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# Lawrence Livermore National Laboratory



# 2007

*Annual Report*

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# Lawrence Livermore National Laboratory



## About the Cover

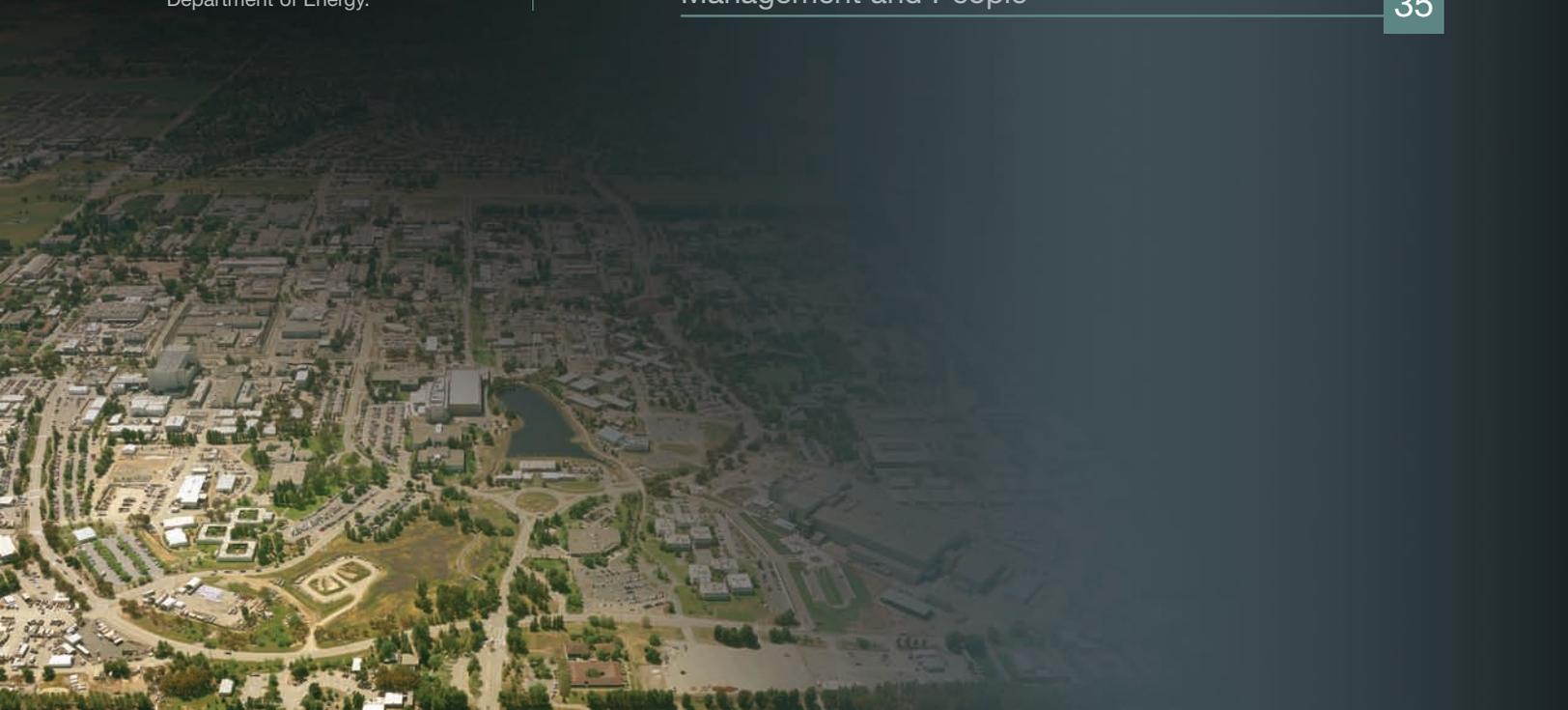
Looking north to the Laboratory  
from nearby vineyards.

# 2007 *Annual Report* Contents

## About the Laboratory

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons research facility. Livermore has a core mission in national security and uses its scientific and technical capabilities to solve nationally important problems. With its world-class workforce and atmosphere of intellectual integrity and innovation, the Laboratory has sustained scientific and technical excellence for more than 55 years. The Laboratory is managed by Lawrence Livermore National Security, LLC, for the National Nuclear Security Administration within the U.S. Department of Energy.

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# A Message From The Director



Lawrence Livermore National Laboratory's many outstanding accomplishments in 2007 are a tribute to a dedicated staff, which is shaping the Laboratory's future as we go through a period of transition and transformation. The achievements highlighted in this annual report illustrate our focus on the important problems that affect our nation's security and global stability, our application of breakthrough science and technology to tackle those problems, and our commitment to safe, secure, and efficient operations.

In May 2007, the Department of Energy (DOE) awarded Lawrence Livermore National Security, LLC (LLNS), a new public-private partnership, the contract to manage and operate the Laboratory starting in October. Since its inception in 1952, the Laboratory had been managed by the University of California (UC) for the DOE's

National Nuclear Security Administration (NNSA) and predecessor organizations. UC is one of the parent organizations that make up LLNS, and UC's presence in the new management entity will help us carry forward our strong tradition of multidisciplinary science and technology. "Team science" applied to big problems was pioneered by the Laboratory's co-founder and namesake, Ernest O. Lawrence, and has been our hallmark ever since.

Transition began fully a year before DOE's announcement. More than 1,600 activities had to be carried out to transition the Laboratory from management by a not-for-profit to a private entity. People, property, and procedures as well as contracts, formal agreements, and liabilities had to be transferred to LLNS. The pre-transition and transition teams did a superb job, and I thank them for their hard work.

Transformation is an ongoing process at Livermore. We continually reinvent ourselves as we seek breakthroughs that impact emerging national needs. An example is our development in the late 1990s of a portable



LLNS Board of Governors

## A Message from the Director

instrument that could rapidly detect DNA signatures, research that started with a view toward the potential threat of terrorist use of biological weapons. As featured in our annual report, activities in this area have grown to many important projects contributing to homeland security and disease prevention and control.

At times transformation happens in large steps. Such was the case when nuclear testing stopped in the early 1990s. As one of the nation's nuclear weapon design laboratories, Livermore embarked on the Stockpile Stewardship Program. The objectives are to ensure the safety, security, and reliability of the nation's nuclear weapons stockpile and to develop a science-based, thorough understanding of the performance of nuclear weapons. The ultimate goal is to sustain confidence in an aging stockpile without nuclear testing. Now is another time of major change for the

Laboratory as the nation is resizing its nuclear deterrent and NNSA begins taking steps to transform the nuclear weapons complex to meet 21st-century national security needs.

As you will notice in the opening commentary to each section of this report, the Laboratory's senior management team is a mixture of new and familiar faces. LLNS drew the best talent from its parent organizations—Bechtel National, UC, Babcock & Wilcox, the Washington Group Division of URS, and Battelle—to lead the Laboratory. We are honored to take on the responsibility and see a future with great opportunities for Livermore to apply its exceptional science and technology to important national problems.

We will work with NNSA to build on the successful Stockpile Stewardship Program and transform the nation's nuclear weapons

complex to become smaller, safer, more secure, and more cost effective. Our annual report highlights progress in many relevant areas. Laboratory scientists are using astonishing computational capabilities—including BlueGene/L, the world's fastest supercomputer with a revolutionary architecture and over 200,000 processors—to gain key insights about performance of aging nuclear weapons. What we learn will help us sustain the stockpile without nuclear testing. Preparations are underway to start experiments at the National Ignition Facility (NIF), the world's largest laser. They will help us resolve the most important questions we still have about nuclear weapons performance. Future NIF experiments will also explore the promise of an essentially inexhaustible source of clean energy from nuclear fusion. In addition, we have begun the process of eliminating significant quantities of special nuclear materials from the Livermore site.



High-Explosives Applications Facility

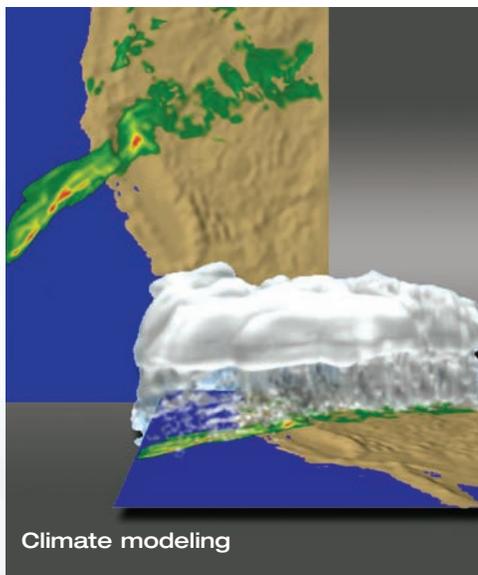


Car powered by hydrogen fuel

Gordon Bell  
prize-winning  
simulation

## A Message from the Director

We will carry forward Livermore's tradition of exceptional science and technology. This is the S&T that led to the design and construction of NIF and leadership in an international consortium that is developing the Gemini Planet Imager. When the Imager comes on line in 2010 at an observatory in Chile, the Imager will bring into sharp focus planets that are 30 to 150 light years from our solar system. It is the S&T that won five R&D 100 awards in 2007 and supercomputing's prestigious Gordon Bell



Climate modeling

Prize for the third year in a row. It is the S&T that set a world record for the distance traveled by a hydrogen-powered car on a single tank of gas and has provided critical technical support to the Intergovernmental Panel on Climate Change (IPCC) since 1990. IPCC was a co-winner of the Nobel Peace Prize in 2007 for its work.

We will expand our efforts to find solutions to 21st-century challenges. Livermore is already engaged in programs ranging from homeland security and disease prevention to fusion energy and global climate. You will find throughout this report other examples of exciting work on advanced defense systems, environmental quality, technology transfer to U.S. industry, biotechnology to improve human health, and basic sciences.

We will enhance Livermore's business and operational performance. In these endeavors, we will build on successful practices already in place and, in other areas, draw on the expertise and best practices of LLNS parent organizations. Particular attention is on conducting safe and secure operations and improving operational efficiency and cost effectiveness. Public trust in our Laboratory depends on meeting mission goals through safe, secure, disciplined, and cost-efficient operations.

Greater cost efficiency is a laudable goal and a necessity in view of overall federal budget constraints and their direct affect on the Laboratory. However, near the end of fiscal year (FY) 2007, we determined that we had to act quickly to reduce costs. The unfortunate consequence is the need for a workforce restructuring in FY 2008. The Laboratory will lose a large number of staff members, who have made significant contributions to our accomplishments. Outstanding people dedicated to service to their country have made and will continue to make Livermore an exceptional laboratory. I thank each departing individual for his or her part in the collective success of Livermore. The ongoing transformation of our Laboratory will take us to an exciting future with many opportunities for us to contribute to national security and global stability. As our annual report reveals, we have an important mission full of science and technology frontiers to explore.



Professional development



Cargo inspection at San Francisco International Airport

## Weapons and Complex Integration

# Innovation in Weapons Research

Since the Laboratory's inception in 1952, our defining responsibility has been the design, development, and stewardship of nuclear weapons. This challenging mission calls for the best in science and technology. Livermore scientists and engineers respond to technical hurdles by seeking ways to "change the game," a tradition that was firmly established in the 1950s with the design of compact thermonuclear warheads that made possible ballistic missiles on submarines.

The NNSA national laboratories committed again to changing the game when nuclear testing ceased in the 1990s. Ensuring the safety, security, and reliability of an aging nuclear stockpile without underground testing demands a fundamental understanding of the physics and engineering performance of nuclear weapons. Science-based stockpile stewardship required an enormous leap in our computational and nonnuclear experimental capabilities.

The Purple supercomputer, part of NNSA's Advanced Computing and Simulation (ASC) program, met a decade-long goal of achieving a

millionfold improvement in computational power when it began operation in 2006. We are now at the threshold of being able to simulate nuclear weapon performance in great detail. ASC Purple and BlueGene/L—and in the future Sequoia—are paving the way to the use of simulations as a predictive science tool. In a similarly dramatic advance, the National Ignition Facility will provide unprecedented experimental capabilities to explore the physical processes that occur when a nuclear weapon explodes.

With these computational and experimental capabilities at our disposal, we are tackling the technical grand challenge of understanding nuclear weapon performance. We face equally formidable programmatic challenges: the nation's nuclear weapons are growing older while the nuclear weapons complex needs to become smaller, safer, more secure, and more cost effective. Livermore will provide technical leadership to NNSA to help transform the nuclear weapons complex and the stockpile. Carrying on the Laboratory's tradition, we will explore game-changing ways to meet our nation's 21st-century deterrence needs.



**Bruce T. Goodwin**  
Principal Associate Director  
Weapons and Complex Integration

## Weapons and Complex Integration

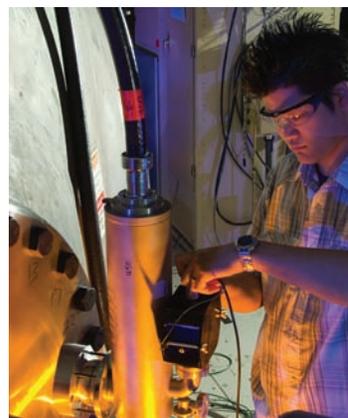
Under the National Nuclear Security Administration's draft plan to transform the nuclear weapons complex, Livermore will serve as a Center of Excellence for Nuclear Design and Engineering. Three Laboratory facilities are further identified as Centers of Excellence. The Terascale Simulation Facility (below) houses computers capable of producing high-resolution simulations of nuclear weapon behavior. The High Explosives Applications Facility (below right) and the National Ignition Facility (below far right) provide essential experimental capabilities.



### Transforming the Nuclear Weapons Complex

In December 2007, Tom D'Agostino, NNSA administrator, announced the release of a draft plan to transform the nation's nuclear weapons complex to make it smaller, safer, more secure, and more cost effective. The NNSA infrastructure needs to be consolidated, made more efficient, and updated. The nation's nuclear deterrence strategy calls for a smaller stockpile, which must be maintained and modernized as needed in the face of future budgets that are expected to remain flat or decline.

The plan is described in a draft *Supplemental Programmatic Environmental Impact Statement (SPEIS)*, which was issued in January 2008. The proposed transformation aims to consolidate special nuclear materials to five sites by the end of 2012. According to the plan, over the next decade, square footage will be reduced by 30 percent and the workforce directly supporting the weapons program will likely see a 20- to 30-percent reduction. Through the transformation, NNSA will eliminate duplicative facilities, reestablish a plutonium-parts production capability, speed up the dismantlement of retired weapons, and implement more efficient and uniform business practices throughout the complex.



The draft SPEIS evaluates four options to meet NNSA's goals and needs. The preferred alternative features distributed centers of excellence with a consolidation of missions and capabilities at existing NNSA sites. As a Center of Excellence for Nuclear Design and Engineering, Lawrence Livermore will retain its special responsibilities for nuclear warhead design and development, including safety, security, and reliability assessments of weapons it has designed and certification of changes made. In support of this mission, the Laboratory will conduct science and engineering research activities that underpin expertise in nuclear weapons and maintain the knowledge base so essential to sustaining the nation's nuclear weapons stockpile without nuclear tests.

Livermore will shoulder special responsibilities in three weapons research areas as part of the draft SPEIS preferred alternative. With its succession of record-breaking computers, the Laboratory will serve as a supercomputing platform host site. The Terascale Simulation Facility is currently home for two of the world's most powerful computers (see p. 8) and in the future will house the Sequoia petascale (quadrillion operations per second) machine. Livermore will also be a Center of Excellence for High Explosive Research and Development with its High Explosives Applications Facility (HEAF). HEAF is a state-of-the-art explosives research facility for formulating, processing, characterizing, and testing energetic materials. HEAF houses fully contained firing tanks for



## Weapons and Complex Integration

detonating up to 10 kilograms of explosives. In addition, NIF, the world's largest laser, will serve as a center of excellence and a science magnet for high-energy-density physics research (see p. 11).

Consolidation plans also call for significant changes at the Laboratory as NNSA's nuclear weapons program is downsized. Security Category I/II amounts of special nuclear materials—plutonium and enriched uranium—are to be removed from Livermore by the end of 2012. Only Security Category III quantities of plutonium will remain for research and development activities. The inventory reduction process has already started (see p. 31). Also, hydrodynamic testing, which now takes place at the Laboratory's Site 300, will eventually transition to the Nevada Test Site. In the interim, such experimental capabilities are to be consolidated. NNSA plans to close Livermore's Contained Firing Facility (CFF) about 2015 and significantly reduce support for Site 300, where the CFF is located.

### Annual Assessment of the Stockpile

Livermore is a key participant in formal review processes and assessments of the safety, security, and reliability of U.S. nuclear weapons. In 2007, the Laboratory met all milestones in support of the 12th cycle of the Annual Stockpile Assessment Process. First mandated by the President in 1995 and now required by law, the annual review includes an assessment of the current status of the stockpile. The review also gives the president an informed judgment of whether a resumption of underground nuclear testing is needed to resolve any issues about the reliability or safety of weapons. The formal process is based on technical evaluations made by Lawrence Livermore, Los Alamos, and Sandia national laboratories and on advice from the secretaries of Energy and Defense, the three laboratory directors, and the commander-in-chief of the Strategic Command.

Lawrence Livermore and Sandia-California prepare annual assessment reports for the nuclear weapons systems for which the two laboratories are jointly responsible: the W62 and W87 intercontinental ballistic missile warheads, B83 strategic bomb, and W80 and W84 cruise missile warheads. Laboratory scientists and engineers review and integrate all available information about each weapon system, including physics, engineering, chemistry, and materials-science data. This work is subjected to rigorous, in-depth intra-laboratory review and expert external review, including formal use of red teams. Weapons experts from Livermore also provide peer review for the annual assessment reports prepared by Los Alamos and Sandia-New Mexico for the weapon systems under their joint responsibility.

Laboratory weapons experts depend on information from aboveground testing, supercomputer simulation results, stockpile surveillance data, and the existing nuclear test database to complete the annual assessment process and formal certification of refurbished or replacement warheads. This collection of data underpins the resolution of any issues arising about deployed systems. The data are also essential input for a methodology called quantification of margins and uncertainties (QMU), which scientists use to evaluate weapons performance and make decisions about refurbishing weapons or providing reliable replacements. The methodology entails the development and application of a rigorous set of metrics and is analogous to the use of engineering safety factors in designing and building a bridge. For every functional requirement, the performance margin is quantified (i.e., how far the system's performance is from failure) and compared to the uncertainty in the estimate of that margin (i.e., how uncertain are the estimates of performance and the point of failure).

A Minuteman-III intercontinental ballistic missile can carry the W87 warhead, a nuclear weapon designed by Livermore and Sandia national laboratories. Livermore met all milestones for its part in the 2007 Annual Stockpile Assessment Process.



## Weapons and Complex Integration

The QMU approach benefits from the application of sophisticated statistical sampling techniques to accurately estimate the magnitude and source of uncertainties in quantitative predictions of weapon performance. This work is helping scientists determine which physics models in simulation codes are most in need of improvements and/or better input data to reduce uncertainties. QMU also helps Livermore to focus experimental programs on gathering data most relevant to measuring system performance and reducing the sources of uncertainty that can lead to system failure. In concert with continuing efforts to improve QMU, NNSA has launched an Advanced Certification Initiative to ensure that the necessary data are gathered, including more and better information from stockpile surveillance.

### Design of a Reliable Replacement Warhead

In March 2007, NNSA announced the selection of the design team from Lawrence Livermore and Sandia-California to develop a Reliable Replacement Warhead (RRW)—designated WR1—for the nation's sea-based nuclear deterrent. The proposed concept combined innovation with tested features to meet all RRW goals. To develop the proposal, the Laboratory fielded a major hydrodynamics test in addition to smaller experiments, and designers ran more than 20,000 simulations to examine system trade-offs.

The goal of the RRW approach is to replace aging warheads with ones manufactured from materials that are more readily available and more environmentally benign than those used in current designs. RRWs can include advanced safety and security technologies, and they are designed to provide large performance margins for all key potential failure modes. Large margins enhance weapons reliability and help to ensure that underground nuclear testing will not be required for design certification.

After NNSA's selection of the Livermore/Sandia-California design, NNSA and the U.S. Navy began to develop a detailed WR1 project plan and cost estimate. The effort has since been halted. While seeking clarification on a number of related policy and technical issues, Congress stopped funding for RRW work in FY 2008.

### Predictive Simulations for Stockpile Stewardship

ASC computers Purple and BlueGene/L, with a combined peak speed of about 700 teraflops (trillion floating-point operations per second), are being used by scientists and engineers at all three NNSA laboratories to make major contributions to stockpile stewardship. They are ushering in a new era of "predictive simulation."

Using the 100-teraflop Purple system, Laboratory scientists have gained new insights into weapon performance with simulations at unprecedented levels of resolution, revealing phenomena that had previously been hidden. The machine is being used for many series of six-month simulation campaigns, the first of which was completed in April. October marked the end of Purple's first year as a national user facility—managed in a manner similar to a large experimental facility. Each of the three NNSA laboratories proposes computing campaigns, which aim to achieve major ASC milestones and require Purple's size and capability for at least one major calculation. The proposals are reviewed and prioritized for relevance, importance, and technical rationale. Then, machine time is allocated accordingly. Purple is the first ASC system to be managed in this way.

BlueGene/L retained its number-one rank as the world's fastest supercomputer on the Top500, which was released in November. After a recent expansion, the machine clocks an astonishing 478.2 teraflops on the industry standard LINPACK benchmark. Its peak speed is 596 teraflops. Formerly

housed in 64 cabinets, the system now includes 208,000 processors in 104 cabinets. The upgrade was made to accommodate the growing demand for simulations of the most complex nuclear weapons phenomena. The expansion effort began in May. By September, scientists from Livermore and Los Alamos were running atomic-scale simulations of the ejection of fragments from shocked copper, a process that is very difficult to study experimentally.

For the third year in a row, a team from Livermore and IBM won the Gordon Bell Prize for Peak Performance for a materials-science simulation using BlueGene/L. The scientists were able to study, for the first time, how a Kelvin-Helmholtz instability develops from atomic-scale fluctuations into vortices at the scale of micrometers. The Kelvin-Helmholtz instability leads to the formation of wind-blown ocean waves, sand dunes, and swirling cloud billows. Understanding how the interactions of discrete atoms lead to seemingly continuous behavior observed at the macroscopic scale is important for stockpile stewardship and many other Laboratory programs. The innovative



## Weapons and Complex Integration

computational technique that was used, which required the simulation to self-correct for routine hardware errors, could change the way high-performance scientific computing is conducted on future machines with millions of processors.

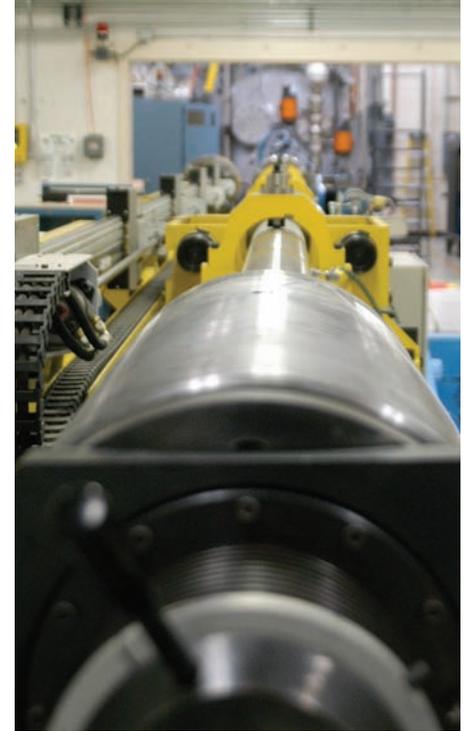
### Fundamental Properties of Materials

Plutonium is arguably the most complex material known, and understanding its detailed properties is a major challenge. In 2007, Livermore researchers met an important stockpile stewardship milestone with the development of a new plutonium equation of state—a description of the state of matter under a given set of physical conditions. The new equation of state is based on advanced theory, simulations only now possible with the Purple and BlueGene/L supercomputers, and very accurate experimental data. Static experiments used a diamond anvil cell to squeeze plutonium to extremely high pressures—about one million atmospheres. Dynamic experiments used the two-stage gas gun at the Joint Actinide Shock Physics

Experimental Research (JASPER) Facility at the Nevada Test Site. JASPER's gas gun accelerates a projectile up to 8 kilometers per second, producing on impact an extremely high-pressure shock wave in the targeted material.

Livermore scientists completed a new strength model for tantalum to meet a programmatic milestone. The model also lays the foundation for a new generation of models of material constitutive properties for use in multiphysics weapons simulation codes. Success with the tantalum stress model required combining new theoretical developments and detailed experimental measurements with modeling and simulation at several scales: quantum molecular dynamics, classical molecular dynamics, dislocation dynamics (irregularities in crystals), and macroscopic continuum physics. Developing the new strength model would not have been possible without ASC simulation tools and supercomputers. In particular, the dislocation dynamics simulations used one-third of BlueGene/L and would have taken more than 20,000 years to run using the largest computer that was available 20 years ago.

Experiments in the gas gun at the Joint Actinide Shock Physics Experimental Research Facility were important for work on a new equation of state for plutonium.



The cabinets that house BlueGene/L, the world's most powerful computer, are slanted on the front to keep cooled air flowing properly around the processors.

## Weapons and Complex Integration

### “Getting the Job Done” across the Weapons Complex

The Laboratory strongly supports the priorities that comprise NNSA's “Getting the Job Done” list with its ongoing stockpile stewardship activities and by assisting other sites in the nuclear weapons complex.

Livermore performs detailed peer review of the work of Los Alamos and Sandia-New Mexico on the stockpiled weapons for which they are responsible. Laboratory experts also help their colleagues to address issues as they arise. In 2007, Livermore support included fielding a large-scale hydrodynamics experiment at the CFF at

To help NNSA in “Getting the Job Done,” researchers use the Contained Firing Facility for hydrodynamic tests, including a large-scale experiment in 2007 in support of a Los Alamos weapons program.



Site 300. The Laboratory also aided with the resumption of pit manufacturing at Los Alamos, where a team succeeded in fabricating and certifying new pits for the W88 submarine-launched ballistic missile warheads. Livermore supplied radiographic inspection capabilities, produced small-scale plutonium samples for testing, and provided engineering evaluations and peer reviews based on a wide range of independently conducted experiments and simulations.

The Laboratory is an active participant in initiatives to significantly improve processes as well as the throughput of the nuclear weapons complex. Livermore engineers are working closely with the Pantex and Y-12 Throughput Improvement Project teams to increase plant efficiencies, expedite completion of joint projects, and introduce new capabilities. Pantex, in particular, improved dismantlement rates by more than 50 percent in 2007—significantly increasing throughput over previous years—and implemented new processes for surveillance of the W80 cruise missile warhead, a weapon for which Livermore is responsible. The Laboratory completed work with Pantex on a set of nuclear safety and weapons response issues that resulted in faster throughput by eliminating overly conservative controls in operations without compromising safety. At Y-12, technical experts from Livermore reviewed material fabrication process issues that were seriously delaying the start-up of new operations.

## National Ignition Facility and Photon Science

# The Power of Light

Excitement is growing at NIF as the giant laser nears completion. We are busy preparing for experiments on NIF that will dramatically demonstrate the “power of light.” The 192-beam laser system is a cornerstone of NNSA’s Stockpile Stewardship Program and will serve as a preeminent scientific user facility for decades to come.

In 2007, Laboratory scientists, engineers, and technicians made extraordinary progress on NIF. They commissioned the first of two 96-beam laser bays, firing beams in groups of eight and producing a total of more than 2 million joules of laser energy. NIF’s energy output is already 40 times more than the operating energy of the previous largest lasers. Overall commissioning of NIF is to be complete in March 2009, and fusion ignition experiments are scheduled to begin in 2010.

NIF will provide the first laboratory setting for examining the fusion reactions that occur in supernovae, our Sun and other stars, and nuclear weapons. NIF was designed with three specific research goals in mind: to support stockpile stewardship, show the feasibility of inertial confinement fusion (ICF) as a clean source of energy, and make significant strides in fundamental high-energy-density science. These three missions share the need to prepare materials at extreme conditions—pressures of quadrillions of pascals, temperatures of 100 million kelvins, and densities of 100 grams per cubic centimeter.

NIF was a dream nearly 50 years ago when Laboratory researchers first pointed the way to thermonuclear burn using lasers. NIF is the product of bold and courageous thinking and the innovations of generations of scientists and engineers at Livermore. The work we do on NIF will be key to our future as a premier international research laboratory.



**Ed Moses**

Principal Associate Director  
National Ignition Facility and  
Photon Science

## National Ignition Facility and Photon Science

## Commissioning NIF

In the early hours of a July morning, control room operators fired a series of laser shots in a group of eight beams known as Bundle 44. The last shot lasted about 25 billionths of a second, a tiny fraction of the time it takes to blink an eye. The infrared energy of each beam was more than enough to meet NIF's operational and performance qualification requirements. The achievement successfully brought to a close the sequential testing of all 96 beams in one of NIF's two laser bays, a process that has taken about two years.

The night shift in the National Ignition Facility's control room executed shots to commission laser bay 2. The real-time control system is one of the most complex ever designed for a scientific machine.



Using NIF's state-of-the-art control system, the "owl" shift executed this series of laser shots, without physicists and chief engineers present. In January, NIF extended laser operations to 24 hours, 5 days a week by adding a second shot operations shift covering the period from 1 to 7 a.m. Extended operations allowed a 130-shot performance campaign and a large number of controls test shots and reliability testing to be completed more quickly than previously planned.

Installation of optics and other components in NIF's second laser bay is well over 90 percent complete, and preliminary testing is under way. In December, workers began installing the first of 192 integrated optics modules onto the target chamber. These devices are the final components through which a laser beam passes before it enters NIF's target chamber. Each module contains crystal plates that convert the laser light from infrared to ultraviolet. Installation of the optical assemblies will continue through 2008.

Tests and sophisticated computer simulations confirm that NIF is well on the way to reaching its design specification of 1.8 million joules of ultraviolet energy when overall commissioning of the beamlines is complete. The tests measured the quality of each beam's spatial profile



All of the beams in laser bay 2 have been commissioned. Eight laser beams are encased in each of the 12 "bundles" on the left.



Workers in clean-room garb install one of the first integrated optic modules onto the target chamber. These final optics are assembled in a newly built clean room.

## National Ignition Facility and Photon Science

and temporal pulse shape. Even though each shot is exceedingly short in time, its energy output and frequency are designed to vary significantly throughout its duration to meet the specific needs of the experiment being conducted.

### Countdown to Ignition

The National Ignition Campaign (NIC) encompasses all experiments, hardware, and infrastructure needed to carry out the initial ignition experiments in 2010 and continuing research in the following years. NIC is managed for NNSA by the Laboratory and also includes Los Alamos and Sandia national laboratories, the Laboratory for Laser Energetics at the University of Rochester, and General Atomics of San Diego. NIC's goal is to use NIF laser energy to demonstrate ICF—compressing and heating a millimeter-size target filled with deuterium and tritium (DT) to achieve fusion ignition and the generation of more energy than is input. The NIC team will also transition NIF to routine operations as a highly flexible high-energy-density science facility by 2012.

The first experiments using 96 beams are scheduled for 2009 and will help select the optimum radiation temperature for the hohlraum that encloses the target capsule in ignition experiments. Computer simulations are helping to guide the design of the 96-beam experiments. As highlighted in the September 2, 2007, online edition of *Nature Physics*, a set of simulations very closely matched data from NIF Early Light experiments conducted in 2003–2004 that studied the interaction of intense laser light with hot plasmas. The results indicate that NIF's laser beams will propagate effectively through the hot plasma generated in fusion experiments and will achieve ignition.

### The Target Challenge

A major component of NIC is the development of systems for ignition targets,

which comprise three areas: integrated target systems, cryogenic target positioner systems, and target diagnostics systems. In 2007, the main thrust in all three areas was to prepare for the 2009 experimental campaigns to validate the target's design.

NIC targets generally consist of a capsule assembly, hohlraum, and a surrounding thermal-mechanical package. Their manufacture presents challenges in coatings, micromachining, laser machining, characterization, and assembly. Several development efforts focused on the capsule assembly, which is a sputter-coated, copper-doped beryllium shell with a fill tube attached. New methods for coatings and laser machining yielded production processes that

A fully assembled target for ignition experiments incorporates a tented capsule, hohlraum, thermal-mechanical package, and silicon cooling arms.



## National Ignition Facility and Photon Science

A target alignment sensor positioner ensures that targets are aligned with all 192 laser beams.

meet specifications for retention of the DT gas fuel as well as for the geometry and allowable defects at the fill hole.

The hohlraum incorporates a layer of sputtered gold and uranium whose stability has been problematic because of uranium's reactive nature. A new uranium deposition process has resulted in far greater stability. New fabrication processes are being pursued to increase production rates for both the capsule assembly and the hohlraum to meet the demands of NIC's planned experiments. A new clean room at General Atomics houses metrology equipment for target subcomponents. In addition, Livermore commissioned a clean room for final assembly of targets on a scale that meets NIC needs.

The NIC cryogenic targets include a thin layer of DT ice on the inside of the beryllium shell. The ice surface must be almost perfectly smooth so that the capsule implodes symmetrically. A new process for rapidly cooling DT to the required temperature results in a smoother ice surface than the previous slow-cooling method. The targets must be used quickly before the smoothness of the rapidly cooled ice layer begins to deteriorate.

Early in 2007, the first ignition target inserter cryostat was assembled and tested in the process integration laboratory's vacuum vessel. The cryogenic system demonstrated the ability to meet the temperature stability requirements of less than 1 millikelvin for the target's ice layer over a 45-hour period. NIF's existing target positioner for noncryogenic targets is being modified to accommodate the inserter cryostat and cryogenic targets. The cryogenic target positioner places the target assembly precisely in the center of the target chamber, where the target alignment sensor positioner aligns the target with NIF's laser beams.

The target diagnostics systems, originally fielded for the NIF Early Light experimental campaign several years ago, are being upgraded and reinstalled on the target chamber. New diagnostic equipment required for the shot campaigns is being readied for installation and commissioning.

Some experiments on NIF will not require fusion ignition and call for different kinds of targets. In parallel with NIC target development, Livermore scientists are experimenting with a variety of extremely low-density foams, graded-density foams, and other specialized materials from which nonignition targets will be fabricated.

### After Ignition

All of this activity at NIF, as well as ongoing experiments at the OMEGA facility at the Laboratory for Laser

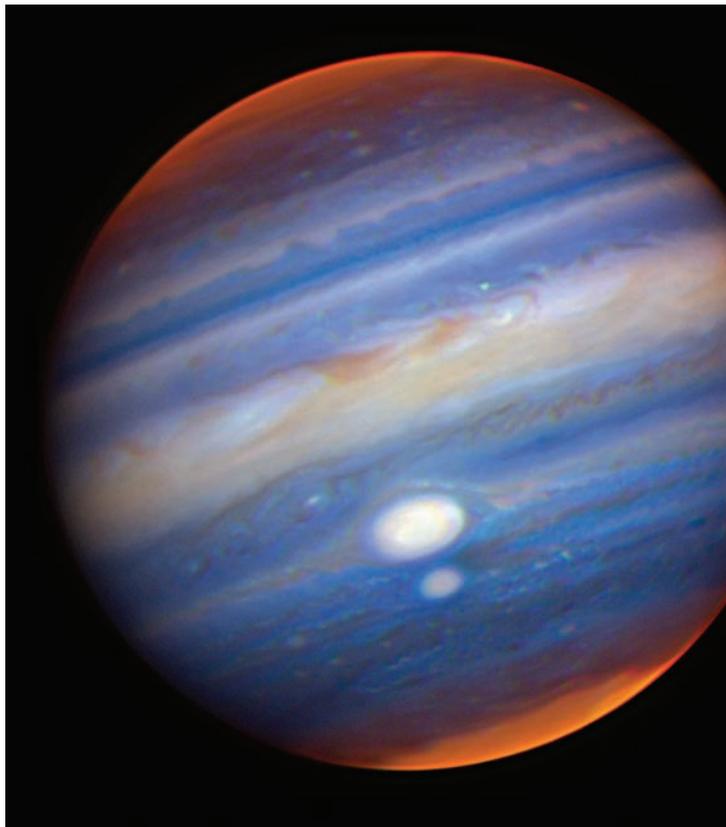


## National Ignition Facility and Photon Science

Energetics at the University of Rochester, focuses on experiments to support stockpile stewardship and explore high-energy-density physics. When fully operational, NIF will be the only experimental facility capable of creating the temperatures and pressures necessary to study the physics of the nuclear phase of weapons performance. The long-term success of the Stockpile Stewardship Program will rely on a wide variety of ignition and nonignition experiments to help scientists understand underlying issues about nuclear weapon performance and gather data to improve and validate weapons-physics simulation models. Together, experiments and simulations support the annual assessments of the stockpile, investigations of stockpiled weapons systems, decisions about weapons refurbishment or replacement, and certification of weapons modifications (see p. 7).

Ignition experiments will demonstrate the feasibility of fusion as a path to abundant clean energy and are critical to understanding fusion burn, a phenomenon central to the performance of nuclear weapons. Ignition and thermonuclear burn are complex processes in weapons that involve the physics of hot, dense plasmas—a regime that is not fully understood. In NIF experiments, scientists will gather key data that can help them improve the physics in computer codes. For example, in 2007, NNSA launched an initiative to improve understanding of the process by which fusion reactions increase the fission output of weapons. This initiative will require a significant effort over many years, including the use of NIF as a source of experimental data.

Nonignition experiments at NIF will give researchers additional information about the performance of a nuclear weapon during its nuclear phase. The new data, which also pertain to basic science issues, will include information about equations of state at pressures up to quadrillions of pascals, opacity (the absorption and transmission of



The National Ignition Facility will be used by physicists from around the world. One team has already formed to use NIF experiments to study the interiors of huge planets, such as Saturn and Jupiter.

x rays by materials at weapon-like temperatures), and the strength of solid materials at pressures of trillions of pascals under dynamic conditions. NIF is unique in its capabilities for these experiments because of its excellent diagnostic tools and its ability to produce very high temperatures in a large enough volume for a sufficiently long period of time.

### A Community of Users

In August, about 70 scientists from the United States and Europe gathered in Livermore for a NIF nuclear astrophysics workshop. This meeting was the first in a series of “Science Use of NIF” workshops that will help lay the groundwork for NIF’s evolution into an international center for experimental science. Researchers at the workshop brainstormed experimental topics and discussed additional diagnostic devices

that might be required for experiments on how the universe operates at both the smallest and the largest scales. Additional workshops in a variety of physics areas are planned for 2008.

Already four research teams have formed and received seed grants from the Laboratory to design experiments and targets for NIF shots. The teams, comprising scientists from institutions around the U.S., will initially examine four high-energy-density problems. The first team will study the response of materials to enormous pressures such as those found in the interiors of Jupiter and Saturn; the second, the kinds of turbulent hydrodynamic processes that affect the evolution of supernovae; the third, the instabilities that occur when lasers interact with large-scale plasmas; and the fourth, some of the nuclear reactions that occur in stars. Livermore scientists will serve as liaisons between the groups and

## National Ignition Facility and Photon Science

NIF to help field their experiments and interpret the results.

The Laboratory has created a NIF Users' Office and is drafting a governance plan for proposing and conducting experiments on NIF. One goal of the outreach effort is to find a mechanism for providing additional seed grants over the next several years so that other university teams can develop experiments for NIF.

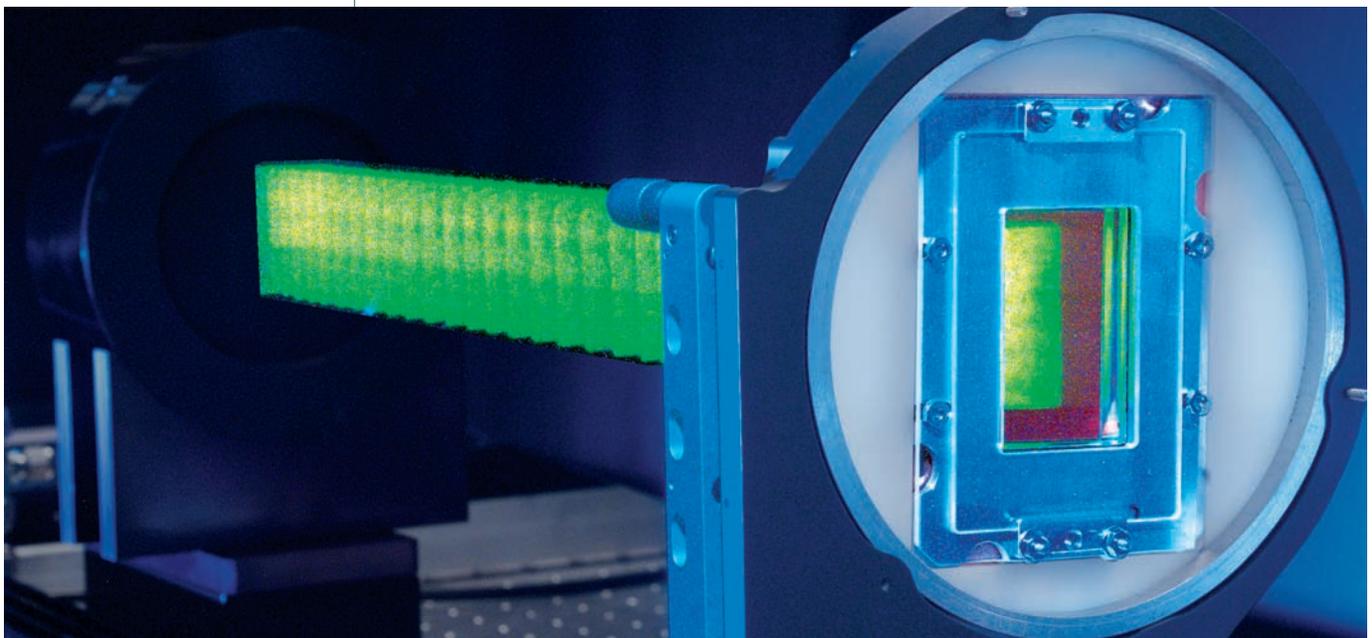
### Photon Science Advances

Mercury, a single-beam laser, is serving as a test bed for the laser driver technology that will be essential for a practical inertial fusion energy power plant. NIF operations permit all 192 beams to fire simultaneously only once every few hours. Thousands of optics must cool before they can properly function again. For Mercury, Laboratory scientists have developed a method of continuously cooling the optics, allowing the laser to fire rapidly over extended periods. As laser pulses pass through the optics at a rate of 10 per second, high-velocity helium gas is propelled across the optics to keep them cool. In Mercury, diode

lasers have replaced NIF's seven-foot-tall flashlamps, increasing efficiency and reducing heat output. Mercury is designed such that it could be scaled up to the size needed for a fusion energy plant. A future fusion power generating facility would combine the energy output of NIF with the rapid-fire shot capability of a Mercury-like laser to supply virtually inexhaustible energy.

Mercury is just one example of the innovative work under way on photon science and applications at the Laboratory. A team of experts on advanced optical components is designing and fabricating a variety of custom diffractive optics for Laboratory projects and for researchers worldwide. The Advanced Radiographic Capability is extending Livermore's expertise in high-energy petawatt lasers for use in multiframe, hard-x-ray radiography of imploding NIF capsules, a diagnostic tool that is critical to the success of proposed future experiments at NIF. Progress also continues on the solid-state heat-capacity laser, which is setting the stage for both tactical and strategic laser weapons in the coming decade (see p. 19).

An award-winning wavelength converter is a critical element of the Mercury laser. The yttrium-calcium-oxyborate crystal in the center of the holder shifts the wavelength of invisible infrared light on the right to green light on the left.



## Global Security

# Vision for a Safer World

In today's interconnected world, national security is not a single-nation issue. Rather, it must be addressed within the global context. The ambitions and policies of nation states and subnational groups play out upon the world stage. The threats posed by asymmetric warfare and the proliferation, terrorist acquisition, or use of weapons of mass destruction (WMD) know no boundaries. Likewise, energy and environmental issues are not confined by national borders but have intercontinental reach and effect. This is the landscape for Lawrence Livermore's mission in global security.

In explicit recognition of the links between energy and environmental issues, regional tensions, and national and global security, in October 2007 the Laboratory aligned its nonproliferation, counterterrorism, and energy and environmental security efforts into a single organization. The goal of the new Global Security Principal Directorate is to provide the most effective technical means possible for anticipating,

predicting, preventing, mitigating, and responding to global threats. Five program thrusts—intelligence, nonproliferation, defense, domestic security, and energy and environmental security—draw on long-standing Laboratory expertise and singular accomplishments in weapons science and technology, high-performance computing, and information exploitation, as well as extensive capabilities in the life sciences, physical sciences, and engineering.

A common theme among these programs is the need for global awareness and response. Knowledge of existing, emerging, and potential future threats is essential if the nation is to respond effectively to events as they unfold, whether the threat is nuclear smuggling, asymmetric warfare, a resurgent Russia, an emerging disease, or global climate change. Fulfilling this need is a challenge of unprecedented scale, complexity, and technical difficulty. Livermore researchers are devising new ways of acquiring multifaceted data on a global scale together with new ways of anticipating, recognizing, and responding to critical events and threats.



**John Doesburg**

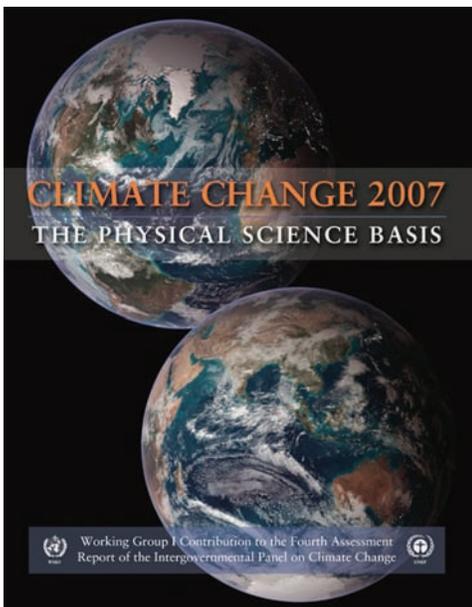
Principal Associate Director  
Global Security

## Global Security

### Promoting Energy and Environmental Security

The awarding of the 2007 Nobel Peace Prize to former vice president Al Gore and the Intergovernmental Panel on Climate Change (IPCC) was a cause for celebration by members of the Laboratory's Program for Climate Model Diagnosis and Intercomparison (PCMDI), which supports the IPCC with assessments of the scientific performance of climate models from across the globe. PCMDI also analyzes, archives, and distributes the climate simulations and data sets that provide the scientific basis for the IPCC's assessment reports, the most recent of which (Fourth Assessment Report) was published in 2007. The IPCC honored the PCMDI this summer with the presentation of a plaque bearing the inscription, "In recognition of extraordinary contributions to the Fourth Assessment Report."

Scientists in the Laboratory's Program for Climate Model Diagnosis and Intercomparison contributed to the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change.



This past year, Livermore helped lead a major multi-institution technical evaluation of carbon capture and sequestration technologies and the economic, statutory, and regulatory issues affecting the use of geologic carbon sequestration in California. A Laboratory scientist was one of the principal authors of the resulting report, *Geologic Carbon Sequestration Strategies for California, the Assembly Bill 1925 Report to the California Legislature*, which was adopted by the California Energy Commission in December. Carbon sequestration is being investigated as a means of reducing the buildup of carbon dioxide in the atmosphere. As an example of this concept, carbon dioxide is separated from industrial effluent gases and then injected underground, where it can be stored or used to enhance oil recovery.

The Laboratory is working with industry partners to develop power plants that incorporate carbon capture and sequestration. In July, BP signed an agreement to work with Livermore on the development of underground coal

gasification technology that incorporates carbon sequestration. Using field data provided by BP Global, the Laboratory is providing expertise and model results for the operation and environmental management of the underground coal gasification process. Last summer, Xcel Energy contracted with Livermore to provide technical expertise and analysis for the siting of a new power plant that will capture and sequester the majority of the carbon dioxide it produces.

Livermore researchers set a world record in 2007 for the longest distance traveled by a hydrogen-powered car on a single tank of fuel. Hydrogen-burning vehicles offer great potential for reducing the use of fossil fuels and thereby curbing the release of carbon dioxide and other greenhouse gases (transportation accounts for more than two-thirds of the nation's daily petroleum consumption). In the demonstration, a Prius, modified to run on hydrogen by Quantum Fuel Systems Technologies Worldwide, Inc., traveled more than 650 miles on a tank containing 150 liters of liquid hydrogen. The key to this achievement is a superinsulated, lightweight, ultrasafe hydrogen fuel tank that holds 10 kilograms of liquid and can fit in the vehicle's trunk. The Laboratory is collaborating with industry to design more compact fuel tanks with improved thermal properties and has had discussions with automakers regarding the potential for mass-produced hydrogen-fueled vehicles.

Livermore assists in the development of nuclear power technologies that are resistant to proliferation. Several projects initiated this past year in support of the Global Nuclear Energy Partnership establish the Laboratory as a leader in computational materials science to support the design of advanced fuel systems. Working closely with counterparts at Argonne National Laboratory, Livermore researchers have modified an existing structural mechanics code to investigate in high resolution the deformation of nuclear fuel assemblies and perform detailed design

## Global Security

studies of advanced high-neutron-flux reactors. In addition, the VisIT software for scientific visualization is being augmented for use by the nuclear reactor design community.

### Protecting the Nation and Its Military Forces

Laboratory scientists and engineers develop new concepts and demonstrate new capabilities for the Department of Defense, such as a high-average-power (100-kilowatt-class), diode-pumped, solid-state heat-capacity laser, which has potential for use as a directed-energy “speed of light” weapon. In 2007, extensive laser-material interaction experiments revealed the behavior of several destructive mechanisms, from ignition of high explosives, to combustion of materials, to aerodynamic breakup due to laser-heating-induced deformation. Possible military applications of a battlefield laser system include the targeting and destruction of short-range rockets, guided missiles, unmanned aerial vehicles, and improvised explosive devices (IEDs).

A new simulation was created last year, based on Livermore’s Joint Conflict and Tactical Simulation (JCATS), to handle the increased complexity of battlespace intelligence observables. This new capability, which was used in three major exercises, substantially increases the Defense Department’s ability to describe a battlespace in simulation exercises. JCATS is the most widely used model for training and real-world rehearsals of U.S. military tactical missions. It has been used by military units for tactical training prior to deployments for Operation Iraqi Freedom, Operation Enduring Freedom (Afghanistan), and Sharp Focus (a peacekeeping operation in Africa). JCATS also supports U.S. Northern Command homeland security training events and is used to plan security at sites or events where terrorism may be an issue.

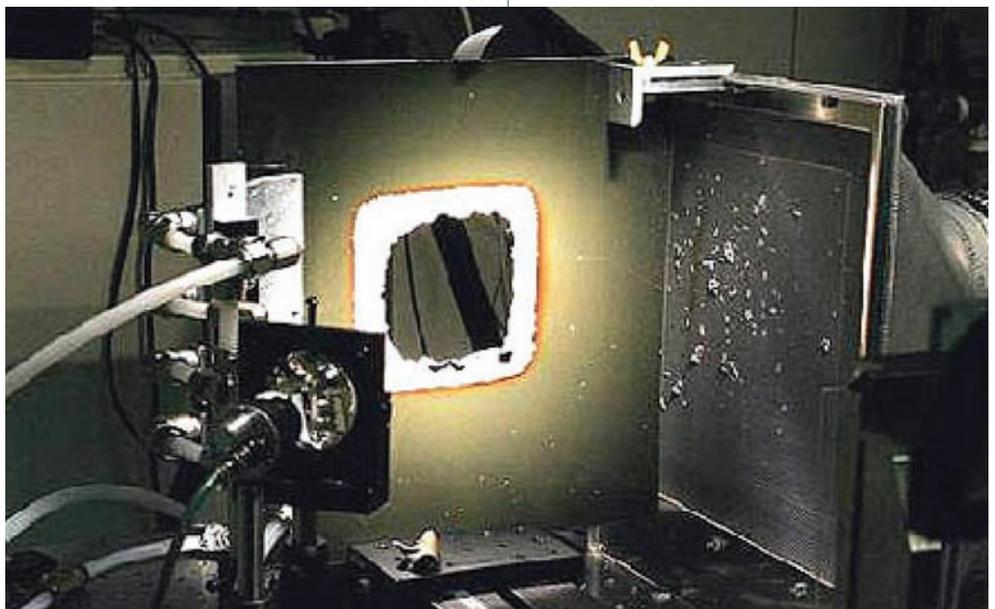
The Laboratory is also contributing to the nation’s ballistic missile defense effort with

assessments of the effects of kinetic-energy interceptors on ballistic missiles and potential WMD warheads. Last year, Livermore supported Missile Defense Agency flight tests, using the Laboratory’s Remote Optical Characterization Sensor Suite to verify the intercept kill assessment. In a related project, high-performance computers and high-fidelity hydrodynamics codes were used to model the breakup and debris created from the impact of the interceptor and warhead. Simulations were then compared with actual radar data acquired from intercept tests.

### Understanding Threats and Adversaries

Laboratory researchers work at the intersection of science and technology and intelligence analysis to provide the federal government with technically informed insights into the threats, motivations, intentions, and capabilities of various foreign entities that challenge the nation’s security. Each year, Livermore prepares numerous assessments on a variety of proliferation, terrorism, and technical topics for the departments of Energy and

Livermore’s solid-state heat-capacity laser is being developed as a possible weapon for the Department of Defense. Experiments have shown that the laser can destroy targets through a variety of mechanisms.



## Global Security



Livermore analysts assisted the International Atomic Energy Agency with information regarding Iran's nuclear program.

Homeland Security and other agencies. These analytical efforts aim to discover early indications and fully characterize threats arising from the proliferation of conventional, nuclear, chemical, and biological weapons as well as missile delivery systems and emerging asymmetric uses of technology.

Laboratory analysts are frequently requested to provide expertise on technical and country-specific issues of current concern and to contribute to National Intelligence Estimates. For example, this year, the U.S. Ambassador and Permanent Representative to the United Nations in Vienna requested the participation of Livermore analysts in a meeting of technical experts at the International Atomic Energy Agency on Iran's nuclear program.

### Defending the Homeland

Livermore leads the Nuclear Assessment Program (NAP), the national effort for evaluating communicated nuclear threats. Laboratory analysts assess dozens of nuclear-related threats and a hundred or more nuclear smuggling incidents each year. These subject matter experts also assist law enforcement officials and first responders at home and abroad in their efforts to thwart nuclear

terrorism. For instance, they supported the U.S. government's response to the November 2007 seizure of uranium in Slovakia. The NAP is part of the Laboratory's program in domestic security, which addresses the threat of an attack against the U.S. homeland by terrorists or other adversaries using WMD, IEDs, or other asymmetric weapons.

The Large-Area Imager, a 2007 R&D 100 Award winner, is a recent success in the continuing quest for increasingly capable nuclear detection technologies. Developed in collaboration with Oak Ridge National Laboratory and the UC Berkeley Space Sciences Laboratory, the Large-Area Imager uses a method developed for astrophysics research—a coded aperture, or mask with a special pattern—to conquer the problem of background clutter. The current design fits on the back of a small truck or trailer and can be used in either stationary or mobile mode. It can sweep an area about 25 times faster than other detection technologies and can pinpoint a radiation source within a 25-square-meter area. Customs inspectors, border agents, law enforcement officers, and incident response personnel can use the instrument to monitor port and harbor entries, scan buildings and warehouses, inspect special event venues, or conduct searches based on intelligence and law enforcement information.

A team of scientists from Livermore and UC Davis is exploiting advances in microfluidic engineering to create a system that can detect viruses in sample amounts a million times smaller than possible in current instruments. This new technique rapidly identifies viruses—a critical capability for responding effectively to an act of bioterrorism or a pandemic. In the analysis-on-a-chip system, DNA copying via polymerase chain reaction (PCR) is performed inside 10-picoliter droplets on a silicon chip. Because the droplets are so tiny, the number of PCR thermal cycles needed for detecting a pathogen is roughly halved, greatly shortening the detection time. This work was featured as the cover

story of the November 15, 2007, issue of *Analytical Chemistry*.

Livermore scientists continue to provide technical support to BioWatch, the national system for detecting large-scale bioattacks against key U.S. cities. The Laboratory operates two BioWatch laboratories, one in Livermore and the other in the Washington, D.C., area. They provide supplementary sample analysis, subject matter expertise, and consequence management capabilities. In addition, the Laboratory's Autonomous Pathogen Detection System (APDS) is being commercialized by an industrial partner, and units are being deployed within the national BioWatch network.

An outbreak of a foreign animal disease such as foot and mouth disease virus (FMDV) could devastate the nation's livestock industry. Laboratory researchers have developed a multiplex assay for FMDV and six other look-alike animal diseases to aid in the rapid detection of an outbreak. This assay has been successfully demonstrated in 14 National Animal Health Laboratories and evaluated at Pirbright Laboratory in England (the world reference laboratory for FMDV). The U.S. Department of Agriculture is using this assay, together with these validation data, to develop a national-scale assay for domestic and foreign animal diseases. Livermore has also developed the Multiscale Epidemiologic Simulation Analysis (MESA), the first and only nationwide epidemiological model for simulating foreign animal disease transmission. It provides the ability to track response resources (e.g., vaccines, diagnostic capability, personnel) and can be used for response planning and countermeasures assessment. MESA can also model a country by region to reflect each region's disease transmission attributes and response capabilities.

The Department of Homeland Security's Air Cargo Explosives Detection Pilot Program addresses 2007 Congressional legislation to screen for explosives in

## Global Security

100 percent of the air cargo carried on passenger aircraft by 2010, without impacting commerce. Three major airports are participating in pilot programs to understand the technical and operational issues involved in detecting explosives in air cargo and to develop and demonstrate new systems for screening significantly more air cargo than currently possible. In collaboration with the Transportation Security Administration, Livermore leads the San Francisco International Airport (SFO) effort. This past year, construction of the SFO pilot screening system was completed. Months of operational data were collected and are now being analyzed.

As home to the National Atmospheric Release Advisory Center (NARAC) and provider of technical capabilities for the Interagency Modeling and Atmospheric Assessment Center (IMAAC), Livermore is an important element of the nation's

emergency response infrastructure. Newly developed modeling capabilities allow NARAC/IMAAC to accurately predict complex flow and dispersion in urban areas. This past year, NARAC/IMAAC responded to more than 7,000 requests for assistance and nearly 25 major incidents, and supported roughly 100 drills, including the TOPOFF 4 exercise. Conducted over three days in October, TOPOFF 4 tested full-scale response to radiological dispersal device attacks in three locations (Guam, Oregon, and Arizona) and involved more than 15,000 participants from every level of government, as well as the international community and private sector. Nearly 50 Laboratory scientists participated, both during the planning stages, where they helped construct the exercise scenario and provided input data and "ground truth," and during the exercise itself, where they deployed nuclear incident response capabilities and provided round-the-clock expertise.

Training and preparation of state and local personnel are essential for effective response to a terrorist attack. This past fall, the Livermore-led Training, Exercises and Lessons Learned Program conducted a computer-simulation-driven exercise in Anaheim, California. An eight-person Incident Management Team (IMT) was immersed in the first few hours of a coordinated terrorist chemical attack. Computer simulations tracked the scenario ground truth and provided situational awareness data via the operational tools available to the IMT in their mobile command post (e.g., radio, telephone, FAX, Web-based situational awareness tools). Any decisions made by the IMT were conveyed back into the simulations, affecting the evolution of the scenario and its ultimate outcome. The IMT learned by conducting the exercise itself, later reviewing the recorded communications and significant events, and seeing the consequences of their decisions.



State and local personnel participated in an exercise designed to plan and train for responding to a chemical attack by terrorists. Livermore computer simulations tracked the scenario and all communication, incorporating all decisions back into the simulation.

## Global Security

### Preventing Proliferation at the Source

As a participant since the inception of the NNSA's cooperative nonproliferation programs, Livermore engages in projects throughout Russia and around the world to secure nuclear material. In 2007, the Laboratory completed material protection, control, and accounting upgrades for the last two Russian navy sites in the Kamchatka region. Livermore is also leading the effort to secure the more than 1,000 radioisotopic thermoelectric generators deployed across Russia. These devices, installed in the 1970s as power sources for remote lighthouses and navigational beacons, are highly radioactive and largely unsecured. They thus pose significant proliferation and terrorism risks. This past year, more than two dozen were successfully recovered, replaced with alternate power sources (e.g., solar), and

then moved to a newly constructed, secure storage facility near Vladivostok.

Another essential element of nonproliferation is detecting and interdicting smuggled nuclear material and technology. As part of the U.S. effort to stop the spread of sensitive nuclear technology, Laboratory analysts annually review more than 4,500 license applications that are submitted to the Department of Commerce for the export of dual-use sensitive technology.

Livermore is also part of the national program to develop the technical capabilities for worldwide monitoring of underground and underwater nuclear explosions. Recent efforts have focused on developing tools and methodologies for identifying and locating seismic events in regions of proliferation concern where data are sparse and the U.S. has little access. This past year, Laboratory

scientists produced regional seismic calibrations for the Persian Gulf and surrounding regions. They also developed a model-based signal processing algorithm that can predict the waveforms for earthquakes in the Korean peninsula based on detailed knowledge of the region's crustal structure. This technique is being generalized to predict waveforms from explosions at arbitrary points in the earth, which will enhance monitoring of regions where there are no prior waveforms from explosions.

Livermore participates in NNSA's International Safeguards and Engagement Program, providing technical insight on the development of the safeguards and security infrastructure needed to support the growth of nuclear power while minimizing the risk of nuclear proliferation. As part of this effort, Livermore leads the NNSA's Sister Laboratory Program in North Africa, with participation by Morocco, Libya, Egypt, and Algeria. Technical experts from U.S. national laboratories and laboratories in the participating countries collaborate to develop civil nuclear energy applications under the terms of the Nuclear Nonproliferation Treaty. In 2007, Livermore hosted a Moroccan nuclear scientist for hands-on technical training in radiological analysis for environmental monitoring. In addition, Laboratory health physicists assisted Libya in the restart of its nuclear reactor at Tajura with low-enrichment fuel and in the calibration of a new modern dosimetry system. Livermore technical experts also engaged in follow-up transparency activities in Libya for the trilateral U.S.–U.K.–Libya agreement under which Libya eliminated its clandestine nuclear weapons program.



As part of its involvement in the Sister Laboratory Program in North Africa, Livermore hosted a Moroccan scientist (center, in gloves) who was trained in radiological analysis for environmental monitoring.

# R&D Advances Laboratory Missions

Lawrence Livermore National Laboratory is a home of extraordinary science and technology. We are a place where researchers model the motion of millions of atoms for billionths of a second to determine the property of materials and also simulate weather patterns and ocean currents on the scale of tens of kilometers for hundreds of years to study climate change. Engineers develop micromechanical systems to quickly detect biological agents and search for planets in other solar systems. Scientists manufacture new materials by layering atoms to make, for example, mirrors for x rays that are used to image complex molecules. The particle is frozen in motion because the pulse of the x rays is only quadrillionths of a second long.

More than the prospect of scientific discovery or technical breakthrough, our scientists and engineers are motivated by the importance of the Laboratory's missions and the opportunity to contribute to national security and

global stability. We take a multidisciplinary approach to problem solving by drawing on the work of exceptional individuals and team efforts.

The sponsors of our work rely on and invest in our unique capabilities, the special skills of our researchers, and our broad science and technology base. Our internal investments—such as the Laboratory Directed Research and Development Program—closely align with our missions. We strive to make dramatic advances to meet mission objectives and prepare for emerging national needs.

Breakthroughs made by Laboratory scientists and engineers often have broad applicability. For example, developments in adaptive optics that made possible the National Ignition Facility also vastly improve the capabilities of ground-based telescopes and aid in the search for distant planets. Our research efforts frequently entail partnerships with other laboratories, industry, and research universities. Through these collaborations and peer review of our work, we benefit from advances in international science and technology to meet mission needs.



**Cherry Murray**

Principal Associate Director  
Science and Technology

## Science and Technology

### Materials at the Fundamental Level

Experiments performed at the FLASH free-electron laser facility in Hamburg, Germany, demonstrated a new technique for studying the dynamic properties of materials under extreme conditions. Sir Isaac Newton's "dusty mirror experiment" gave a Laboratory physicist the idea for the work, and results were reported in the August 9, 2007, issue of *Nature*. The research team placed an x-ray mirror a short distance behind the targeted material. An extremely short x-ray laser pulse blew up the target and the pulse bounced off the mirror, allowing the researchers to look at the object again after it exploded. The diffracted light from the pulse and its reflection was combined, creating an interference pattern that was used to form a hologram (three-dimensional image) of the object at the scale of nanometers and femtoseconds (quadrillionths of a second). This technique was developed for experiments that will image single molecules using the Linac Coherent Light Source at Stanford University when it opens in 2009.

To probe the properties of materials under extreme static conditions, Laboratory researchers use a diamond anvil cell. One research team studied the electronic spin state of iron in ferropericlase (iron magnesium oxide) at the high temperatures and pressures

that exist in Earth's lower mantle. They were able to determine the location of the spin-transition zone in the mantle, where iron is in a mixture of high- and low-spin states. Ferropericlase is the second most abundant mineral in the lower mantle, and by determining its spin state, scientists can better understand Earth's structure, composition, and dynamics, which affect geological activities on the planet's surface.

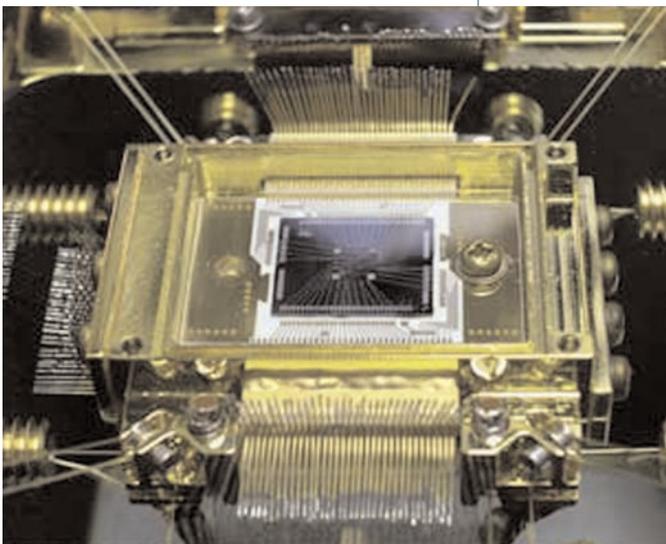
Researchers used this detector to obtain the most accurate measurements yet of the energy difference between the ground state and the first excited state (isomer) of thorium-229. This success brings scientists one step closer to being able to turn on and off the decay of a nuclear isomer.

*Physical Review Letters* reported in 2007 on the efforts of a Livermore-led nuclear physics collaboration that measured the energy difference between the ground and first excited (isomer) state of thorium-229. Excited states of nuclei are thousands of times more energetic than electron excited states. The thorium isomer is of particular interest because the energy difference is low enough that the isomer is accessible to laboratory study. The next step is to use a tabletop laser to transition thorium-229 nuclei between its ground and isomeric states. The amount of energy that could be stored would be much higher than that in conventional energy storage devices, opening up exciting potential applications and new physics to explore.

### Supercomputing Challenges

In 2007, Livermore's "Grand Challenge" scientific computing program allocated 83.7 million hours of machine time on the Atlas and Thunder supercomputers to 17 research projects. Atlas and Thunder, at 44 teraflops and 23 teraflops, respectively, are the workhorses for unclassified, high-end computing across the Laboratory. To be considered for the program, a project has to address a grand-challenge-scale, mission-related problem that promises unprecedented discoveries in a particular scientific and/or engineering field of research. An additional criterion is that if the work is successful, it will result in high-level recognition by the scientific community at large. Results from calculations on the two machines advanced research in nuclear physics, materials science, global climate change, and more.

The March 2007 cover of *IEEE Transactions on Magnetics* featured simulations of magnetic fields in complex geometries using EMSolve, a computer code developed at Livermore for simulating the propagation and interaction of electromagnetic fields. It is the most



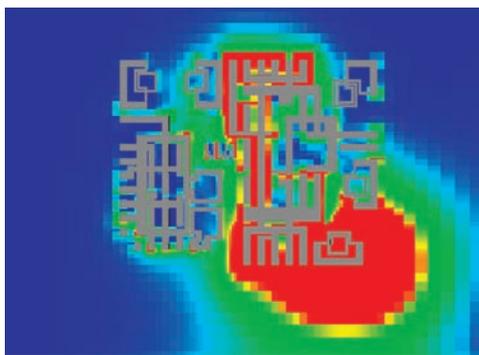
## Science and Technology

accurate, powerful, and flexible tool ever developed for solving Maxwell's equations, which describe how a changing magnetic field produces an electric field and vice versa. Laboratory scientists and engineers use EMSolve to simulate electromagnetic fields in structures ranging in size from a computer chip to a two-story building. Magnetic fusion energy, lasers, radar, nuclear weapons effects, electronics, and communication systems all involve electromagnetic phenomena that must be accurately calculated. EMSolve has also been licensed to private industry.

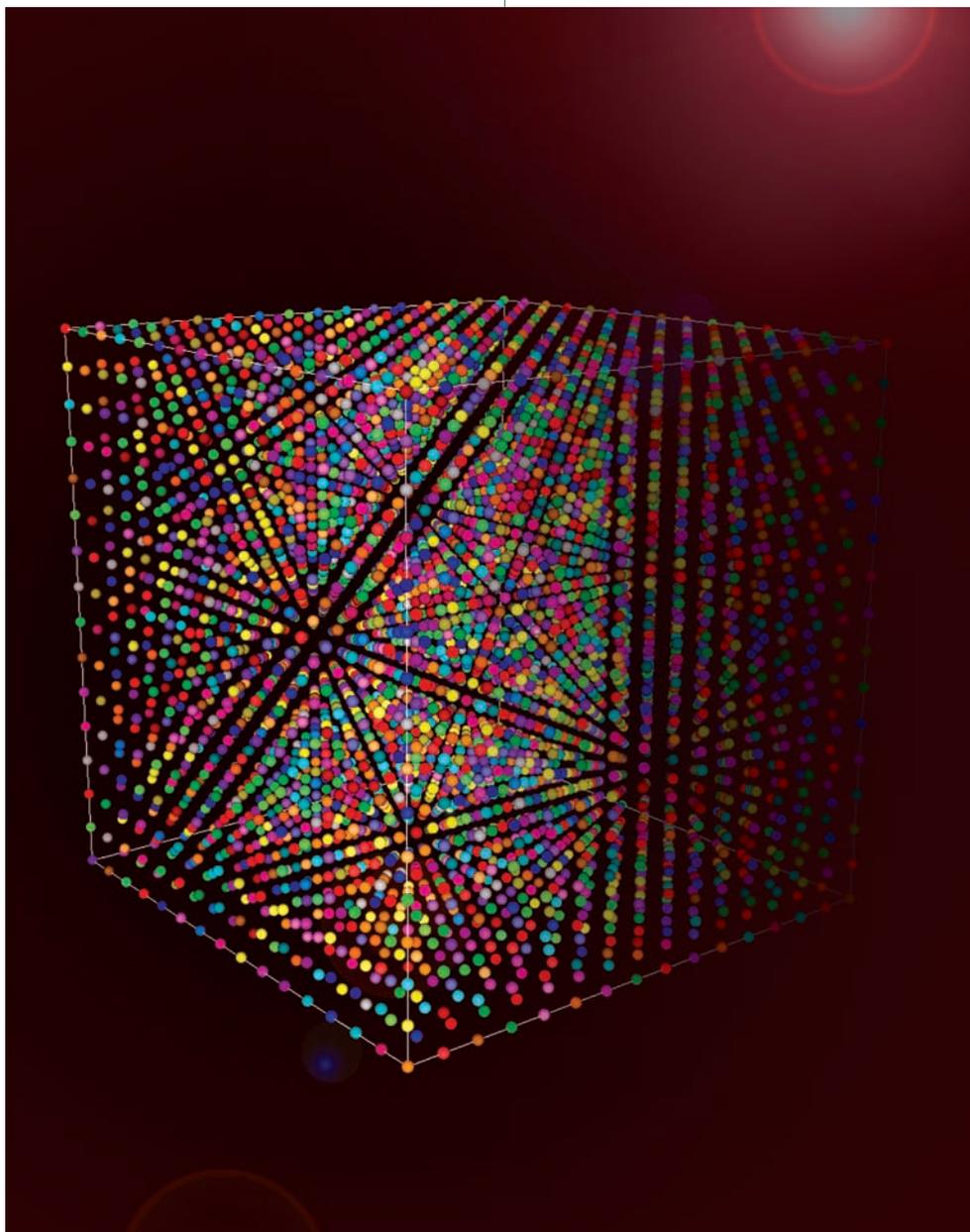
BlueGene/L, the world's most powerful computer (see p. 8), is proving to be an essential tool for studying the behavior of nuclear particles immediately after the big bang. Quarks, the building blocks of all nuclear material, ran free in a hot plasma for about 10 millionths of a second after the big bang. As the universe continued to expand and cool, the quarks coalesced into protons and neutrons. In a very brief reverse big bang, experiments at Brookhaven National Laboratory succeeded in creating individual quarks by colliding extremely high energy gold ions. The particle interactions were much stronger than expected. To explore the discrepancies, a large Livermore-led

collaboration is simulating the plasma from when the transition from quarks to larger particles occurred to determine its equation of state. Only with an accurate equation of state can the full hydrodynamics of the transition be modeled. Equation-of-state calculations to date have narrowed the estimated temperature at the transition—approximately 2 trillion degrees or 170 million electronvolts—to within about 10 million electronvolts.

A simulation of quark behavior captures the potential energy between two quarks. Various types of quarks make up protons, neutrons, and other nuclear particles.



An analysis using the electromagnetic code EMSolve studied noise in integrated circuits containing both digital and analog components. In this simulation, red denotes the highest magnitude and blue the lowest of the electric current in the substrate.



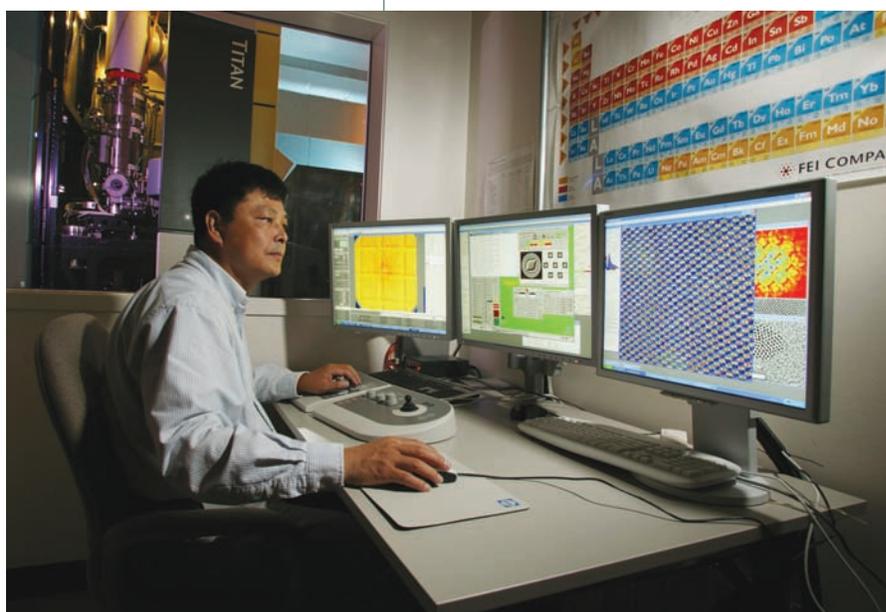
## Science and Technology

The Laboratory's newest super scanning transmission electron microscope can resolve objects smaller than 1 nanometer.

### Tools to Power Nanoscale Research

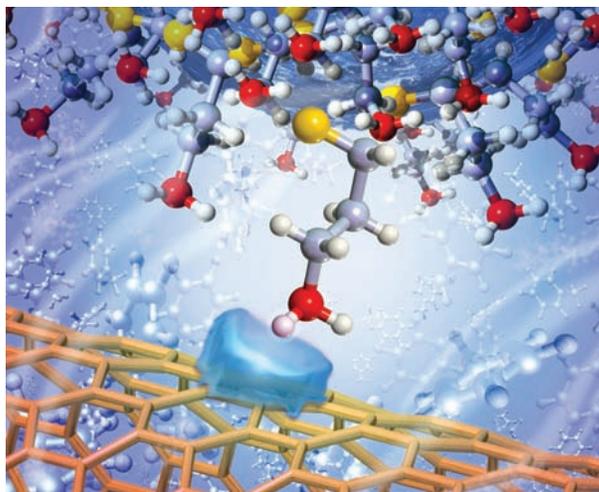
Acquired in 2007, the Laboratory's new super scanning transmission electron microscope (SuperSTEM) is the highest resolution microscope in the world and is one of several new devices at the Laboratory that are revealing the behavior of materials at the formerly invisible nanometer scale (one million nanometers equals one millimeter). This more advanced instrument, able to resolve features as small as 0.08 nanometers, replaces the world's first super

scanning microscope, which was installed at the Laboratory in 2004 and used in the analysis of samples from Comet Wild 2. SuperSTEM is an advanced form of a transmission electron microscope with an added electron beam that focuses on a narrow area of the sample and scans it, providing the means to derive the identity and chemical and electronic states of individual atoms. This information is obtained simultaneously as an image builds up, thereby forming a direct correlation between the image and electronic data. SuperSTEM produces images magnified more than 1 million times.



With chemical force microscopy—a nanoscale technique that measures interaction forces using tiny spring-like sensors—researchers measured a single interaction of a chemical functional group with a carbon nanotube. Carbon nanotubes are used in composite materials, biosensors, nanoelectronic circuits, and membranes. Yet little is known about the interaction at the atomic scale of nanotubes and chemical functional groups, the smallest group of atoms that determines the chemical reactions of a molecule. Livermore scientists achieved a true single function group interaction by reducing the probe–nanotube contact area to about 1.3 nanometers. Their research, published in the October 14 online issue of *Nature Nanotechnology*, indicates that the interaction strength depends on the intricate electronic interactions between the nanotube and the functional group. Understanding these interactions is necessary for the engineering of future generations of sensors and nano devices that will rely on single-molecule coupling between components.

An artist's rendering depicts an experiment that achieved a true single function group interaction. An amine functional group, attached to the tip of a probe, is brought near the surface of a carbon nanotube. As it approaches, a polarization charge, shown by the translucent blue shape, forms on the nanotube.



Using a high-resolution secondary ion mass spectrometer (NanoSIMS), a team that included Livermore researchers has shown that blue-green algae are significant species in the global carbon cycle. Imaging and tracking nutrient uptake at the nanoscale revealed that these cyanobacteria transform nitrogen gas from the atmosphere into a usable nutrient, enabling photosynthesis in nutrient-poor waters. NanoSIMS provided the

## Science and Technology

ability to map the distributions of elements and isotopes with a 50- to 100-nanometer resolution. The research, which demonstrated the utility of NanoSIMS as a cellular microbiology research tool, appeared in the August 1, 2007, issue of *The International Society for Microbial Ecology Journal*.

### Sharp Focus on Adaptive Optics

Livermore leads an international consortium that is developing the Gemini Planet Imager, which will allow scientists to directly image planets around distant stars. When it comes online in Chile in 2010, the Imager will bring into sharp focus planets and other objects 30 to 150 light years from our solar system. It will be the most capable adaptive optics system in the world.

Adaptive optics use a mirror whose shape can be adjusted hundreds of times per second. This allows astronomers to compensate for atmospheric turbulence and take the twinkle out of starlight, bringing

into focus stars, galaxies, and planets in a telescope's field of view. At the heart of the Gemini Planet Imager are next-generation adaptive optics designed by Laboratory scientists to gain even sharper, higher-contrast images. To keep the mirror small while incorporating 10 times as many actuators as in current adaptable mirrors, scientists chose a silicon microelectromechanical system (MEMS) device. It is lithographically patterned and etched like a microchip. The Laboratory is home to one of the world's best adaptive optics teams, who apply the technology to the National Ignition Facility, satellite-based surveillance, astronomy, vision correction, and more.

Livermore physicists used adaptive optics to discover the location and makeup of a pair of supermassive black holes at the center of a collision of two galaxies more than 300 million light years away. Scientists at the W. M. Keck Observatory in Hawaii were able to obtain clear images of the hot dust in the infrared wavelength,

the stars in the visible and infrared, and the x rays and radio emissions coming from around the black holes. These observations lend support to the theory that black holes at the center of galaxies reach their immense mass through mergers with nearby black holes. Studying galaxy mergers is a way to learn how galaxies evolve and the role black holes play in the process.

A MEMS-based adaptive optics system is central to a new ophthalmoscope that won a Laboratory team an R&D 100 Award in 2007. The ophthalmoscope sharpens images of the retinal cell layers in a patient's eye, allowing clinicians to diagnose macular degeneration and other retinal diseases much earlier than was previously possible. The system can also be used to monitor a patient's treatment. Similarly, a team from national laboratories, universities, and private industry has developed a miniscule device that is inserted in the human eye to restore some sight for those with retinal disease.

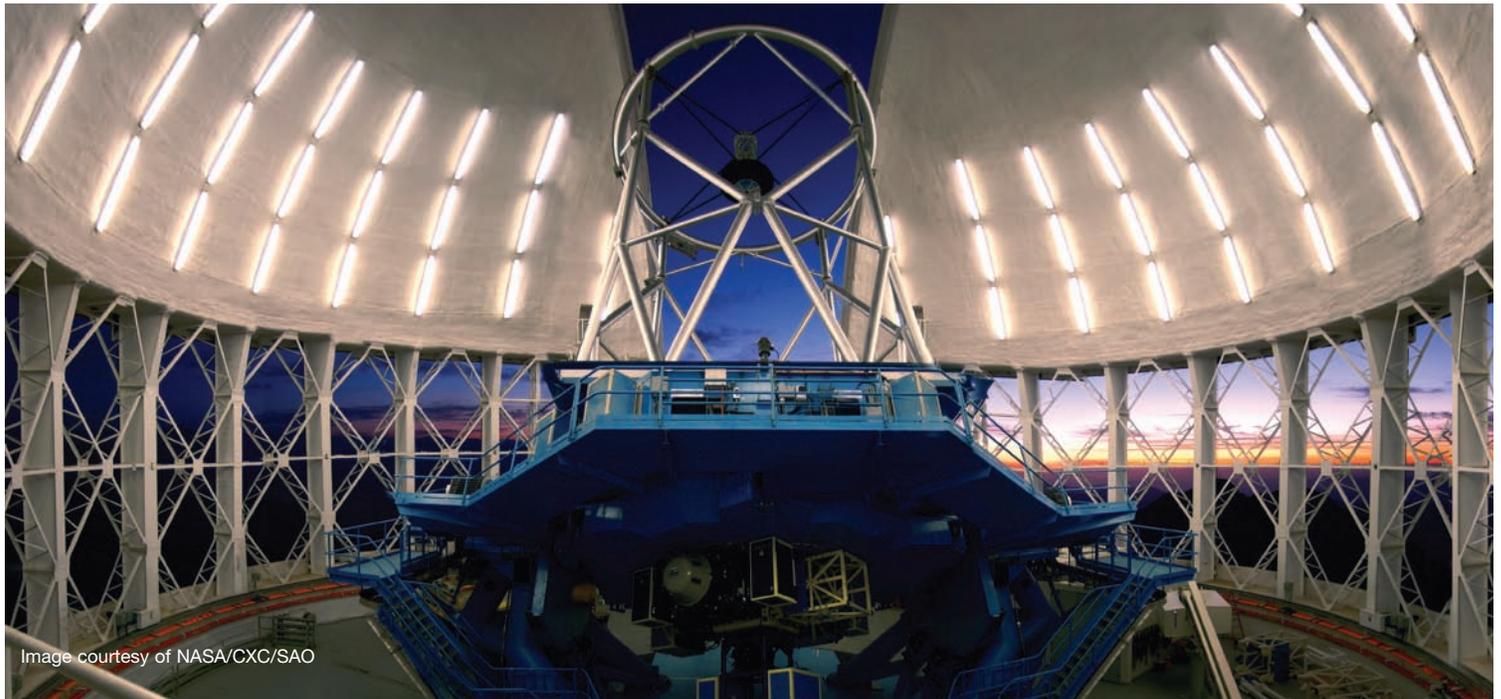


Image courtesy of NASA/CXC/SAO

The Gemini Planet Imager, which will allow scientists to directly image planets around distant solar systems, will be installed at the Gemini South telescope in Chile in 2010. (Courtesy of Gemini Observatory and the Association of Universities for Research in Astronomy.)

## Science and Technology

A medical physicist at the University of California (UC) at San Francisco shows how a patient with melanoma of the eye would receive proton beam therapy when a proposed compact proton therapy machine is available. Here he uses a larger device at the Crocker Nuclear Laboratory at UC Davis, which is partnering with Livermore in developing the new device.



Livermore engineers designed the MEMS-based array of actuators.

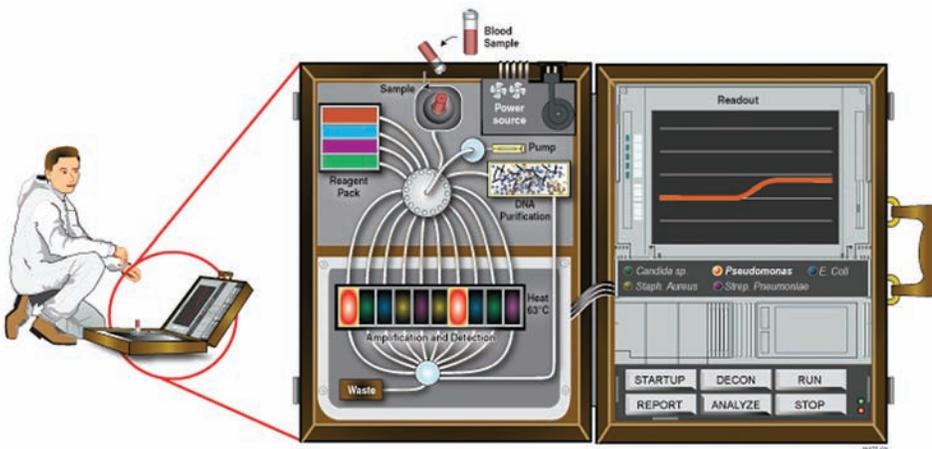
### Improving Human Health

TomoTherapy Incorporated of Madison, Wisconsin, entered into an agreement with the Laboratory and UC Davis in June to develop the first compact proton therapy system, one that will fit in any major cancer center and cost a fifth as much as the larger machines used today. Proton therapy is considered the most advanced form of radiation therapy available, but size and cost have limited the technology's use to only six cancer centers nationwide. TomoTherapy is funding development of the first clinical prototype, which will be tested on patients by physicians at the UC Davis Cancer Center. Livermore researchers overcame the size obstacle by using dielectric wall accelerator technology developed through defense research. They have demonstrated in principle that this technology will accelerate proton particles to an energy of at least 200 million electronvolts within a light-weight, insulator-based structure just 2.2 meters long. Existing systems use accelerators that weigh up to several hundred tons and are the size of a basketball court. The new system will also improve on existing technology by including the capability to

vary the energy, intensity, and "spot" size of the proton beam.

Researchers from the Laboratory and the UC Davis Health System were awarded a five-year grant in November 2007 to develop new technologies for "point-of-care" (POC) testing. Instead of having to transport a blood sample to a hospital, doctors will be able to diagnose bloodstream infections at the scene of a disaster. The National Institute of Biomedical Imaging and Bioengineering, part of the National Institutes of Health, granted funds to develop two prototype instruments that simultaneously conduct five bacterial and fungal evaluations. One instrument is for use in hospital settings and the other is portable, for use in the field. Grant funds will also be used to evaluate other exploratory diagnostic technologies intended to prepare the nation for disasters. This work is being undertaken through the UC Davis–Livermore Center for POC Technologies, which is part of the newly established National Institute of Biomedical Imaging and Bioengineering POC Technologies Research Network.

A Livermore team has developed a new method using accelerator mass spectrometry (AMS) to examine the metabolism of a chemical DNA lesion called 8-oxodG, one of the most prevalent mutagenic lesions found in DNA and an apparent cause of cancers and diseases related to aging. Their findings were featured on the cover of the July 3, 2007, issue of the *Proceedings of the National Academy of Sciences*. Considerable data exist about how DNA can repair this lesion, but little was known about where in the cell 8-oxoG is formed and how it is metabolized and incorporated into DNA. With AMS, the team precisely measured the metabolism of 8-oxoG in a type of human breast cancer cell called MCF-7. Researchers exposed cells to 8-oxoG tagged with carbon-14 and used AMS to measure the incorporation of 8-oxoG into MCF-7 cells over time. This research demonstrated that 8-oxoG can be absorbed by the cells and incorporated in the DNA to cause mutations that lead to disease. Prior to this study, researchers believed that 8-oxodG only formed directly in the DNA.



This artist's concept illustrates how the point-of-care diagnostic unit being developed by Livermore and the University of California at Davis will operate. Doctors will be able to identify bloodstream infections in an hour instead of a day or more.

# Teamwork to Improve Work Practices

LLNS assumed management of the Laboratory with the aim of strengthening the collective commitment to safety, security, and environmental stewardship and improving operational efficiency and effectiveness. Livermore's operations and business functions had in place many best-in-class practices. Yet, in many operations and business areas, we can do better.

We are building on our successful work practices by making certain that they are followed consistently across the Laboratory. Taking work safety as an example, the National Ignition Facility project has excellent safety programs and an outstanding record of safety performance. Best practices in this project and other successful endeavors are being standardized institutionally and lessons learned will be widely shared with the aid of safety specialists who are integrated into programmatic activities across the Laboratory. Safety is a team effort, depending on a personal commitment by all employees and their participation in the development and

implementation of prudent work control processes.

We are also bringing new tools into the workplace—in some cases from LLNS parent organizations—to help us do our job better. The Earned Value Management System (EVMS) is being evaluated for application across the Laboratory on a graded basis, with the first deployment to support operations and business functions. Selected areas of the Laboratory are already using EVMS for project management to meet technical requirements, cost, and schedule. We are implementing Six Sigma methods to support continuous improvement initiatives, and the Laboratory's Business Systems Improvement Project aims to integrate financial, procurement, and human resource systems for better project management.

The key to higher quality and more cost-efficient operations is teamwork—a hallmark of this Laboratory. We are working together for continuous improvement with a focus on standardizing work processes, eliminating duplication and redundancies, and implementing value-adding tools and systems to manage work.



**Frank Russo**

Principal Associate Director

Operations and Business

## Operations and Business

### Safety is Paramount

Livermore's Integrated Safety Management (ISM) system provides a framework for continually improving safety procedures and practices. A focus on safety by each individual, sound implementation of ISM, and a commitment at all levels of management are critical to success. The Laboratory director's A List features "Strengthen our collective commitment to safety, security, and environmental stewardship" as the first item, and the director stresses this theme in all of his Laboratory-wide talks to employees.

Illness and injury rates are stable after a dramatic decline since the early 2000s. For FY 2007, the rate for recordable cases (number of cases per 100 employee-years) was 2.59, while the rate for cases with days away, restrictions, or job transfers was 1.00. The Laboratory as a whole can do better and has since the beginning of FY 2008 in October. The new management team has set "The Goal is Zero" for

accidents and reinvigorated senior management leadership in safety. In addition, Laboratory management is revitalizing grass-roots safety committees and seeking employee involvement in improving health and safety programs.

One particular focus is to strengthen implementation of more uniform, high-quality safety practices across the Laboratory. The Office of Independent Oversight of the DOE Office of Health, Safety, and Security identified this issue during an inspection of the Laboratory in January 2007. The inspection also revealed a number of positive safety activities, including effective processes for annual assessments of ISM implementation, work control in the Plutonium Facility, waste management and cleanup in the Contained Firing Facility, and pollution prevention/waste minimization.

In May, NNSA's Livermore Site Office approved the Laboratory's Worker Safety and Health Program plan. Required for all

The Laboratory's annual environment, health, and safety fair in June drew hundreds of attendees. The 2007 theme was "Live Safely—Work Safely."



## Operations and Business

DOE sites by federal regulations (10 CFR 851), the document describes Livermore's plan to protect against workplace hazards and reduce or prevent injuries, illnesses, and accidental losses. The well-being of all employees is also the focus of the Laboratory's Healthy Heart Program. To date, more than 2,000 individuals have participated in risk assessments, offered at no cost to employees. The goals of the Healthy Heart Program are to reduce the risks of cardiovascular diseases and diabetes through comprehensive screenings, education, and programs that create a healthier work environment.

### Consolidating Nuclear Materials

The Laboratory's Plutonium Facility (Building 332, also known as the Superblock) provides vital support to NNSA's Stockpile Stewardship Program. Research and development activities at the facility include nonnuclear testing of weapons components



Visitors to the Superblock from the Defense Nuclear Facilities Safety Board and NNSA discuss with a Laboratory expert the packaging of materials to be shipped off site.

for surveillance programs, physics and engineering experiments on plutonium, and investigation of technologies for remanufacturing plutonium parts in nuclear components. In the future, Laboratory scientists and engineers will be using facilities elsewhere to conduct much of this work. NNSA's plans for transforming the nuclear weapons complex include the consolidation of weapons-grade plutonium and enriched uranium to fewer sites, including the removal of Security Category I/II quantities of special nuclear materials from Livermore. Only Security Category III amounts of nuclear materials will remain for small-scale experiments.

The removal of weapons-grade nuclear materials from Livermore is to be completed by 2012—two years earlier than planned when the first shipment of plutonium left the Laboratory for Los Alamos National Laboratory in late 2006. In 2007, additional material was characterized, processed, packaged to meet rigorous shipping requirements, and moved from Livermore to the Savannah River Site in South Carolina, where surplus nuclear materials are being consolidated. The

shipment fully complied with safety and environmental laws and procedures. The move required extensive planning and coordination with DOE headquarters and Savannah River personnel. To develop the overall plan to remove materials from the Superblock by 2012, Laboratory experts had to consider isotopic content, mass, form, and other factors because they affect packaging, shipment, and disposition at the receiving sites.

Efforts continue to increase efficiency, lower costs, and increase safety in Superblock operations as programmatic work continues. Effective and well-defined work control processes are in place, and the Laboratory has made significant improvements in surveillance testing, maintenance, and the process for handling unreviewed safety questions. Implementation of Building 332 Documented Safety Analyses and Technical Safety Requirements is on schedule. Other important improvement initiatives are under way as well, including activities in response to DOE's 2007 independent oversight inspection and a LLNS AIM (assess, improve, and modernize) team review of Nuclear Operations in November 2007.



## Operations and Business

The Laboratory installed photovoltaic lighting along some pathways at the Laboratory. Each of the solar lighting units is independent and none are connected to the power grid. Installation is less costly than conventional lighting.

### Responsible Environmental Management

Results reported in the *Lawrence Livermore National Laboratory Environmental Report 2006*, released in December, exemplify the Laboratory's commitment to environmental cleanup and environmentally responsible management of its activities. The report found no adverse impact to public health or the environment. The assessment was based on samples taken from air, water, vegetation, soil, and wastewater on site and in surrounding communities as well as wine from vineyards near the Laboratory. In addition, the report documents the

substantial actions the Laboratory takes to comply with federal, state, and local environmental laws, including the Clean Air Act, Resource Conservation and Recovery Act, and National Environmental Policy Act, among others. For FY 2007, environmental restoration projects for the Livermore Site and Site 300 continued to meet their milestones.

In implementing its ISO 14001 Environmental Management System (EMS), the Laboratory established directorate-specific targets and objectives for significant activities, products, or services that influence the environment and are within the organization's control or influence. EMS, which is part of Livermore's ISM system, promotes responsible environmental stewardship practices with continuous improvement through pollution prevention and conservation measures.

Aggressive programs at Livermore in pollution prevention, waste minimization, and recycling have led to numerous awards from DOE and external regulatory agencies. The Laboratory earned the Environmental Protection Agency Region 9 Champions of Green Government Award for an innovative strategy using contractual mechanisms to eliminate waste streams and increase reuse of materials. The NNSA presented the Pollution Prevention Program Best-In-Class Award to the Laboratory's Space Action Team. In the demolition of old structures, the team reduced costs by finding and removing lead paint and other hazardous materials to allow more metal items to be recycled and minimizing the amount of hazardous waste. The waste minimization practices at Site 300's Contained Firing Facility garnered an NNSA Pollution Prevention Environmental Stewardship Award. In addition, the Laboratory received from the White House an honorable mention Closing the Circle Award.

With the opening of the new E85 fuel station on site in May 2007, the Laboratory became a test site for the use of ethanol in



## Operations and Business



The new E85 ethanol-gasoline fueling station helps the Laboratory comply with presidential executive orders to "green the government" and reduce consumption of petroleum products.

vehicles. With 281 alternative-fuel vehicles, the Laboratory has the largest fleet of E85 fueled vehicles in California and the largest of any DOE national laboratory. E85 is a blend of 85 percent ethanol and 15 percent gasoline. Using ethanol reduces the use of petroleum and the amount of pollutants emitted into the atmosphere.

### Effective Facilities Management

Unique, state-of-the-art experimental and computational facilities are a core strength of the Laboratory. The Terascale Simulation Facility and the nearly completed National Ignition Facility are flagship facilities and cornerstones of NNSA's Stockpile Stewardship Program. In 2007, the \$26.6 million Engineering Technology Complex Upgrade was completed to modernize a facility that provides a precision fabrication capability

essential for stockpile stewardship and other programs at Livermore.

As the transformation of the nuclear weapons complex proceeds, the list of older buildings and legacy facilities is growing. In addition, the Laboratory's information-technology infrastructure is in need of modernization. Livermore's facility and infrastructure investment strategy, formulated in full partnership with NNSA, balances efforts to rehabilitate older facilities, consolidate activities as mission priorities change, maintain aging mission-critical facilities, and efficiently manage legacy facilities. Through effective facility management practices, including an aggressive reinvestment program established in 1998, the Laboratory has stabilized its backlog of deferred maintenance at a level that met NNSA's corporate goals several years ahead of schedule.



Former Laboratory scientific leaders, Jay Davis and Hans Mark, discuss the historic significance of Building 212, which housed a 90-inch cyclotron, with the project manager responsible for the building's demolition.

Livermore is widely recognized as having a highly cost-effective program for decontaminating and demolishing buildings, with a best-in-class safety and environmental record. From 2002, when NNSA began funding such projects through this coming year, the Laboratory will have demolished approximately 400,000 gross-square-foot (gsf) of legacy space. Among the larger projects, decontamination and demolition of Building 431—a 53-year-old, technically obsolete, five-story structure—was completed in 2007, and demolition is under way on the 64-year-old Building 212, for a total of about 150,000 gsf. Livermore expects to contribute an additional 470,000 gsf toward the complex-wide goal of demolishing 5 million gsf of legacy space by 2017.

## Operations and Business

### Upgrading Business Systems and Practices

Activities to upgrade information and financial systems, adopt best practices in all areas of business services and operations, and continuously improve work processes aim to increase the cost efficiency of Laboratory work as well as sponsor satisfaction with the quality of work products. Multiyear initiatives to improve work tools and practices are under way, and they are enhanced by the expertise and proven systems that the new management team and LLNS parent organizations bring to the Laboratory.

Large projects at the Laboratory, such as the National Ignition Facility and recently

completed Engineering Technology Complex Upgrade, and a growing list of smaller efforts have benefited from the use of EVMS. Considered to be a best-practices tool, EVMS provides an effective means for evaluating how well a project is being executed with respect to technical requirements, cost, and schedule. EVMS offers a clear view of status and progress to sponsors, Laboratory managers, and those engaged in the project. Implementing EVMS across the Laboratory is being done on a graded basis, first in selected directorates as a pilot project. Effective use of EVMS depends on the accurate development of a project's Work Breakdown Structure (WBS)—the work elements of a project and their relationships with each other and the final product. WBS tools,

training, and integration into the financial management systems are critical for optimal project management.

The multiyear Enterprise Project Accounting and Reporting Program, now called the Business Systems Improvement Project (BSIP), completed the second of four development and release phases in 2007. BSIP aims to integrate Livermore's financial, procurement, and human resources systems. Improvements to date pave the way for the ongoing third phase, which is to convert all institutional business systems from a cost account basis to a project and task basis, allowing effective use of WBS and EVMS. In the human resources area, the Laboratory's system for managing employee information, the Livermore Administrative People Information System (LAPIS), continues to be upgraded with new online, self-service features. LAPIS was able to handle most personnel actions related to employment and retirement options during the transition from management by UC to LLNS. The Laboratory is completing transfer of the day-to-day operation of these institutional computer systems to a new secure, highly reliable data center that was built and opened for service in 2007.

The Contractor Assurance System Continuous Improvement Office is providing resources to assist organizations in performance improvement. Three process analysts work alongside teams within organizations to help improve existing processes and design new practices to meet customer needs. In 2007, these analysts undertook Bechtel's Black Belt training in Six Sigma, a data-driven methodology for increasing the quality and efficiency of work activities. More than 60 process improvement projects are completed or well underway, spanning every directorate at the Laboratory. Many projects are focused on achieving greater cost efficiencies.



The National Ignition Facility has successfully used the Earned Value Management System for several years to track construction and commissioning activities and keep them on schedule.

# Making Our Future

Since its founding, the Laboratory has sustained a remarkable focus on mission. Multidisciplinary teams execute work in the tradition of Laboratory co-founder E.O. Lawrence, who demanded scientific and technical excellence. Not surprisingly, "Passion for Mission" tops the list of our shared values. LLNS, the new management and operating contractor, is fully committed to the Laboratory's long-held values and carrying on the tradition of scientific and technical excellence in service to the nation.

The vision for the Laboratory is to provide national security in a global context. We bring technical leadership to the transformation of the nuclear weapons complex, deliver exceptional science and technology, expand our work for other sponsors, and enhance operational performance. This vision calls for change at the Laboratory and in our working relationships with our primary customer, the NNSA, as well as other work sponsors.

A challenge within the Director's Office is to lead the way through changes to make the Laboratory's future. One major thrust is to improve cost efficiency as we sustain our reputation for mission delivery and scientific and technical excellence. We are drawing on best practices, lessons learned, and expertise from across the Laboratory and LLNS's parent organizations to achieve consistently high standards in work performance. We are also enhancing safety and security as well as our capabilities and systems to provide assurance to NNSA and ourselves that we are meeting our performance goals.

A second major thrust is to ensure that the Laboratory is appropriately sized and has a workforce with the proper mixture of skills to meet the future. As Livermore undergoes change—at times stressful—we are keeping the big picture in mind: the importance of service to the nation, an outstanding diverse workforce, and trust in the institution by our neighbors and the general public.



**Steve Liedle**  
Deputy Laboratory Director

## Management and People



Laboratory director George Miller serves as president of Lawrence Livermore National Security, LLC, the new public-private partnership that began managing and operating the Laboratory on October 1.

### LLNS Takes Charge

On October 1, 2007, a newly formed public-private partnership, LLNS, began its contract with DOE to manage and operate the Laboratory. LLNS is a limited-liability company made up of Bechtel National, Inc., UC, Babcock & Wilcox Company, the Washington Group Division of URS Corporation, and Battelle. Four small business subcontractors and Texas A&M University are also members of the team. Laboratory director George Miller serves as president of LLNS and reports to NNSA and the LLNS Board of Governors.

LLNS brings together an enormous experience base. Bechtel is the largest project management contractor in the United States, and UC is the world's largest academic research institution. Babcock & Wilcox Company and the Washington Group Division of URS Corporation are the top two DOE nuclear facilities contractors. Between them, they manage and operate

four of DOE's five safest sites. Battelle is a national leader in managing research and development laboratories and commercializing technology. As an academic affiliate of LLNS and a major university system, Texas A&M adds strengths in national and homeland security science and policy areas.

The parent organizations contribute to the success of the Laboratory through their oversight of performance, primarily executed through a Board of Governors. Seven Board committees provide oversight support, review strategic plans, and advise on future trends and challenges. Systems, tools, and best practices, such as AIM (assess, improve, and modernize) teams, are being brought into Livermore from the parent organizations. An AIM team arrived in November to review nuclear operations, identify improvement activities, and suggest possible "imports" from other sites. More such AIM reviews will occur during this fiscal year.

Individuals from many Laboratory organizations prepared for the transition and then worked with the Lawrence Livermore National Security, LLC transition team after their arrival in May.



## Management and People

### Making the Transition

Transition to LLNS management of the Laboratory formally began with DOE's announcement of the selection in May 2007, following the first open competition for managing Lawrence Livermore. One of the LLNS partners—UC—had operated the Laboratory since its inception in 1952 as part of E. O. Lawrence's Radiation Laboratory.

Almost a year before the contract award, pre-transition activities started to prepare for the process of transferring people, property, and procedures as well as contracts, formal agreements, and liabilities to the new contractor. The team identified more than 1,600 activities that had to be carried out, many of them driven by the change from a not-for-profit to a private entity. Throughout the process, the Laboratory maintained a website to keep employees informed and answer questions about the transition. Communication efforts also included a special Web site, benefits hotline, frequent features in the Laboratory's newspaper, *Newsline*, and on-site and off-site briefings to employees and retirees.

Many transition tasks were formidable. For example, the complete organizational structure of the Laboratory was documented, and more than 7,700 offer letters were mailed. The transition team, assisted by 18 Laboratory hazards control experts, conducted a walkdown and assessed more than 7.5 million square feet of facilities. A complete inventory of all Laboratory assets, comprising more than 62,000 pieces of property valued at \$1.3 billion, was reviewed. All of the Laboratory's roughly 900 policies and procedures also were reviewed, and more than 3,000 subcontracts were formally transferred to the new LLC.

Two special events on September 25, marked the end of the transition. The LLNS Board of Governors held its first meeting at the Livermore site. The board reviewed readiness reports prepared by transition team

leaders and future plans for the Laboratory presented by the incoming management team. At a noontime gathering, employees celebrated the Laboratory's UC heritage with lunch, displays by directorates, and distribution of a Laboratory photo-history book commissioned by UC. The formal program that followed included the screening of a video recollecting the shared history with UC, remarks by UC president Robert Dynes, and personal observations from a panel of former Laboratory leaders.

At an event commemorating the Laboratory's 55-year connection to the University of California, director George Miller applauds as University president Robert Dynes receives a box of thank you notes from Laboratory employees. The cover of a photo-history book appears in the background.



## Management and People

### Managing Budget Realities

In anticipation of the impending contract competition, the Laboratory began in FY 2006 to aggressively cut costs and restricted hiring to “right-size” the workforce. The management change from a not-for-profit to a private entity led to additional costs. However, contract costs are higher than expected, and the number of employees leaving the Laboratory in FY 2007 was much smaller than in a normal year. In September, with federal budget uncertainties looming, NNSA administrator Tom D’Agostino directed each of the NNSA site contractors to actively collect information and prepare documents necessary to meet the legal requirements associated with “workforce restructuring.” The need for further downsizing and greater cost efficiency was apparent.

The Laboratory has formed a task force to identify and implement ways to reduce Laboratory operating costs. More than \$34 million in savings were initially found and cost-reduction efforts continue. The Laboratory also began drafting for NNSA a general workforce restructuring plan that would provide the basis for implementing a specific plan if one is warranted. In addition, in mid-November, the Laboratory announced significant reductions in its supplemental and flexible workforces for January 2008.

When the Laboratory’s budget situation clarified—with about a \$100 million cut for FY 2008—the Laboratory decided a restructuring of the permanent workforce was needed to further reduce the size of the Laboratory by about 10 percent. In Laboratory-wide meetings, Laboratory

Former Laboratory leaders shared their recollections of the the Laboratory’s history with the University of California.



## Management and People

director George Miller acknowledged that the process would be stressful but was necessary for Livermore to become “more capable, more cost effective, and more competitive.” The specific plan seeks to mitigate the impact of reductions by starting with a voluntary phase. The plan is designed to shape the workforce in a way that positions Livermore for FY 2009. The Laboratory will maintain the critical skills, special capabilities, and diversity necessary to sustain Livermore’s intellectual vitality, meet mission deliverables, add new customers, and perform work safely, securely, and efficiently.

### Improving Security and Emergency Response

The Laboratory operates routinely at a heightened security level. Continual improvements are being made in cyber security. As a site with Security Category I/II special nuclear materials, Livermore requires the highest level of protection. Beginning in 2003, the Laboratory significantly upgraded its security posture by adding a number of officer survivability features, deploying force multiplier technology, and further hardening potential targets. This approach allowed Livermore to successfully meet the required protection criteria with a minimal increase in recurring costs. The Laboratory continues to adjust its security posture consistent with DOE requirements and the complex restructuring and consolidation initiative.

Effective implementation of Livermore’s Integrated Safeguards and Security Management (ISSM) helps to ensure that security is a top priority for all employees. Individual and collective responsibilities for safeguards and security are made clear to Laboratory personnel, who are required to complete necessary training. Line management is accountable for performance and conducts an annual self-assessment in



The Alameda County Regional Emergency Communications Center, located at the Laboratory, installed a new computer-aided dispatch system in May.

the areas of classified removable electronic media, locks and keys, security incident prevention, and implementation of ISSM.

The Central Alarm Station Upgrade Project, completed at the beginning of the year, benefits both safety and security as well as Livermore’s Emergency Response Programs. The upgrade provides the capability to contact, without delay, qualified experts to respond to national, DOE, or Laboratory emergencies. The Laboratory also benefits directly from being the host site for the Alameda County Regional Emergency Communications Center. In 2007, the center was upgraded with the installation of a new computer-aided dispatch system, reducing response times and providing real-time information to both the dispatcher at the center and firefighters in the field. The center dispatches for a consortium of public safety agencies within Alameda County, which

jointly funded the \$1.2 million project. With the change to LLNS management, fire protection service at the Laboratory is now provided by contracted Alameda County Fire Department firefighters.

### Ties to the Community

In early October, the Laboratory hosted Community Leader Day at the Bankhead Theater in downtown Livermore. The event provided an opportunity for members of neighboring government, education, and business groups to meet and mingle with the new Laboratory senior management team. More than 450 officials and representatives from throughout the local area attended and heard about LLNS and the Laboratory’s plans for the coming year. The ceremony ended with the presentation of a \$10,000 check from the LLNS Board of Governors to the Livermore Valley Performing Arts Center,

## Management and People

which first opened its doors that week. The donation was the first such corporate contribution to be presented by LLNS.

In the annual Help Others More Effectively (HOME) Campaign, Laboratory employees raised more than \$1.4 million and LLNS acknowledged the employees' contribution with a \$1 million match. The \$2.4 million total represents the largest amount ever raised in more than 30 years of the HOME Campaign. The charitable drive benefits more than 400 community and nonprofit agencies in the Livermore/Tri-Valley area, San Joaquin Valley, and greater San Francisco Bay Area.

In addition to the HOME Campaign, Laboratory employees participate in educational outreach programs as well as various charitable and economic development organizations. More than 500 staff members each year volunteer their time to serve as science lecturers,

mentors, science fair judges, and presenters or instructors in workshops and classrooms. Two of the more prominent activities are "Science on Saturday" and the local Tri-Valley Science and Engineering Fair.

"Science on Saturday" is a series of free lectures and demonstrations by top Livermore researchers—together with local school teachers—on topics at the forefront of science and technology. It is held in both Livermore and Tracy, California. Hosted by the Laboratory at a community center in Livermore, the Tri-Valley Science and Engineering Fair motivates more than 200 local students in grades 7 through 12 to apply their creativity to the solution of science, engineering, and math problems. They compete for cash and other prizes, with their science projects evaluated by more than 100 judges, many of whom are Laboratory employees.

On behalf of Lawrence Livermore National Security, LLC, Laboratory director George Miller presented the organization's first corporate contribution to a new performing arts center in Livermore.



"DNA Day" was one of many educational outreach programs in 2007. Nearly 700 fifth-graders in Tracy, California, participated in this event and made DNA necklaces to commemorate the completion of the Human Genome Project in April 2003 and the discovery of DNA's double helix in 1953.

## Management and People

### People and Programs in the News

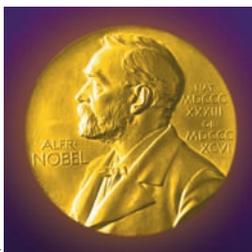
Livermore stays vibrant by attracting and retaining a high-quality, diverse workforce that is dedicated to excellence. The strength of the current workforce is demonstrated by the many awards received for scientific accomplishments and quality operations. However, science isn't the whole story at Lawrence Livermore. Many other individuals and teams are also recognized for their contributions both inside and outside the Laboratory.

Laboratory scientists and engineers were responsible for 161 invention disclosures, 125 U.S. patent applications, 29 first foreign patent applications, 62 issued U.S. patents, and 21 issued foreign patents in fiscal year 2007.

The American Physical Society honored John Lindl with the 2007 James Clerk Maxwell Prize for Plasma Physics. Lindl, chief scientist for the National Ignition Facility and Photon Science Directorate, was lauded for 30 years of contributions in high-energy-density physics and inertial confinement fusion research.



Nearly 40 Laboratory scientists contributed to the Intergovernmental Panel on Climate Change (IPCC), which, along with former vice president



Al Gore, won the Nobel Peace Prize. The Laboratory's Program for Climate Model Diagnosis and Intercomparison has made major contributions to all of the IPCC reports, from the First Assessment Report in 1990 to the 2007 Fourth Assessment Report (see p. 18).

Tomas Diaz de la Rubia, associate director for Chemistry, Materials, Earth, and Life Sciences, was named a fellow of the American Association for the Advancement of Science. Later in the year, he was tapped to be a co-editor-in-chief of the new Springer journal *Scientific Modeling and Simulation*.



Peter Celliers, Jim De Yoreo, and Denise Hinkel were named fellows of the American Physical Society. Celliers was recognized for improving ways of measuring shock waves used to study material states. De Yoreo (now at Lawrence Berkeley National Laboratory) was honored for work using in situ atomic force microscopy to understand the physical principles underlying biocrystallization. Hinkel was cited for contributions to laser-plasma interaction physics and radiation hydrodynamic design of inertial-confinement fusion targets.

A team of scientists from the Laboratory and IBM won supercomputing's Gordon Bell Prize for the third year running. Their entry, "Extending Stability Beyond CPU Millennium: A Micron-Scale Simulation of Kelvin-Helmholtz Instability," was able to show, for the first time, how this physical phenomenon develops from atomic-scale fluctuations to larger vortices (see p. 8).

The American Institute of Chemical Engineers elected safety analysis engineer Diane Spencer as a fellow for her advocacy on behalf of her profession. She has educated California legislators about updating laws and serves as a delegate for the California Legislative Council of Professional Engineers.



## Management and People

The Institute of Electrical and Electronics Engineers Computer Society awarded the 2007 Sidney Fernbach Memorial Award to David Keyes. He was honored for his contributions to Newton-Krylov-Schwarz methods for the efficient solution of nonlinear partial differential equations, which have enabled users to make efficient use of parallel computers, from small clusters to the world's largest computers.

- A software library called *hypre* that allows researchers to more effectively use massively parallel supercomputers and conduct larger, more detailed simulations faster than ever before. *Hypre* provides linear solver algorithms developed specifically for large numbers of processors. Simulations that previously took days can now be run in hours or less.



The Laboratory won five R&D 100 awards among the 100 awarded by *R&D Magazine* for the top industrial innovations worldwide in 2007. The Laboratory has received a total of 118 awards since 1978. The 2007 winning technologies include:

- A microelectromechanical systems (MEMS)-based Adaptive Optics Scanning Laser Ophthalmoscope, which could revolutionize retinal imaging, providing eye doctors with the capability to better detect, diagnose, and treat blinding retinal diseases.

- The Noninvasive Pneumothorax Detector, a hand held instrument that can detect in real time when air is trapped in the space between the wall of the chest cavity and the lung. The award was shared with Electrosonics Medical Inc., of Cleveland, Ohio, who licensed the technology.

- Continuous phase plate optics, an important breakthrough for the National Ignition Facility. These optics, developed in conjunction with Zygo Corporation of Middlefield, Connecticut and QED Technologies of Rochester, New York, allow the laser's 192 beams to be optimally coupled to targets.

- A radiation detection system, the Large Area Imager, which was developed in collaboration with Oak Ridge National Laboratory and the UC Berkeley Space Sciences Laboratory. The imager sits in a vehicle moving at speeds up to 25 miles per hour and searches a swath 100 meters wide.

Two individuals and four teams garnered NNSA Weapons Awards of Excellence. Cliff Shang and George Zimmerman were honored for work in enterprise modeling and code development, respectively. The group awards were given to the Use Control Analysis Team, the Electronic Redbook Team, the Pit Lifetime Team, the Chancellor Drillback Team, and the Nevada Test Site/Readiness in Technical Base and Facilities Program Management Team.

Hriar Cabayan (below, left) was lauded by the Joint Chiefs of Staff for his 10 years as special technology and science advisor in the Joint Staff Directorate of Operations in Washington, D.C. He acted as a liaison and conduit between the laboratories of the Departments of Defense and Energy, other government agencies, and the Combatant Commands.



While on assignment in Washington, D.C., Greg Simonson was honored by the U.S. Air Force with an award for Exemplary Civilian

## Management and People

Service. As senior scientist for the Counter-Chemical, Biological, Radiological, Nuclear and High Yield Explosives Center, he was responsible for improving response capabilities for the Washington, D.C., area.

The White House Office of Science and Technology Policy selected a former Laboratory postdoctoral fellow for the Presidential Early Career Award for Scientists and Engineers. Shawn Newsam, now an assistant professor in the School of Engineering at the University of California Merced, was nominated for work performed while at the Laboratory.

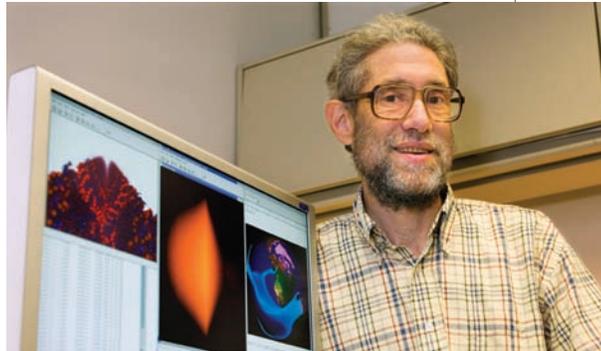
Recipients of the Laboratory's Teller Award for 2007 were Henry Chapman and Dmitri Ryutov. Chapman leads a team that is developing methods to use extremely bright, coherent x-ray beams at the Linac Coherent Light Source to reveal the three-dimensional structures of proteins. Ryutov has pioneered an approach to inertial confinement fusion that uses the Z pinch, an electrical current that compresses plasmas.

The BlueGene/L supercomputer was honored at SC07 for winning three out of four high-performance computing challenges, a set of tests designed to showcase more than LINPACK results.

Arpith Chacko Jacob, a summer intern, won an HPC (high-performance computing) Fellowship award at SC07.

Several highly successful programs in pollution prevention, waste minimization, and recycling won awards from DOE and external regulatory agencies (see p. 32).

For his pioneering work in scientific visualization, Nelson Max received the Steven A. Coons Award for Outstanding Creative Contributions to Computer Graphics. He was honored by the Association for Computing Machinery's Special Interest Group on Graphics and Interactive Techniques.



The American Society of Technical Engineers named Moe Dehghani as a member of its Committee on Engineering Accreditation. Dehghani had volunteered as an evaluator of engineering programs at many institutions for the past 10 years.

Former associate director for Energy David Baldwin received the 2007 Distinguished Career Award from Fusion Power Associates by the group's Board of Directors. The award recognizes individuals who have made lifelong career contributions to fusion development.

Retired physicist Ken Kulander received the 2008 Will Allis Prize for the Study of Ionized Gases from the American Physical Society. He was a theoretical physicist at the Laboratory from 1978–2001.

## Management and People

The Alameda County Women's Hall of Fame selected physicist Hope Ishii (below, third from left) as the 2007 Outstanding Woman in Science. She was honored for research she performed as part of the team that studied bits of dust from the comet Wild 2. The Hall of Fame awards are bestowed each year in 10 categories.



Three teams of employees won awards at a regional competition of the Federal Laboratory Consortium for Technology Transfer. Two awards went to teams that had developed and commercialized a fission meter for identifying radiation and a silver reflector for high-efficiency solar cells. The team that is transforming defense-related research into a compact machine for delivering radiation treatment for cancer won an award for outstanding technology development.

Thomas Luu, Ron Soltz, and Pavlos Vranas won an essay contest sponsored by *Computing in Science and Engineering* magazine for what they would do with a quadrillion floating operations per second (a petaflop) of computing power. They proposed extending research (described on p. 25) to simulate the birth of the universe.

Ronit Ben Abraham Katz (below), lead treating physician of the Laboratory's Health Services Department, received the American Medical Association Foundation's 2007 International Medical Graduate Physician Excellence in Medicine and Leadership Award. The awards are presented to medical students, residents/fellows, young physicians, and international medical graduate physicians for their strong, nonclinical leadership skills in advocacy, community service, or education.



Rulon Linford and Bill Nevins were appointed to serve on an advisory panel to DOE's Fusion Energy Sciences Advisory Committee.

Twenty-two crafts and machinist employees received journeyman certification following completion of a four-year training program.

The Laboratory's flagship magazine, *Science & Technology Review*, won an Award of Excellence from the Society for Technical Communications international competition.

The American Society for Training & Development recognized the Employee Organization and Development Division with its BEST award for enterprise-wide employee learning and development.

Post-doctoral fellow Jennifer Giocondi was honored by the Materials Research Society for her poster, "An In-situ AFM Study of the Affect of Magnesium Impurities on Brushite Growth."

The Laboratory's counterintelligence and counterterrorism effort, called the Security Awareness for Employees (SAFE) Program, earned top marks in a Department of Energy inspection for the second year in a row.

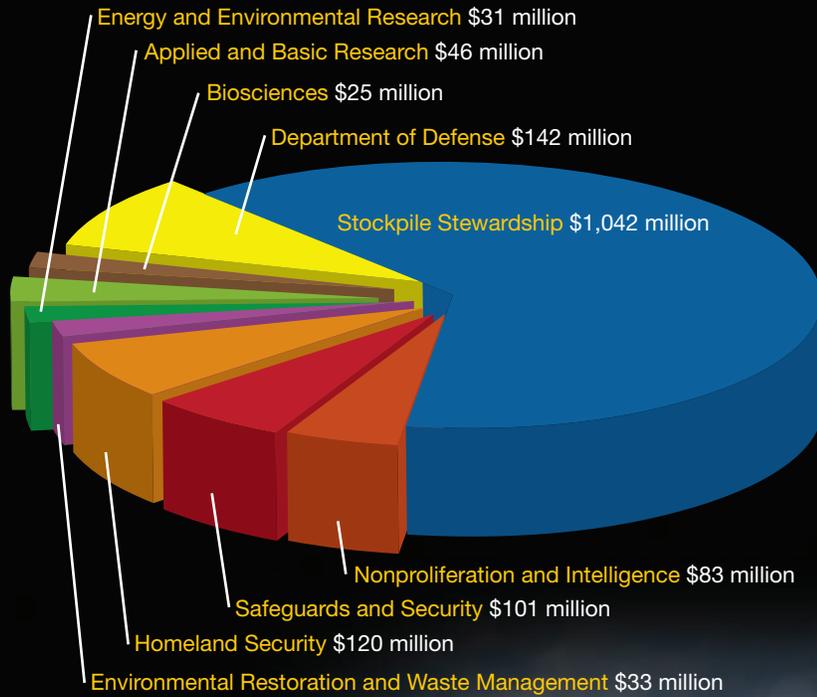
After three months of intensive training, eight new security police officers were sworn in at a ceremony in December.



### Laboratory Funding

Most of Livermore's approximately \$1.6 billion budget for FY 2007 was designated for research and development activities in program areas supporting DOE missions.

As a national security laboratory, Livermore is part of DOE/NNSA. The Laboratory's funding largely comes from the NNSA Office of Defense Programs for stockpile stewardship activities. Support for national security and homeland security work also comes from the NNSA Office of Defense Nuclear Nonproliferation, Department of Homeland Security, various Department of Defense sponsors, and other federal agencies.



### Find out More about Us

Visit the Laboratory's Web site, <http://www.llnl.gov/>, for the latest news on scientific and technical developments as well as opportunities for employment, academic research, industrial partnerships, and fellowships. The Public Affairs Office regularly posts news releases and science features on the site.

Read about Livermore's accomplishments in our award-winning magazine, *Science & Technology Review*. The Laboratory's flagship publication is available on the Web.



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