

## High Energy Density Science

### 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, 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.

### National Ignition Facility

Home of the world's largest and most energetic laser system.



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

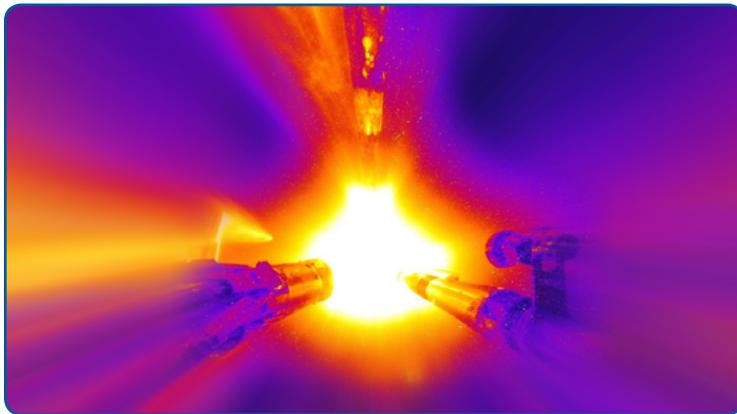
Since NIF became operational in March 2009, more than 2,000 shots have been conducted by researchers from national laboratories, federal agencies, academia, and the international scientific community. NIF is proving itself a critical element of stockpile stewardship to maintain the effectiveness of America's 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 behavior of plutonium in extreme conditions like those found in nuclear weapons. These experiments enable tests of theoretical models used in our nuclear weapons simulations.
- 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  $1.9 \times 10^{16}$  (19 quadrillion) neutrons and 54 kilojoules of fusion energy output, double NIF's previous energy record.
- 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 of UV energy and 438 terawatts of peak power, a 15 percent improvement over NIF's design specification of 1.8 megajoules.
- 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.

# National Ignition Facility & Photon Science

## Scientific Underpinning

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.



## NIF Target Implosion

A NIF target at the moment of implosion. The target positioner is at left and a hardened gated x-ray imaging diagnostic is at right.

- To design successful experiments in NIF's often unprecedented regimes, we draw 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