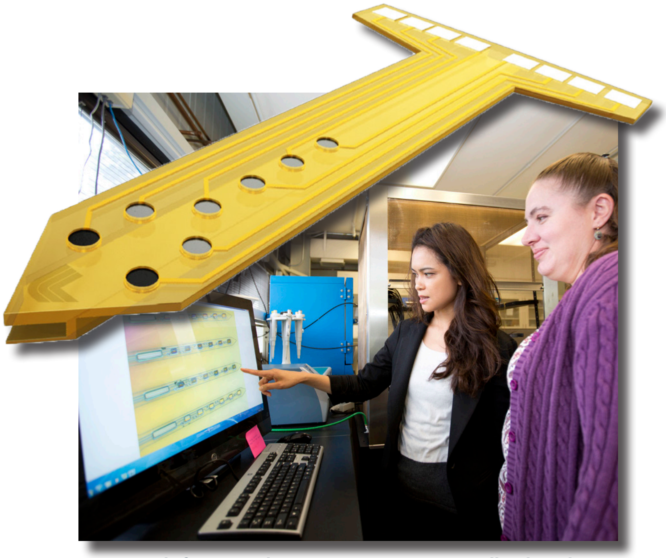
The key to our success is our people. Our staff includes both recognized experts and top-of-their-class, early career researchers in our core competency areas of advanced manufacturing, applied electromagnetics, bioengineering, computational engineering, data sciences, nondestructive characterization, precision engineering, signal and image sciences, structural materials, and systems engineering and analysis.

Advanced Manufacturing

We are developing first-run solutions to manufacturing challenges at extreme scales with unprecedented properties and precision effects. Our efforts in manufacturing science range from developing new additive manufacturing processes to carbon fiber composites. We span size scales from micrometer and nanometer-sized structures to meter-sized components, and our materials sets range from polymers to metals and ceramics. Specific expertise includes multiscale, multiphysics modeling; tailored synthesis of nanomaterials; material characterization; microfabrication; and custom additive manufacturing techniques.

Applied Electromagnetics

LLNL has demonstrated world-class R&D using its electromagnetic infrastructure and computational electromagnetic codes. These have been adapted to solve complex problems in areas from optical regimes to classic microwave and radio frequency research to the static fields associated with fixed magnets. We pioneered the use of time-domain finite difference, finite element, and boundary element methods for analysis of fast transient electromagnetics. Our researchers have developed mobile bistatic ultrawideband radar for detecting and classifying buried metallic objects such as improvised explosive devices (IEDs), and they are refining explosive pulse-power techniques capable of generating million-amp current pulses.



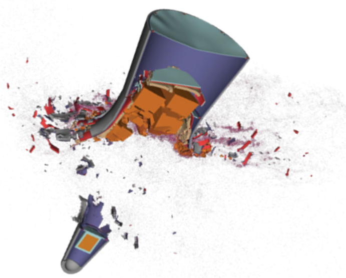
LLNL's multifunctional array contains strategically placed electrodes, chemical sensors, and a microfluidic channel for sustaining and testing live tissue.

Bioengineering

Our Center for Bioengineering is developing leading-edge technologies that support the Laboratory's Biosecurity and Biotechnology programs. These technologies include emerging areas such as neural devices, implants and prosthetics, and engineered (human) tissue platforms, in addition to the traditional areas of microfluidics and biological instrumentation. Our neural prosthetics and implant technologies will be key capabilities for researchers trying to unravel complex signaling processes in the brain and the neural system.

Computational Engineering

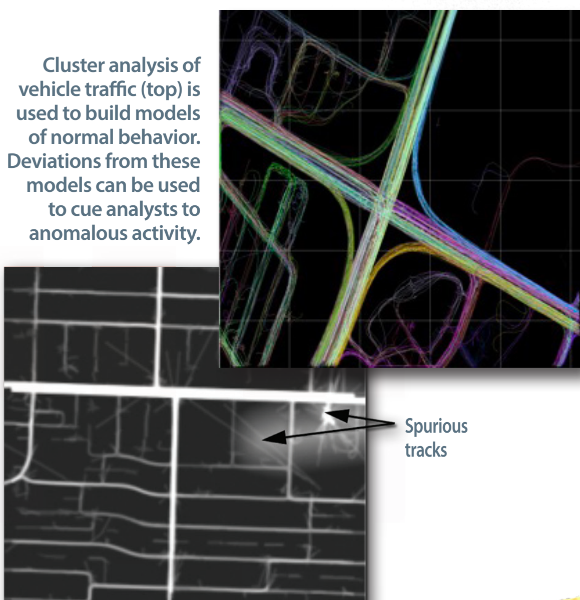
With some of the fastest high-performance computing resources on the planet located here on site, our computation engineers solve practical engineering analysis and design problems using physics-based computational models and supercomputer simulations. Such efforts play a significant role in our weapons, lasers, energy, and security programs. Numerous personnel are also engaged in smaller scale, entrepreneurial R&D projects in collaboration with universities and industry. Areas of expertise include computational electromagnetics, computational mechanics, defense systems analysis, energy conversion and storage, materials modeling and simulation, structural and applied mechanics, and thermal fluids.



Advanced simulations provide insight when assessing the effects of kinetic impactors.

Data Sciences

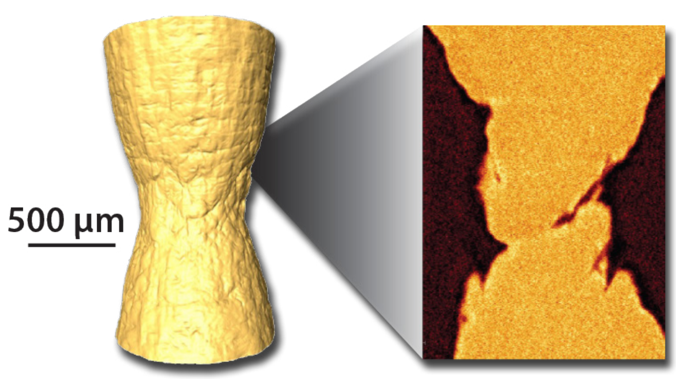
LLNL data science experts specialize in decision sciences, statistics, and machine learning. With our state-of-the-art data analysis techniques and deep experience, Lawrence Livermore can turn highly complex, multi-modal data sets into information that can be applied to actionable decisions, optimally deployed resources, and informed tradeoffs. Example applications include real-time data processing and content inference of large-scale video surveillance, optimization modeling to inform enterprise decisions, uncertainty quantification for renewable energy forecasting and climate modeling, and disease models and simulations for evaluating epidemic countermeasures.



Cluster analysis of vehicle traffic (top) is used to build models of normal behavior. Deviations from these models can be used to cue analysts to anomalous activity.

Nondestructive Characterization

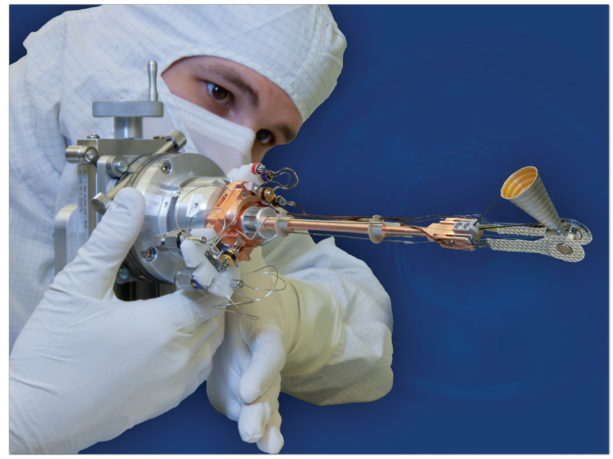
In LLNL's Nondestructive Characterization Institute (NCI), our facilities, technologies, and top research staff combine to provide unequaled capabilities in the nondestructive evaluation (NDE) of materials and systems across all length scales, from macro to nano. We are the recognized leader in x-ray nondestructive characterization within the Department of Energy complex of national laboratories, and we maintain several dedicated NDE facilities on site, housing x-ray, ultrasonic, computed tomography (CT), particle, and other systems.



CT systems produce 2D and 3D digital images showing a tensile specimen under loading. Failure mechanism is imaged in real time.

Precision Engineering

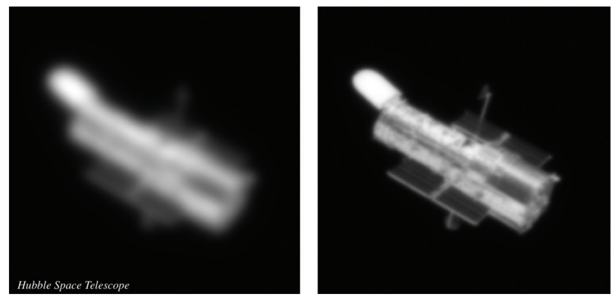
Since the Laboratory's early days, Livermore engineers have been working to make manufacturing processes more precise. They have developed instruments that brought greater accuracy to measurements of dimensions, shapes, densities, and surface finishes than was possible with existing instrumentation. A commitment to determinism underlies our rigorous design, construction, and metrology of mechatronic systems, instruments, and manufactured components, yielding solutions that are quantifiable, measureable, predictable, and repeatable. Our precision engineering expertise has been applied to the fabrication of targets for high-energy lasers, optics manufacturing, extreme ultraviolet lithography, assembly robots, surveillance systems, orbital telescopes, diamond turning, and measurement systems.



A NIF technician holds a keyhole target attached to equipment that is part of the cryogenic cooling system.

Signal and Image Sciences

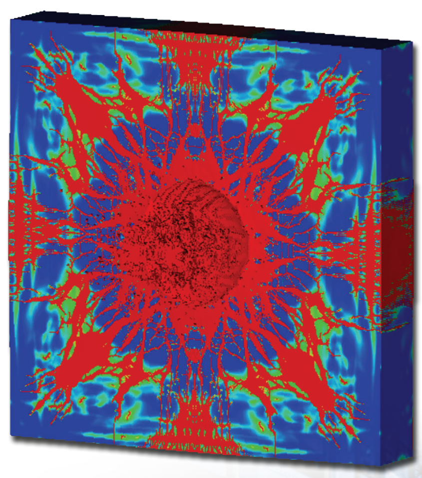
Engineers in this competency create and implement technologies to extract information from signals and imagery, and use the extracted information to inform decisions and control systems. This broad competency combines understanding of the underlying physical processes, statistical analysis, and sophisticated mathematical techniques that can extract quantitative information and derive uncertainty estimates from corrupted observations and models. The associated Center for Advanced Signal and Image Sciences (CASIS) hosts an annual forum that frequently features luminaries in the field. Technical strength areas include adaptive optics, optical engineering and systems, acoustical signal processing, hyperspectral image processing, and computer vision and pattern recognition.



Removal of temporal wavefront errors in fast-slewing telescopes using predictive adaptive optics.

Structural Materials

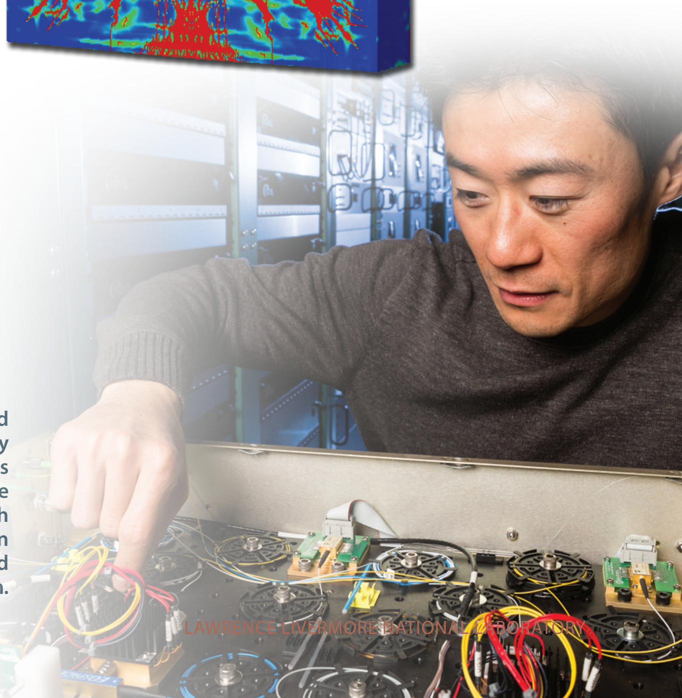
Researchers in the Center for Engineered Materials, Manufacturing and Optimization are driving toward dramatically impacting manufacturing processes and developing new materials with customizable properties that reduce costs and increase sustainability for our key mission sponsors. Our state-of-the-art techniques integrate simulation, synthesis, characterization, and fabrication to meet manufacturing challenges at extreme scales with unprecedented properties and precision effects. Early work has suggested fundamentally new approaches to some of our nation's manufacturing challenges of the future.



Advanced models enable the simulation of response, damage, and failure of a structural part.

Ultrafast Optics and Photonics

LLNL is a world leader in developing temporal imaging, ultrafast chipscale photonics, radiation-to-optical transcoders, and high-speed radio frequency (RF) instrumentation technologies. Our ultrafast optical and electronics systems staff is engaged in developing advanced techniques for generating, controlling, transcoding, and recording ultrafast signals in order to support a broad spectrum of Laboratory missions, including stockpile stewardship science, the National Ignition Facility (NIF), and Department of Defense applications. To support the cutting-edge science performed at the Laboratory, we build systems with performance well beyond the limits of commercially available optics and electronics technologies. Such systems include ultrafast lasers and diagnostics for optical phenomena with timescales much less than 1 nanosecond, or high-speed RF electronics operating at frequencies far above 1 gigahertz.



In the past, operators needed up to 12 hours to manually screen 48 critical checkpoints for harmful laser pulses at the National Ignition Facility. With Laser SHIELD, the screening can be done in less than 1 second and at the push of a button.

Special Capabilities and Unique Facilities

The Engineering Directorate owns and manages a number of facilities at the Laboratory, including engineering laboratories and shops. Within these facilities, we have developed special capabilities that produce leading-edge results and advance our technical expertise.

Micro-/Nanotechnology Facility

Our state-of-the-art micro- and nanotechnology fabrication facility has the equipment and infrastructure needed for lithography, etching, diffusion, wafer bonding, and thin-film deposition and vacuum techniques such as metal evaporation and sputtering, plasma enhanced chemical vapor deposition (PECVD), and low-pressure chemical vapor deposition (LPCVD). The facility houses over 6000 square feet of Class 10–1000 clean rooms for micromachining, silicon microelectronics, III–V semiconductor optoelectronics, and guided-wave photonics.

Nondestructive Evaluation Facilities

Our facilities consist of a primary and several satellite locations to service customers across the Laboratory. The primary facility is a unique, four-story structure housing six subsurface, shielded x-ray bays. Equipment includes advanced commercial systems such as Xradia microscale and nanoscale radiography/computed tomography (CT) devices, as well as custom, LLNL-built systems such as the Confined Large Optical Scintillator Screen and Imaging System (CoLOSSIS), a 9-MeV radiography/CT system with 35-cm field of view and 400-μm spatial resolution.

Mechanical Fabrication

Our ISO 9001 certified mechanical fabrication facilities include a range of activities, from metals machining to refined optical/glass techniques and laser processing. Other services include CAD/CAM design, metallographic analysis, and custom machine-tool development.

Electronics Manufacturing

Electronics manufacturing facilities (ISO 9001 certified) include central drafting, electronic fabrication/packaging, printed circuit board/surface mount technology, and a through-hole technology facility.

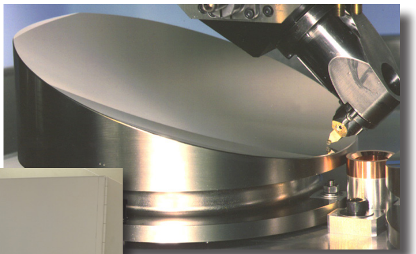
High Pressure Lab

Our high-pressure lab is one of the most complete high-pressure design, fabrication, and testing facilities in the world.

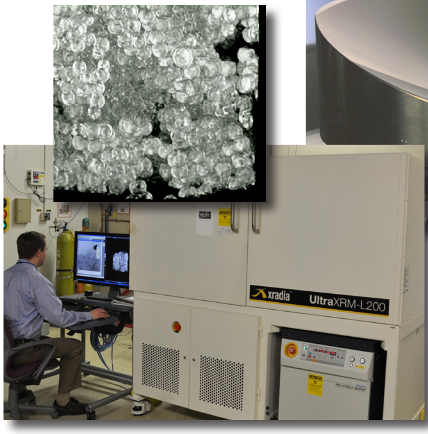
Defense Science Facilities and Electromagnetics

The unique connectivity at the Laboratory between electromagnetic modeling, design, construction, experiments, systems analysis, and field work allows Engineering to work in many leading areas in high power systems. We design, construct, and test total systems including the necessary support circuits, subsystems, and software.

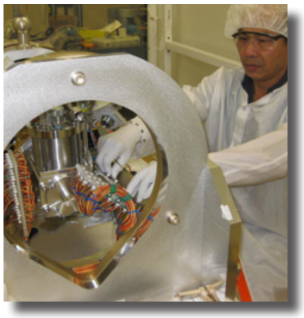
Class 100 cleanroom.



Diamond-turning machine.



50- to150-nm spatial resolution CT system (UltraXRM). (Inset) 3D rendered image of copper foam (many 1-μm hollow 100-nm wall thickness copper beads).



Electronic fabrication.

High-pressure lab.

Performing a compression test on a helmet pad.

To learn more, visit us at engineering.llnl.gov