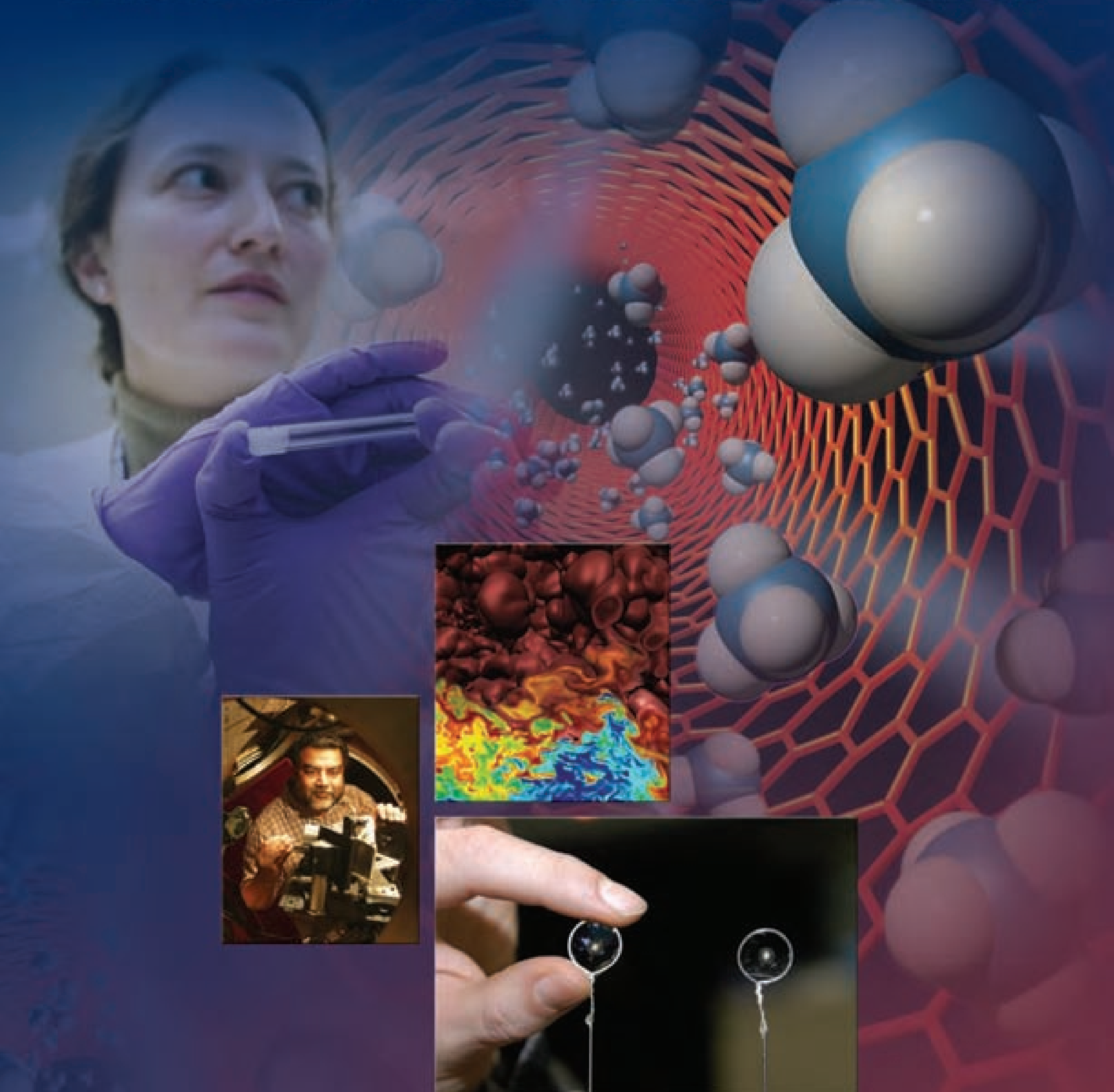
Lawrence Livermore National Laboratory



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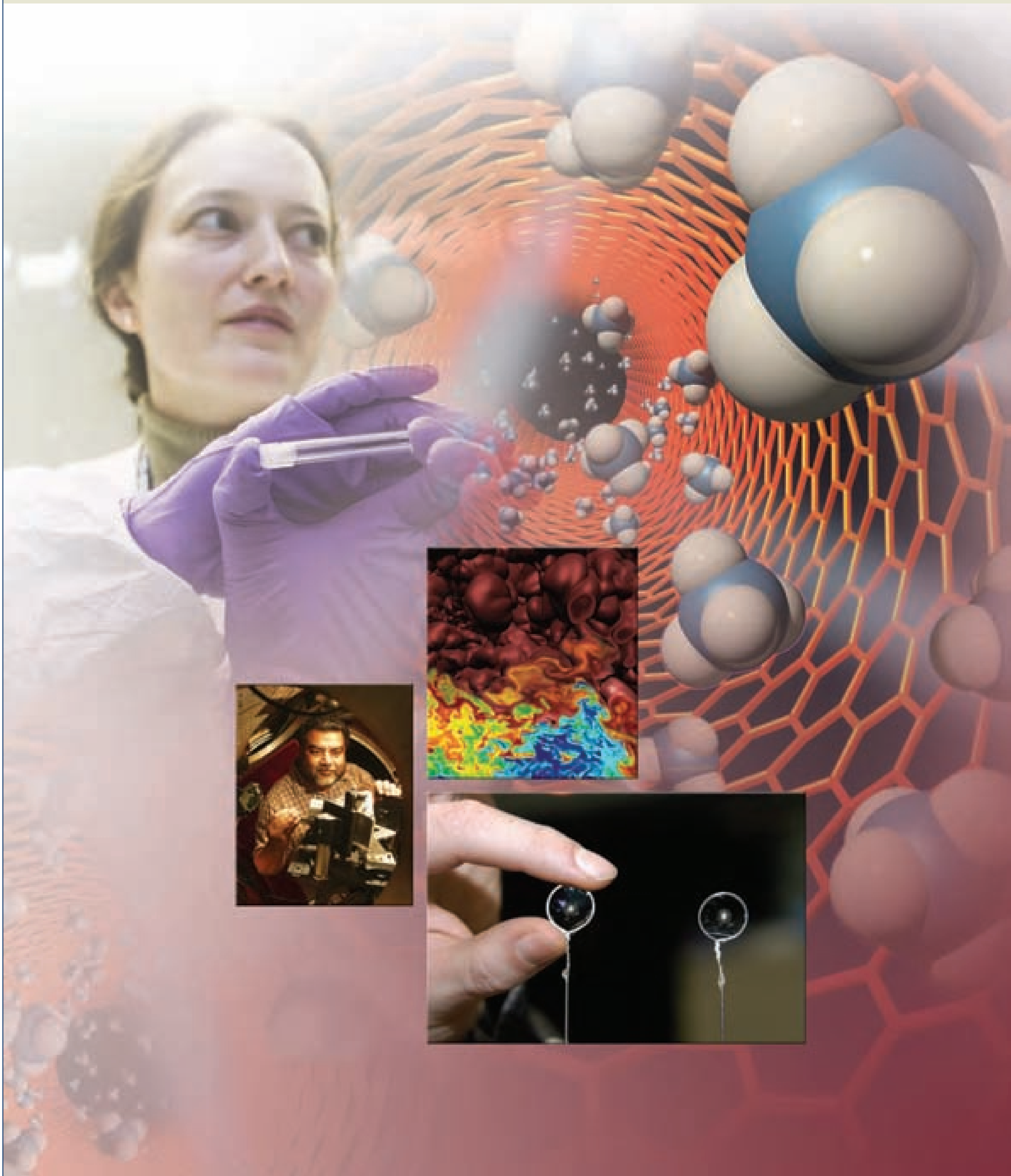

2006 Annual Report

About the Cover

Carbon nanotubes, laser targets, materials under extreme conditions, supernova behavior, and cometary science—the Laboratory made major advances in these fields and more in 2006.

About the Laboratory

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons research facility. The Laboratory has been managed since its inception by the University of California, originally for the Atomic Energy Commission and now for the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy. Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and establish an atmosphere of intellectual integrity and innovation, both of which are essential for sustained scientific and technical excellence. As an NNSA national laboratory with more than 8,000 employees, Livermore has a compelling core mission in national security and uses its scientific and technical capabilities to solve nationally important problems.

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A Message from the Director

George Miller

For the Laboratory and staff, 2006 was a year of outstanding achievements. As the many accomplishments in this annual report illustrate, the Laboratory's focus on important problems that affect our nation's security and our researchers' breakthroughs in science and technology have led to major successes.

As a national laboratory that is part of the Department of Energy's National Nuclear Security Administration (DOE/NNSA), Livermore is a key contributor to the Stockpile Stewardship Program for maintaining the safety, security, and reliability of the nation's nuclear weapons stockpile. The program has been highly successful, and our annual report features some of the Laboratory's significant stockpile stewardship accomplishments in 2006. A notable example is a long-term study with Los Alamos National Laboratory, which found that weapon pit performance will not sharply degrade from the aging effects on plutonium. The conclusion was based on a wide range of nonnuclear experiments, detailed simulations, theoretical advances, and thorough analyses of the results of past nuclear tests. The study was a superb scientific effort.

The continuing success of stockpile stewardship enabled NNSA in 2006 to lay out Complex 2030, a vision for a transformed nuclear weapons complex that is more responsive, cost efficient, and highly secure. One of the ways our Laboratory will help lead this transformation is through the design and development of reliable replacement warheads (RRWs). Compared to current designs, these warheads would have enhanced performance margins and security features and would be less costly to manufacture and maintain in a smaller,

modernized production complex. In early 2007, NNSA selected Lawrence Livermore and Sandia National Laboratories California to develop "RRW-1" for the U.S. Navy.

Design efforts for the RRW, the plutonium aging work, and many other stockpile stewardship accomplishments rely on computer simulations performed on NNSA's Advanced Simulation and Computing (ASC) Program supercomputers at Livermore. ASC Purple and BlueGene/L, the world's fastest computer, together provide nearly a half petaflop (500 trillion operations per second) of computer power for use by the three NNSA national laboratories. Livermore-led teams were awarded the Gordon Bell Prize for Peak Performance in both 2005 and 2006. The winning simulations, run on BlueGene/L, investigated the properties of materials at the length and time scales of atomic interactions. The computing power that makes possible such detailed simulations provides unprecedented opportunities for scientific discovery.

Laboratory scientists are meeting the extraordinary challenge of creating experimental capabilities to match the resolution of supercomputer simulations. Working with a wide range of collaborators, we are developing experimental tools that gather better data at the nanometer and subnanosecond scales. Applications range from imaging biomolecules to studying matter at extreme conditions of pressure and temperature. The premier high-energy-density experimental physics facility in the world will be the National Ignition Facility (NIF) when construction is completed in 2009. We are leading the national effort to perform the first fusion ignition experiments using NIF's 192-beam laser and prepare to explore some of the remaining important issues in weapons physics. With scientific colleagues from throughout the nation, we are also designing revolutionary experiments on NIF to advance the fields of astrophysics, planetary physics, and materials science.

Mission-directed, multidisciplinary science and technology at Livermore is also focused on reducing the threat posed by the proliferation of weapons of mass destruction as well as their acquisition and use by terrorists. The Laboratory helps this important national effort by providing its unique expertise, integration analyses, and operational support to the Department of Homeland Security. For this vital facet of the Laboratory's national security mission, we are developing advanced technologies, such as a pocket-size explosives detector and an airborne persistent surveillance system, both of which earned R&D 100 awards. Altogether, Livermore won seven R&D 100 awards in 2006, the most for any organization.

Emerging threats to national and global security go beyond defense and homeland security. Livermore pursues major scientific and technical advances to meet the need for a clean environment; clean, abundant energy; better water management; and improved human health. Our annual report highlights the link between human

activities and the warming of tropical oceans, as well as techniques for imaging biological molecules and detecting bone cancer in its earliest stages. In addition, we showcase many scientific discoveries: distant planets, the composition of comets, a new superheavy element.

Livermore's national security mission means that the Laboratory must be protected against both physical and cyber threats and that employees shoulder extraordinary responsibilities to work safely and securely. As the most important considerations in day-to-day operations, safety and security are integrated into all work planning and execution. We strive to follow best practices and to continually improve all aspects of Laboratory operations. Quality operations and scientific and technical excellence together make possible our programmatic accomplishments and sustain public trust in the Laboratory.

Exceptional people make Livermore an exceptional national laboratory. An outstanding, dedicated staff working in the national interest and contributing to the collective successes of the Laboratory has always been the key to our achievements. Livermore has a heritage of accomplishing challenging tasks through innovative, multidisciplinary teamwork. "Team science" was pioneered by Ernest O. Lawrence, who co-founded Livermore as a branch of the University of California Radiation Laboratory.

Beginning in October 2007, Lawrence Livermore will no longer be managed and operated by the University of California. The University, however, is an important part aof Lawrence Livermore National Security, LLC, the management team selected in May 2007. Livermore employees will continue to have opportunities to make important national contributions, have access to outstanding research capabilities and facilities, and enjoy an inclusive, collegial work environment. These aspects of the Laboratory are an enduring part of our University of California heritage.

Both through the transition period and under operation by the new contractor, our priorities remain clear. We will continue our strong programmatic and mission focus, applying the best science and technology to important national issues; keep the Laboratory operating smoothly using best business, safety, and security practices; fulfill our compliance commitments; and meet customer expectations. We will continue to be an exceptional national laboratory with exceptional people.

Nuclear Weapons Stockpile Stewardship

Lawrence Livermore National Laboratory was established in 1952 to help ensure national security through the design, development, and stewardship of nuclear weapons. National security continues to be the Laboratory's defining responsibility. Livermore is one of the three national laboratories that support the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE).

Livermore plays a prominent role in NNSA's Stockpile Stewardship Program for maintaining the safety, security, and reliability of the nation's nuclear weapons and in NNSA's vision for the future, Complex 2030. The Stockpile Stewardship Program integrates the activities of the U.S. nuclear weapons complex, which includes Livermore, Los Alamos, and Sandia national laboratories as well as four production sites and the Nevada Test Site. Successes to date in stockpile stewardship make possible the Complex 2030 vision of transforming the nation's nuclear weapons enterprise to be less costly, highly secure, and fully capable of responding to national security needs on a timely basis.

As stockpiled nuclear weapons age, Laboratory scientists and engineers are challenged to ensure their performance, refurbish weapons, and as necessary, supply reliable replacements without conducting nuclear tests. The researchers attend to the immediate needs of the stockpile through assessments and actions based on a combination of laboratory experiments and computer simulations of nuclear weapon performance. In addition, Livermore is acquiring more powerful experimental and computational tools for assessing aging weapon systems and certifying reliable replacement warheads. The replacement warheads are central to NNSA's strategy to make the 21st-century complex more responsive to the need for a smaller stockpile that is even safer, more secure, and easier to maintain.

Complex 2030 Sets a Course for the Future

In April 2006, Tom D'Agostino, NNSA deputy administrator for Defense Programs, presented to Congress NNSA's plan for consolidating the DOE weapons complex. The plan, called Complex 2030, builds on the recommendations of the Secretary of Energy's Advisory Board (SEAB) task force on the nuclear weapons complex infrastructure. The SEAB task force recommended that the Cold War nuclear weapons stockpile be replaced with a sustainable stockpile and that NNSA complement its investments in the nuclear weapons laboratories with investments to consolidate and modernize production.

Complex 2030 supports vital 21st-century national security objectives. The United States needs to ensure the long-term safety, reliability, and security of its nuclear deterrent and reduce the stockpile's size to the lowest number of weapons consistent with national security objectives. The life of selected aging weapon systems must be extended while the complex is transformed to a more sustainable future stockpile and infrastructure. The Reliable Replacement Warhead (RRW), which is discussed below, is a key concept for achieving a smaller stockpile and more responsive infrastructure.

The Complex 2030 plan retains two independent centers of excellence for nuclear warhead design and development at Livermore and Los Alamos, each supported by Sandia for nonnuclear component design. Working together in an integrated program, the laboratories improve their understanding of nuclear weapons science and technology and use their expertise to assess the performance of aging weapons. They also develop necessary refurbishments to weapons to extend their life and pursue concepts for replacement warheads. During a visit to Livermore in May, D'Agostino stressed the importance of Lawrence Livermore "…as a key component of the future of the nuclear weapons program…and national security as a whole."

Achieving the Complex 2030 vision will require significant change. The plan calls for dismantling retired weapons, consolidating special nuclear materials, eliminating duplicative capabilities, establishing a consolidated plutonium center, and implementing more efficient and uniform business practices. All Category I/II special nuclear materials—plutonium and highly enriched uranium—are to be removed from Livermore by the end of 2014, except for small amounts of plutonium for research and development activities. In 2006, NNSA began the inventory reduction process, with materials shipped to Los Alamos.

NNSA Defense Program activities at Site 300 are to be phased out as alternatives for performing the work become available elsewhere. Hydrodynamic testing is to be consolidated at other sites, with all large-scale hydrotesting eventually conducted at the Nevada Test Site. A plan for Site 300 is to be prepared this year. Livermore's Contained Firing Facility (CFF), which is located at Site 300, conducted eight major (large-scale) hydrodynamic tests and

Tom D'Agostino, NNSA deputy administrator for Defense Programs, visited the Laboratory to discuss Complex 2030.

Inside Site 300's Contained Firing Facility, John Given sets up equipment for a "shot" as part of large-scale hydrodynamics testing. These tests are essential for verifying the safety and reliability of the nuclear stockpile.

21focused (smaller-scale) experiments in fiscal year 2006 in support of the National Hydrotest Program.

In October 2006, NNSA announced plans to prepare an environmental impact statement for Complex 2030. George Allen, director of the NNSA Office of Transformation, visited Livermore in December to discuss complex transition issues with Laboratory employees, and he had his first tour of Site 300 and CFF. Allen also hosted public meetings in Livermore and Tracy, California, to gather public comments about the Complex 2030 plan.

Design of a Reliable Replacement Warhead

In early 2007, NNSA announced its decision that Livermore and Sandia national laboratories will lead the design of the RRW for the U.S. Navy. NNSA will work with the Navy to develop a detailed RRW project plan and cost estimate for developing and producing the system. A team from Lawrence Livermore and Sandia/California and another from Los Alamos and Sandia/New Mexico submitted RRW proposals; according to D'Agostino, "Both teams developed brilliant designs." Higher confidence in the ability to certify the Livermore design without underground nuclear testing was the primary reason for its selection.

The RRW approach to achieving a long-term sustainable nuclear stockpile is critical to the success of the Complex 2030 vision. The goal is to replace existing aging warheads with ones manufactured from materials that are more readily available and more environmentally benign than those used in current designs. These modified warheads would be less costly to manufacture and maintain by a smaller, modernized production complex. In addition, the designs will include advanced safety and security technologies, and their reliability would be easier to certify without underground nuclear testing. The goal of the RRW is to maintain the current military capability, not to improve it.

A responsive nuclear infrastructure, together with the RRW Program, make possible significant reductions in the size of the nuclear stockpile.

The Nuclear Weapons Council (NWC), a working group of senior officials from the Department of Defense and NNSA, launched the RRW Feasibility Study in 2005 after authorization by Congress. Lawrence Livermore and Sandia/California competed with Los Alamos and Sandia/New Mexico to develop and submit design data packages for an RRW for the nation's sea-based nuclear deterrent. After submission in March 2006, both designs were subjected to detailed interlaboratory peer review and evaluation by teams from the RRW Project Officers Group and members of the U.S. Strategic Command Advisory Group. In December, the NWC determined that "…the RRW is feasible as a strategy for sustaining the nation's nuclear weapons for the long-term without underground nuclear testing."

In developing its design data package, Laboratory personnel worked closely

Staff of the Defense and Nuclear Technologies Directorate celebrate the success of their RRW design proposal with associate director Bruce Goodwin.

with Sandia/California and the production agencies to meet all RRW goals using an approach that combined innovation with tested features. The effort heavily exercised the design, engineering, experimental, and simulation capabilities of the Laboratory. One of the major hydrodynamic experiments executed at Site 300 in fiscal year 2006 proved the soundness of the RRW design and approach. In addition, Livermore worked on developing plutonium-part manufacturing technologies. Features in the "RRW–California" design proposal reduce the need for surveillance activities and improve manufacturability.

Intensive use of Advanced Simulation and Computing Program computers and simulation codes (see p. 9) was crucial to the RRW design effort. Laboratory scientists ran more than 28,000 simulations to examine tradeoffs between performance and ease of manufacturing and to map out margins and uncertainties for potential failure modes. They needed to ensure that the RRW–California design provided large performance margins for all key potential failure modes in order to increase weapon reliability and provide strong assurance that underground nuclear testing would not be required for design certification. The evaluations of weapon performance are underpinned by a formal methodology called quantification of margins and uncertainties (QMU), which has been developed by Livermore and Los Alamos. Laboratory scientists continue to refine QMU and apply it to all major weapon development and assessment activities.

Now that a baseline design has been selected, the next step is a study to further define and develop detailed cost estimates for the RRW program. This work will support a future decision to seek congressional authorization and funding in order to proceed into system development and subsequent production.

Annual Assessment of the Stockpile

Livermore is a key participant in formal review processes and assessments of the safety, security, and reliability of weapons in the stockpile. In 2006, the Laboratory met all milestones in support of the eleventh cycle of the Annual Assessment Review. First mandated by the President in 1995 and now required by law, the annual review assesses the current status of the stockpile and gives the President an informed judgment of whether a resumption of underground nuclear testing is warranted to resolve any issues about the reliability or safety of weapons. The formal process is based on technical evaluations made by the laboratories and on advice from the secretaries of Energy and Defense, the three laboratory directors, and the commander-in-chief of Strategic Command.

Lawrence Livermore and Sandia/California prepare Annual Assessment Reports for each of the nuclear weapons systems for which the two laboratories are jointly responsible: the W62 and W87 intercontinental ballistic missile (ICBM) warheads, the B83 strategic bomb, and the W80 and W84 cruise missile warheads. As input to the reports, Laboratory scientists and engineers collect, 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 intralaboratory review and to 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.

Representative Ellen Tauscher (Tenth District, California, center), and General James Cartwright, commander of the U.S. Strategic Command (right), visited the Laboratory in October. They met with Laboratory director George Miller (left) and received briefings on national security progress and science and technology accomplishments.

Near the end of the 2006 process, the directors of Livermore and Los Alamos national laboratories, together with senior managers in their weapons programs, met to jointly review the nuclear weapons stockpile. The meeting was an opportunity to become better informed about each other's weapon systems, discuss issues, and look for additional opportunities for increased collaboration. This was the first year that such a joint session was held. It will become part of the Annual Assessment Review in future years to further strengthen the overall process.

Mark Seager of the Computation Directorate accepts the certificate for the world's fastest supercomputer, BlueGene/L, during announcement of the new Top500 list in Tampa, Florida.

Predictive Simulations Support Stewardship

The Advanced Simulation and Computing (ASC) Purple and Blue Gene/L computers at Livermore, with a combined peak capability of nearly half a petaflop (that is, nearly 500 trillion floating-point operations per second), are making major contributions to stockpile stewardship problems ranging from RRW design to plutonium aging to fundamental weapons physics. Scientists and engineers at all three NNSA laboratories are using these machines to usher in a new era of predictive simulation.

ASC Purple is capable of operating at nearly 100 teraflops. It was delivered from IBM in 2005, tested, and brought into use for classified production runs in April 2006. With over 12,000 next-generation IBM Power5 microprocessors and 2 million gigabytes of storage, Purple is currently ranked the fourth fastest computer in the world by the Top500 organization. Soon after Purple began operating, a joint team of scientists from Livermore and Los Alamos performed a series of weapon simulations at unprecedented spatial resolution using the most advanced ASC simulation software. The results gave dramatic new insights into weapons physics by pointing to phenomena not seen at lower resolution. The machine runs the most demanding three-dimensional weapons simulation codes with high-fidelity physics models.

BlueGene/L is number one on the Top500 list of the world's fastest supercomputers, clocking an astonishing 280.6 teraflops on the industry standard LINPACK benchmark. With its 65,536 nodes (131,072 processors) and "system-on-a-chip" technology, BlueGene/L is a world apart from other scalable computers not only in terms of performance but also in size, cost, and design. BlueGene/L contributes to stockpile stewardship by performing simulations of materials at atomic and molecular scales and of hydrodyamics phenomena. It has been remarkably successful, efficiently running simulation codes capable of addressing a broader range of weapons issues than originally envisioned.

For the second year in a row, a Livermore-led team won the Gordon Bell Prize for Peak Performance for a materials-science simulation using BlueGene/L. A second Special Achievement award was granted to a team that included a Livermore scientist. The prizes are awarded to innovators who advance high-performance computing.

The calculations for the first award set a world record for a scientific application by achieving a sustained performance of 207.3 teraflops. Qbox, a first-principles quantum molecular dynamics code designed to predict the properties of materials under extreme conditions, was used to study 1,000 molybdenum atoms under high pressure. Molybdenum, a heavy or high-Z metal, is of particular interest to scientists in the Stockpile Stewardship Program. Until now, such quantum simulations have been restricted to about 50 atoms. Simulations of 1,000 atoms make possible studies of hetero-geneous mixtures of molecules and "extreme chemistry." Classical molecular dynamics calculations are typically much larger in size; the Laboratory's Gordon Bell prize-winner in 2005 was a 2-million-atom simulation of the resolidification of tantalum.

Assessing the Lifetime of Plutonium Pits

A concerted long-term study by Livermore and Los Alamos researchers showed that the performance of plutonium pits in U.S. nuclear weapons will not sharply decline due to aging effects. Because plutonium is highly radioactive, over time it damages materials in weapons, including the pits themselves. However, the effort concluded that the plutonium pits for most nuclear weapons have minimum lifetimes of at least 85 years. These definitive results met a major Stockpile Stewardship Program milestone, and the answer has important implications in planning for the weapons production complex of the future.

Laboratory researchers executed a broadly based program of experiments, simulations, and analyses of previous underground nuclear test results to provide the data needed for the pit assessment. Understanding the detailed properties of plutonium metal and alloys and how they age is a major scientific challenge because plutonium is an unusually complex material. Among the sources of data are experiments conducted at the Joint Actinide Shock Physics Experimental Research (JASPER) facility at the Nevada Test Site. JASPER's two-stage gas gun can accelerate a projectile to high speeds and produce an extremely high-pressure shock wave in the targeted material—plutonium—upon impact. Through precise measurements of shock velocity, scientists are improving plutonium equation-of-state models. In fiscal year 2006, eight such experiments were conducted at JASPER, including two experiments with aged plutonium and the first joint experiment with Los Alamos scientists.

In addition, Livermore scientists conduct many types of laboratory experiments, including high-pressure equation-of-state measurements using a diamond anvil cell, x-ray diffraction studies, and transmission electron microscopy analyses. Data from these experiments are used in computer simulations that model the properties of plutonium and the performance of aged weapons.

Materials under Extreme Conditions

The large variety of simulations and experiments exemplifies the great interest and expertise Laboratory researchers have in materials under extreme conditions of pressure and temperature—for stockpile stewardship, inertial confinement fusion, and many other applications. For example, in the September 17, 2006, edition of *Nature Materials*, Livermore researchers and collaborators at Oxford University presented the results of very-large-scale simulations of the dynamical behavior of metals subjected to a strong shock. Because of the size of their simulations and the inclusion of pre-existing

Shock experiments conducted at the JASPER gas gun contribute to understanding plutonium, an essential material in nuclear weapons. Eight tests were performed at JASPER in fiscal year 2006, including the first joint Livermore–Los Alamos experiment.

defects in the crystal, they were able to reproduce experimentally observed three-dimensional effects in shock-compressed material for the first time. A strong shock creates many line defects (dislocations) in the crystalline structure of metals, and this movement relaxes the strain caused by the shock. Among new insights, researchers found that if the shock is too abrupt, the dislocations form too rapidly and become entangled before they can move far enough to relieve the strain.

Together with a variety of collaborators, Laboratory scientists are developing new experimental techniques to gather better data at the nanometer and sub-nanosecond scales characteristic of the simulations. One technique, dynamic x-ray diffraction, uses high-intensity lasers to generate both a shock in a solid and a precisely timed flash of x rays to image the lattice in motion. When the x rays interact with the crystal's atoms, they are diffracted in a pattern that characterizes the lattice. By resolving this time-dependent diffracted signal, scientists can develop a fundamental understanding of the kinetics of transformation and lattice relaxation.

Dynamic x-ray diffraction experiments have been performed at the Trident laser at Los Alamos, the Omega laser at the University of Rochester, the Vulcan laser in the United Kingdom, and the high-energy Janus laser at Livermore. Janus is part of the Laboratory's Jupiter Laser Facility, which includes the Janus, Callisto, Europa, COMET, and Titan lasers and associated target chambers. As reported in *Physical Review Letters* on June 30, 2006, Laboratory scientists used the Europa femtosecond (one millionth of a nanosecond) laser to convert a nanofoil of gold into a dense plasma that retained the electron band structure of an ordered solid. Titan, the newest addition to the Jupiter facility, is one of only three petawatt-class lasers in the world and currently the only one offering synchronized short- and long-pulse operation. Scientists will use Titan to explore the science of fast ignition for

Jim McNaney (left) and Hector Lorenzana check calibrations on the target chamber of Livermore's Janus laser before a dynamic x-ray diffraction experiment.

inertial confinement fusion (ICF). Titan and other Jupiter facility lasers will also support the development of diagnostics and targets for the National Ignition Facility (NIF) as it comes into full operation.

Progress at the National Ignition Facility

Major progress continues to be made on NIF and preparations for fusion ignition experiments with the 192-beam laser. The NIF project is meeting all of its technical performance, cost, and schedule milestones. Current plans are to complete the construction project in March 2009 and begin the first ignition experiments in fiscal year 2010. NIF's laser beams will compress fusion targets to the conditions required for thermonuclear burn, liberating more energy than is required to initiate fusion reactions. ICF energy is a long-standing program goal within DOE. NIF will offer researchers the capability to study physical processes at temperatures approaching 100 million degrees and pressures of 10 billion atmospheres, conditions that exist naturally only in the interior of stars and planets and in exploding nuclear weapons.

NIF is vital to the success of the Stockpile Stewardship Program. It is the only facility capable of creating, in the laboratory, the conditions necessary to experimentally study physical processes that occur during the thermonuclear phase of an exploding nuclear weapon. Data from precisely diagnosed experiments will elucidate key weapon performance issues and assist in validating physics models and numerical simulation codes. Over the coming decades, NIF experiments will also help train and rigorously test the capabilities of weapons scientists, upon whom the nation depends to assess the safety, security, and performance of the U.S. stockpile.

In December 2006, the first of four clusters of laser beams completed operational qualification. NIF broke its own record as the world's most energetic laser and became the first to demonstrate that it can produce over a megajoule of infrared laser energy. The facility has now demonstrated that it ultimately will be capable of achieving 4.2 megajoules in the infrared. By comparison, the Laboratory's previous-generation ICF laser, Nova, typically operated at just over one percent of this energy output.

Laser test shots are being conducted almost on a daily basis. They have demonstrated, for example, NIF's ability to precisely control pulse shape and duration. In addition, the Integrated Computerized Control System has proved its ability to fire an entire shot cycle for a cluster of lasers, from setup to post-shot amplifier cooling, in just over three hours. Meanwhile, equipment continues to be installed. More than 3,200 of NIF's 6,200 line replaceable units (LRUs) have been assembled, tested, and inserted into the beamlines. LRU modules contain instrumentation and optical compo-

NIF's Integrated Computerized Control System handles some 60,000 elements, including safety interlocks, alignment systems, mirrors, lenses, motors, sensors, cameras, amplifiers, capacitors, and diagnostic instruments.

nents and weigh between 500 and 1,000 kilograms each.

NIF Looks toward Ignition

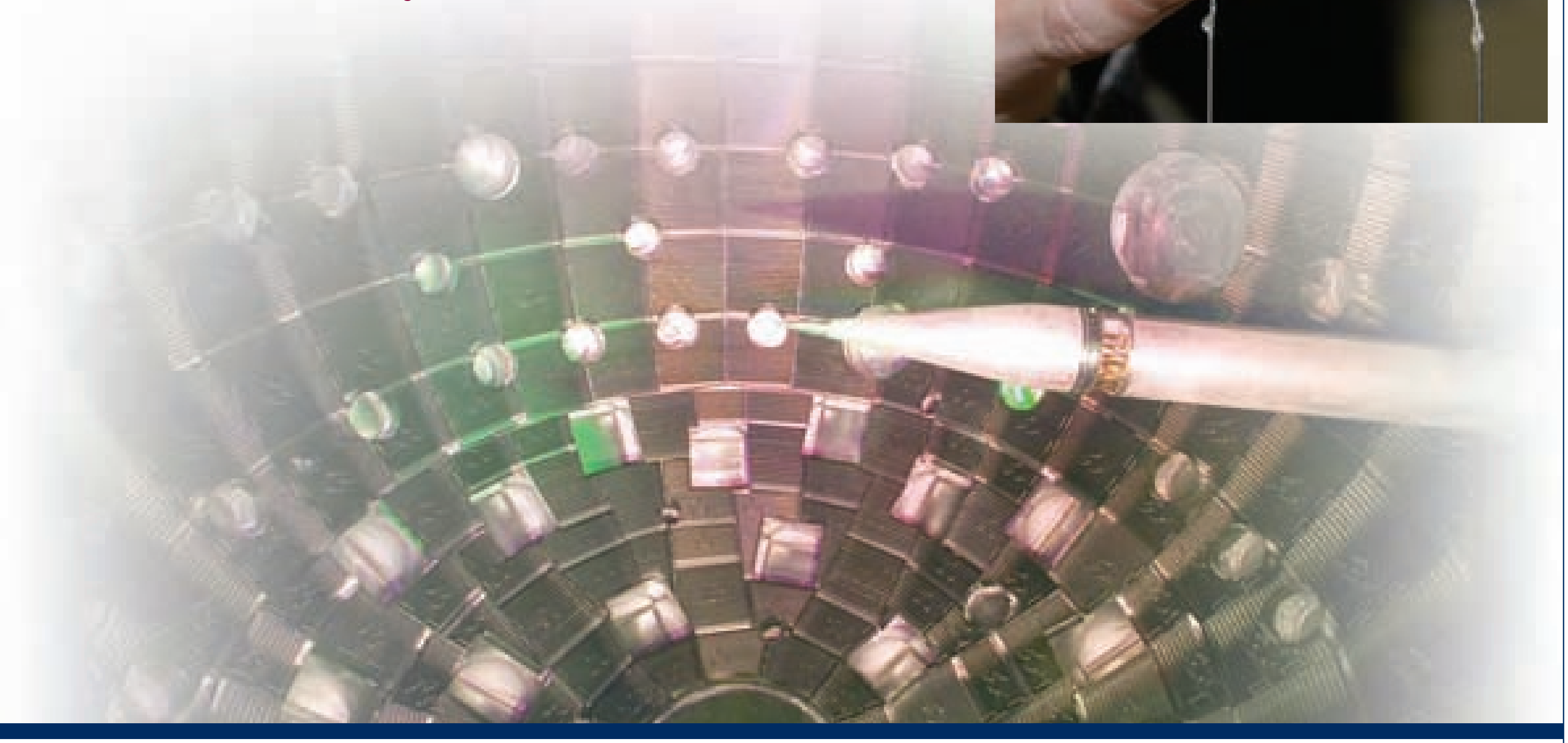
The National Ignition Campaign (NIC), which is being managed for NNSA by the Laboratory, is making significant progress. NIC's objective is to integrate the activities of multiple laboratories to prepare for ignition experiments on NIF in fiscal year 2010 and to transition NIF from project completion to full operations in fiscal year 2012. The goal is to make NIF the international center of high-energy-density science for research in strategic security, energy security, and basic science of matter at extreme conditions. Plans are for a broad-based community to be using the facility 24 hours a day by 2012 for experimental science that cannot be done anywhere else.

In support of NIC, four Integrated Experiments Teams were formed this year in the areas of laser performance, hohlraum performance, capsule performance, and ignition performance. Each team is developing requirements for "tuning campaigns" aimed at reducing risk and optimizing system parameters for the ignition campaign.

The ignition-target point design continues to become more robust. Improvements are based on the combination of simulation modeling efforts and experiments at the Omega laser, Sandia's Z facility, and other facilities worldwide. At Livermore and General Atomics in San Diego, scientists and engineers are progressing in the development of tools and imaging methods for fabricating and characterizing high-precision targets for fusion experiments. Research is moving toward the use of beryllium capsules because they can ignite more efficiently than the plastic shell designs used to date in ICF experiments. In addition, the NIF Experimental Support Technology Program is building and commissioning the experimental systems required for performing user experiments. These systems include the cryogenic target system, target diagnostics systems, user optics, and personnel and environmental protection systems.

Also in fiscal year 2006, the Laboratory and collaborating institutions developed a NIF High-Energy-Density Physics (HEDP) Plan and an accompanying National Calibration Plan. The goal of the HEDP plan is to identify important experimental weapons-physics data needed to develop and validate predictive capabilities for weapons assessment. The calibration plan defines a process and management structure for calibrating HEDP diagnostics for current and future experiments and a roadmap to deliver the enabling capabilities using facilities across the DOE complex.

When NIF begins fusion experiments, beryllium targets (right) will be filled with a fuel of tritium and deuterium. The target positioner (below) will place a target precisely in the center of the 10-meter-diameter target chamber.



W56 Dismantlement and Support of Production Activities

NNSA announced in June that the final W56 nuclear warhead was dismantled safely and securely at the Pantex Plant as part of the nation's effort to significantly reduce the size of its nuclear stockpile. The W56, an intercontinental ballistic missile warhead that saw service until the early 1990s, was designed at Livermore. As part of its cradle-to-grave responsibilities for the weapons it designs, the Laboratory provided support to Pantex for developing the safety-authorization-basis documents that set requirements for production, surveillance, and dismantlement work activities.

It is the Laboratory's mission to support the production plants to ensure that work is conducted safely and efficiently. Cooperative efforts also aim at improving efficiencies and responsiveness. Where necessary, scientists and engineers pursue research and development to resolve critical issues that impede progress in weapons operations at the production plants. As an example, Livermore responded to safety concerns about electrostatic discharge at Pantex by developing a new protocol based on a rigorous model and supporting experiments to understand the effect. Conservative procedures were then devised to safely perform necessary nuclear explosive operations.

The dismantlement of all W56 weapons, which were designed by the Laboratory, was completed by workers at the Pantex Plant.

Plutonium Futures

The Laboratory, in collaboration with Los Alamos National Laboratory, hosted "Plutonium Futures: The Science 2006" in July in Pacific Grove, California. This conference provided an international forum for presentation and discussion of current research on physical and chemical properties and environmental interactions of plutonium and other actinide elements. Nearly 400 researchers from more than 28 countries attended. Paper topics were diverse, including transformations due to temperature, pressure, and other causes; actinide compounds storage; reprocessing of spent materials; and remediation of contaminated sites.

Plenary sessions of the Plutonium Futures conference were held in historic Merrill Hall at the Asilomar Conference Center in Pacific Grove.

Global Threats and Security

The distinction between national security and global security has blurred to the point that, in reality, there is just "security." The threat posed by the proliferation, terrorist acquisition, or use of weapons of mass destruction (WMD) knows no boundaries.

Protecting the United States against this threat requires a broad range of activities, at home and abroad. Livermore participates in international cooperative activities aimed at preventing the proliferation of nuclear weapons. Researchers also play an active role in national efforts to develop countermeasures against nuclear or radiological threats and bioterrorism.

A distinguishing feature of Lawrence Livermore's work for this vital security mission is its integrated, end-to-end approach. To tackle the challenges of WMD proliferation and terrorism, the Laboratory draws on more than 50 years of experience in all aspects of nuclear weapons as well as extensive resources in biology, chemistry, engineering, and computations. Livermore provides technologies, analysis, expertise, and operational capabilities to confront all aspects of the threat.

Cooperation to Prevent Proliferation

As part of the National Nuclear Security Administration (NNSA) Material Protection, Control, and Accounting (MPC&A) program, Livermore researchers oversaw the completion of the Kola Technical Center in Russia. This unique complex offers courses and hands-on training for Russian Navy nuclear security and MPC&A professionals. It will play a critical role in enabling Russia to sustain an effective MPC&A culture.

Building on experience and lessons learned in Russia, MPC&A cooperation has been extended to other countries, including China. Livermore led the project teams that installed nuclear material protection upgrades at several facilities at the Beijing-based China Institute of Atomic Energy, including the Fast Neutron Critical Facility, the Materials Storage Facility, and the Safeguards Laboratory. Livermore personnel also gave workshops and lectures for Chinese safeguards engineers and analysts and civilian nuclear industry officials on such topics as vulnerability assessment, nondestructive analysis, and national-level nuclear material accounting. In June 2006, Livermore also coordinated logistics and led the Regulatory Infrastructure Section of a visit by Chinese experts on nuclear security and safeguards to a number of NNSA facilities and laboratories.

Laboratory scientists have also developed a plutonium gamma-ray simulator for the International Atomic Energy Agency in support of its efforts to safeguard nuclear technology and prevent nuclear proliferation. Hardware and software work together to simulate the pulses that come from a high-purity germanium detector when it interacts with plutonium gamma rays.

The simulator eliminates the need for actual plutonium samples to test the instrumentation and analysis software used in international safeguards activities. Its use significantly reduces testing and training costs and cuts the development time for new monitoring instruments. Large plutonium samples can be simulated in an office environment by a single employee, without incurring any of the safety and security costs and risks associated with Livermore's Plutonium Facility or other comparable facility.

At the joint China-U.S. integrated nuclear materials management technology demonstration in Beijing in fiscal year 2006, then NNSA director Linton Brooks (center, seated), participates in opening ceremonies.

Laboratory researchers have also developed the Livermore Safeguards Systems Analysis Tool (LISSAT) to systematically assess the efficiency and effectiveness of alternative approaches and technologies for nuclear safeguards monitoring. LISSAT has been applied to a generic enrichment facility and to assess the use of antineutrino detectors in reactor safeguards strategies.

In areas where proliferation is a concern, scientific collaboration helps to promote understanding and cooperation. These collaborative efforts also are an aid in defusing regional tensions that might otherwise lead to conflict. For example, Laboratory scientists organized seismic workshops (with the U.S. Geological Survey and the United Nations Educational, Scientific and Cultural Organization) on the December 2004 Great Sumatran earthquake and its aftershocks. Participants from across South Asia attended the conferences in China in 2005 and in Bhutan in 2006. Livermore also leads North African Sister Laboratory projects in Egypt, Libya, Algeria, and Morocco and is developing an integrated safeguards strategy for the region.

Countering the Nuclear Threat

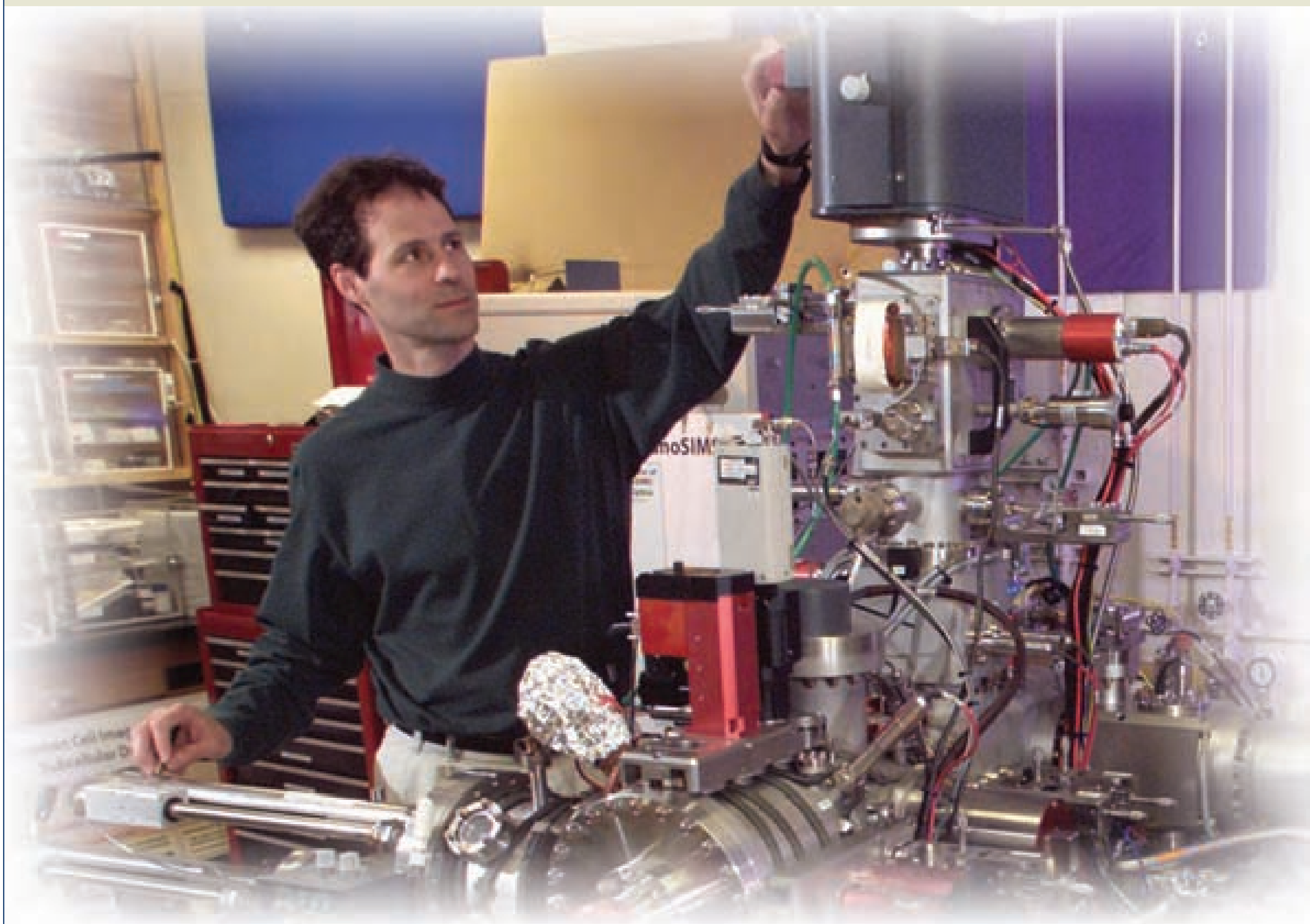
Lawrence Livermore leads the Nuclear Assessment Program (NAP), the national capability for the evaluation of communicated nuclear threats. This program also assesses cases of illicit trafficking of alleged radiological and nuclear materials. Each year, NAP provides dozens of nuclear-related threat assessments and evaluates roughly 100 nuclear trafficking incidents. In addition, NAP analysts provide subject matter expertise, in formal training venues and real-time assistance, to assist first responders and law enforcement officials, at home and abroad, in their efforts to thwart nuclear terrorism.

On the technology side, the Laboratory is developing novel detection approaches for monitoring for radioactive materials at choke points, searching for nuclear materials inside cargo containers, and other activities aimed at countering nuclear or radiological terrorism. A new, large-area, coded-aperture gamma-ray imager has demonstrated its ability to detect small quantities of nuclear materials from distances of more than 80 meters—quite possibly the most significant achievement in radiation detection systems in the past decade. In 2006, a more rugged and compact version of this detector system was assembled that fits in a 15-foot trailer pulled by a pickup truck. This version is suitable for nuclear search operations and can detect threats on both sides of the vehicle simultaneously.

Sonoma Wins R&D 100 Award

The Laboratory develops advanced technologies for detecting and monitoring proliferation-related activities such as the Sonoma persistent surveillance system, which won an R&D 100 Award in 2006 (see p. 44). Sonoma provides continuous, real-time video imagery of an area the size of a city, with resolution fine enough to track 8,000 or more moving objects continuously within its field of view. The system incorporates a novel sensor design that can view wide areas at high resolution and real-time, on-board, automated image and data processing. In addition to its proliferation detection mission, Sonoma could also be used for environmental monitoring, disaster response, border security, and more.

The Sonoma surveillance system offers the resolution shown on the right, covering the area outlined in red, from a single airplane-mounted camera. The satellite image is of Washington D.C.



Peter Weber adjusts the nano secondary-ion mass spectrometer (NanoSIMS), a versatile tool for characterizing not only nuclear materials but also cell function for biological research (see p. 29).

Another priority is to develop new radiation detection materials that offer energy resolution close to that of high-purity germanium yet do not need to be cooled to liquid nitrogen temperatures. To this end, scientists from Lawrence Livermore and Lawrence Berkeley national laboratories are working on the development of high-purity aluminum-antimonide (AlSb) for radiation detection. In 2006, they successfully demonstrated the first-ever detection of gamma rays using an AlSb device. This achievement represents a significant step in the development of AlSb as a next-generation semiconductor material for ambient-temperature gamma detection.

A major deterrent to nuclear terrorism is the ability to identify the origin of interdicted radiological or nuclear materials, which can provide clues to the identity of the perpetrators. The nuclear fuel cycle that supports worldwide use of nuclear power is complex, and there are many points at which materials might be diverted for nefarious purposes. This past year, Livermore scientists applied their forensic analysis capabilities to characterize real-world samples, including uranium ore concentrates, sediment samples, and several samples of unknown origin. Laboratory researchers are also working with representatives in the republics of the former Soviet Union and other countries to develop co-operative frameworks for the sampling and analysis of uranium ore concentrates and nuclear fuels of significance.

Defending against Biological Terrorism

The Laboratory is home to the Biodefense Knowledge Center (BKC) for the Department of Homeland Security (DHS). This national resource provides rapid-turnaround and in-depth analyses of biodefense issues. BKC assessments and knowledge-discovery tools help the homeland security community understand scientific trends that may be exploited by adversaries to develop biological weapons. Assessments also assist in the development of an integrated national effort to respond to emerging threats and help guide the prioritization of national investments in biodefense-related R&D, planning, and preparedness.

Laboratory scientists continue to provide technical support to BioWatch (the national system for detecting large-scale bioattack against key U.S. cities), furnishing reachback expertise by on-call subject matter experts as well as supplementary sample analysis and consequence management capabilities. In 2006, the team supported several exercises and confirmed several positive environmental detections. At the request of DHS and the Centers for Disease Control and Prevention, they also coordinated a pilot program to begin the use of Livermore-developed multiplex assays by the Laboratory Response Network (LRN) laboratories. The effort included developing a training manual for assay use, providing on-site training at ten LRN laboratories, and conducting proficiency testing of those laboratories.

Multiplexed assays are also being developed for human respiratory viruses, including influenza. Hospital

Restoration after a Biological Attack

In January 2006, a two-day demonstration held at the San Francisco International Airport (SFO) laid out the response and restoration protocols that would be undertaken if a biological attack occurred. This demonstration was the culmination of the three-year, $10 million DHS Bio Restoration Demonstration Project. In this project, researchers from Lawrence Livermore and Sandia national laboratories developed restoration plans that integrated technologies and procedures so that airports hit by a biological terrorist attack could be quickly decontaminated and reopened. As part of this effort, scientists developed a test for determining within a few hours the viability of the biological agent (e.g., anthrax spores). The restoration plan demonstrated at SFO is being documented in a joint DHS/Environmental Protection Agency report for adaptation and use by other airports and transit facilities.

A cleanup team confers during a demonstration at San Francisco International Airport of response and restoration protocols following a biological attack.

emergency rooms, clinics, and doctors' offices have a pressing need to rapidly diagnose and differentiate influenza and other respiratory diseases, both to prescribe the appropriate treatment and to promptly identifya disease outbreak. Livermore researchers developed the FluID$_X$ diagnostic system to meet this need. FluID$_X$ is an integrated system that performs multiplexed nucleic-acid-based assays in real time. It autono-mously processes a sample (typically a nasal swab), analyzes the data, reports the results, and decontaminates itself. This past year, the FluID$_X$ system was tested at the University of California (UC), Davis, Medical Center Emergency Department. In October 2006 the system was submitted to the U.S. Food and Drug Administration for approval as a medical device, a process that typically take about a year.

In an effort to protect against agro-terrorism, Laboratory scientists have partnered with researchers from DHS, the U.S. Department of Agriculture, UC Davis, and Canada's National Center for Foreign Animal Diseases. Together they have developed a rapid multiplexed assay that simultaneously tests for foot-and-mouth disease (FMD) and six other look-alike diseases in livestock. Early detection of FMD or other foreign livestock disease is critical to reducing the spread and mitigating the economic impact of an outbreak (one estimate is that the U.S. would lose up to $3 million in direct costs for every hour's delay in diagnosing FMD). The research team has also developed a high-throughput, semi-automated system that can analyze 1,000 animal specimen samples in a 10-hour period using two robotic workstations and two technicians, a ten-fold increase over current capabilities. This system can be readily adapted for use with other

Jim Birch, Jack Regan, and Kristl Adams (below, left to right) view results from FluID$_X$, a system that can diagnose influenza and other respiratory viruses in about two hours. Laboratory veterinarian Pam Hullinger (right) prepares to demonstrate how swab samples are taken from cattle to check for foot-and-mouth disease.

assays, including those that test for human diseases, making it directly applicable to public health monitoring and emergency response.

Infrastructure Protection and Emergency Preparedness

To protect infrastructure and enhance preparedness against WMD threats, Laboratory scientists work closely with infrastructure owners and with local, state, and federal response entities. Together these teams identify and evaluate risks, vulnerabilities, and mitigation options. Laboratory researchers then provide essential capabilities to prepare for and respond to WMD emergencies. Many of these tools can be applied to planning for and responding to natural disasters as well.

The National Atmospheric Release Advisory Center (NARAC), located at Livermore, is the premier capability in the U.S. for real-time assessments of the dispersion and potential impact of hazardous materials released into the atmosphere. NARAC provides the technical, scientific, and operational capabilities for the DHS-led Interagency Modeling and Atmospheric Assessment Center (IMAAC), which serves as the coordinating center and single source of federal plume-modeling predictions in the event of a nationally significant incident.

NARAC/IMAAC annually supports thousands of requests for information and hundreds of drills, exercises, and events. In June 2006, NARAC/IMAAC participated in the national TOPOFF4 Command Post/Marble Challenge/Forward Challenge exercise, conducted respectively by DHS, the Federal Emergency Management Agency, and the Federal Bureau of Investigation. Livermore scientists played a key role in developing the exercise scenarios and participated as exercise controllers.

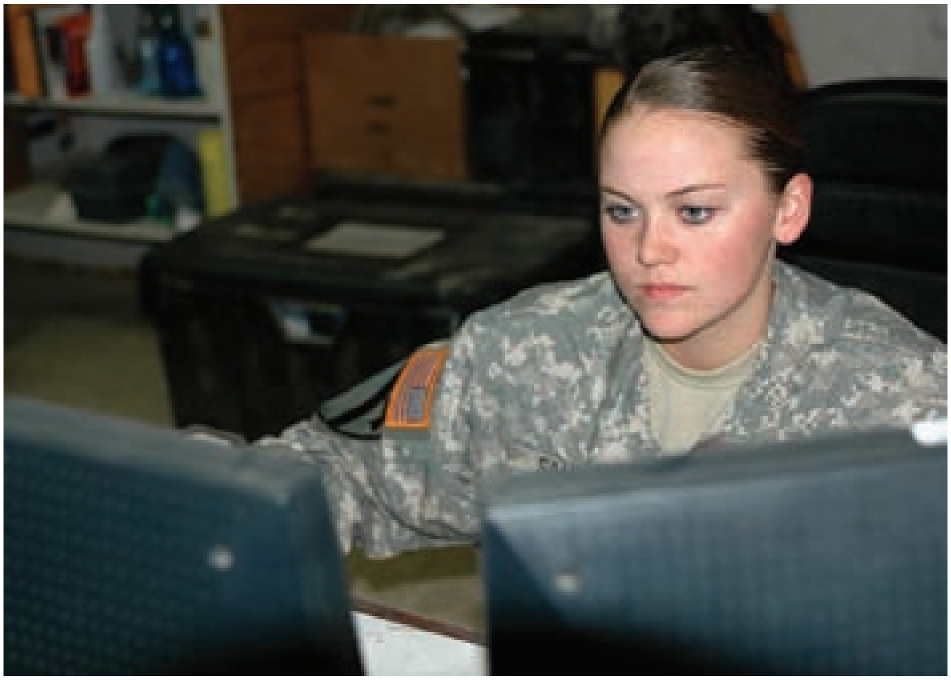
Also in June, the Laboratory was assigned a lead role in the DHS Air Cargo Explosives Detection Pilot Program, which is taking place at San Francisco International Airport, Seattle–Tacoma International Airport, and Cincinnati–Northern Kentucky International Airport. The goal is to thoroughly understand the technological and operational issues involved in

As part of a pilot program to screen aircraft cargo for explosives, Dave Weirup examines the cargo screening area at San Francisco International Airport.

A Pocket-Sized Explosives Detector

A decade of effort culminated in the Easy Livermore Inspection Test for Explosives, or E.L.I.T.E., a credit card-sized device that is self-contained, easy to use, tests for more than 30 different explosives, and yields results within minutes. E.L.I.T.E. won an R&D 100 Award (see p. 44) as well as an award for excellence in technology transfer from the Federal Laboratory Consortium. The E.L.I.T.E. technology has been licensed to Field Forensics Inc., of St. Petersburg, Florida, and E.L.I.T.E. cards are now commercially available.

detecting explosives in air cargo. At San Francisco, cargo inspection lines with x-ray machines have been set up separate from the airport's passenger baggage screening system. Commercially available explosives detection systems are also being used. Different screening approaches are being evaluated at the other two airports in the program. The data collected will be used to develop, test, and optimize concepts of operations and operating procedures and to identify promising technological approaches for improving explosives detection.



A member of the California National Guard uses HOPS during the Vigilant Guard exercise.

Thirty years of Laboratory experience in developing interactive tactical simulation models for the defense community is being applied to enhance infrastructure protection, civil defense, and emergency response. Advanced Conflict and Tactical Simulation (ACATS) is a tool for analyzing tactical vulnerabilities and determining tactical responses to a chemical, biological, or other terrorist attack in an urban environment. ACATS is gaining widespread use at the state and local level to train emergency response personnel in dealing with a terrorist attack.

In a related effort, Lawrence Livermore scientists worked with counterparts at Sandia National Laboratories to produce a Training, Exercise, and Lessons Learned system for DHS. This system supports the National Incident Management System and Incident Command System for multi-level and multi-jurisdictional exercises. A proof-of-concept prototype was successfully demonstrated to senior DHS officials this past year and will be applied in regional exercises in 2007.

Another Livermore-developed tool for infrastructure protection is the Homeland Defense Operational Planning System (HOPS). HOPS provides detailed vulnerability and engineering assessments of critical infrastructures and facilities associated with industry, agriculture, transportation, government/military installations, and important public structures. HOPS is being incorporated into many agencies' response, training, and planning efforts. For example, the California National Guard and the California Office of Homeland Security are using HOPS to analyze the vulnerabilities of critical California infrastructure and then devise measures to protect against and mitigation damage from WMD threats. This past year, a number of major emergency-planning exercises used HOPS, including the seven-state Vigilant Guard exercise, run by the Utah National Guard, the U.S. Northern Command, and the Federal Emergency Management Agency Region 7.

Enduring National Needs

As part of its overarching security mission, the Department of Energy (DOE) pursues research and development to provide reliable and affordable energy for the nation and to keep the U.S. at the forefront of international science and technology. Laboratory research programs support DOE priorities to meet these enduring national needs. Livermore continually seeks challenges that reinforce its national security mission and have the potential for high-payoff results.

Energy security is a central DOE mission, and long-term research is essential to ensuring abundant energy as well as a clean environment. Livermore's energy and environmental programs contribute to the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and for reduced risks to the environment.

Scientific discovery and innovation, also vital to the nation's long-term security, require leadership in science and engineering. Research and development activities at Livermore support DOE's goals in biological and environmental research, fusion and plasma science, computational sciences, basic energy sciences, and acquisition of fundamental knowledge in high-energy and nuclear physics. Projects sponsored by DOE's Office of Science and other customers take advantage of the unique research capabilities and facilities at Livermore. Work supported by Laboratory Directed Research and Development funding aims at scientific breakthroughs to extend Livermore's capabilities in anticipation of new mission requirements.

Stardust Surprises

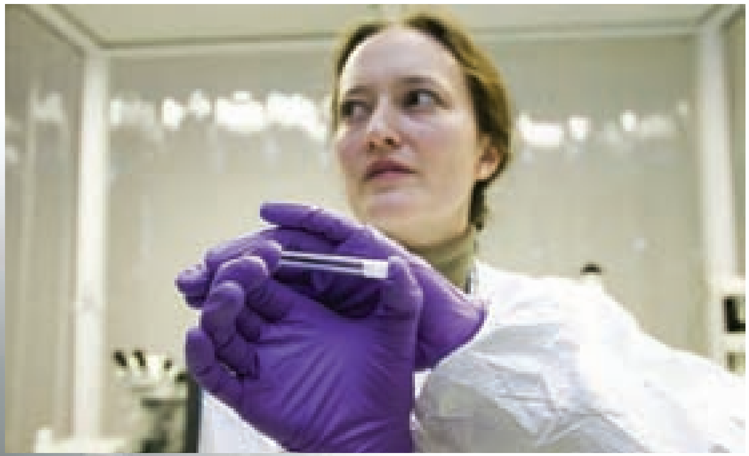
Livermore researchers were on hand in January when samples from the Wild 2 comet first arrived at Johnson Space Center in Houston. The particles were captured in 2004 when the National Aeronautics and Space Administration's (NASA's) Stardust spacecraft flew through Wild 2's tail. Laboratory scientists have been involved in virtually all phases of the highly successful scientific mission—from the development of technologies for sample collection and extraction to the first analyses of the cometary materials, which were full of surprises.

As Stardust neared Wild 2 at a relative speed of more than six kilometers per second, the spacecraft briefly extended a collector filled with lightweight aerogel glass foam to capture thousands of tiny particles from the comet's tail. The 132 aerogel cells in the collector were designed to cushion the impact and prevent significant damage to the particles. With funding from NASA, Livermore had developed methods to produce the ultralow-density silica aerogel for Stardust. Laboratory scientists also played a major role in the technologies adopted by NASA to extract the particles from the aerogel cells, such as a tiny diamond-blade knife to smoothly cut aerogel, and they performed some of the first extractions at Johnson Space Center.

The biggest surprise is that although comets were formed a long distance from the Sun, far beyond the orbit of Neptune, Wild 2 appears to be full of material from the inner solar system, close to the Sun. This unexpected result means that vastly more mixing of material must have occurred while the Sun and planets were forming than previously thought. Preliminary results from the Wild 2 particle analyses were presented at the American Geophysical Union's fall meeting in San Francisco and simultaneously published in the December 15, 2006, issue of *Science*. Laboratory researchers were coauthors on all seven *Science* papers detailing first findings.

Scientific Discovery with Supercomputers

The Laboratory purchased a next-generation supercomputer powered by Linux cluster technology consisting of three clusters, called Atlas, Zeus, and Rhea, for a total of 77 teraflops. The largest cluster, Atlas, at 44 teraflops, will serve as the mainstay of the Laboratory's Multiprogrammatic and Institutional Computing Program, which is a resource for unclassified, high-end computing across the Laboratory. Atlas will greatly



John Bradley (left) celebrated when Stardust returned to Earth, and Hope Ishii (above) showed an aerogel cometary dust collector to the media. Analyses of Wild 2 particles used the Laboratory's unique capabilities, including the super scanning transmission electron microscope (SuperSTEM), the world's most powerful electron microscope. It allows atomic-scale analyses of a particle's composition.

augment the capabilities of Thunder, a 23-teraflop cluster that was the world's second fastest computer when it was introduced in 2004. Thunder runs unclassified "grand challenge" problems—large calculations that promise breakthrough science. Thunder results have helped Laboratory scientists solve problems ranging from high-resolution climate modeling and seismic simulations to protein folding and molecular dynamics.

Several grand challenges lie in the area of material properties. Whether studying an organic material, such as a protein, or an inorganic material, such as a metal, scientists must understand the origin of its microstructural features to predict the material's properties. In metals, atoms stack in an orderly fashion, forming a crystal lattice. However, some regions have impurities or misaligned planes of atoms, called dislocations. In large-scale simulations of dislocation dynamics—the interaction of dislocation lines under conditions of stress—Laboratory scientists found the common presence of three or more intersecting dislocation lines. These knots greatly add to a stressed metal's strength. Results were reported in the April 27, 2006, issue of *Nature*.

Laboratory scientists and collaborators also simulated the folding of the 1BBL protein, which has also been studied in experiments. The simulations, comprising about 65,000 atoms, most of them water molecules, were replicated 256 times at temperatures ranging from 250 to 600 kelvin. The calculations confirmed experimental results that the folding is a "downhill" energy process. However, an initial energy barrier has to be overcome for a synthesized protein to collapse into a globular package that then loses energy as it folds into its native state. These simulations were three times larger and four time longer than any done previously.

In addition, Livermore scientists continue to advance the state of the art in scientific simulations, software development, and data visualization and interpretation. More than 40 Laboratory researchers are working on 14 multi-institutional scientific computing projects as part of the DOE Office of Science Scientific Discovery through Advanced Computing Program. Two R&D 100 award winners in 2006 exemplify the capabilities developed by Livermore computer scientists: Babel, a program that allows software written in different programming languages to seamlessly pass scientific data back and forth, and Sapphire, a sophisticated tool for mining scientific information from terabytes of data.

Tom Arsenlis (left) and Vasily Bulatov used the Parallel Dislocation Simulator (ParaDIS) code to study how metals deform and fail.

Climate: Volcanoes, Hurricanes, and California

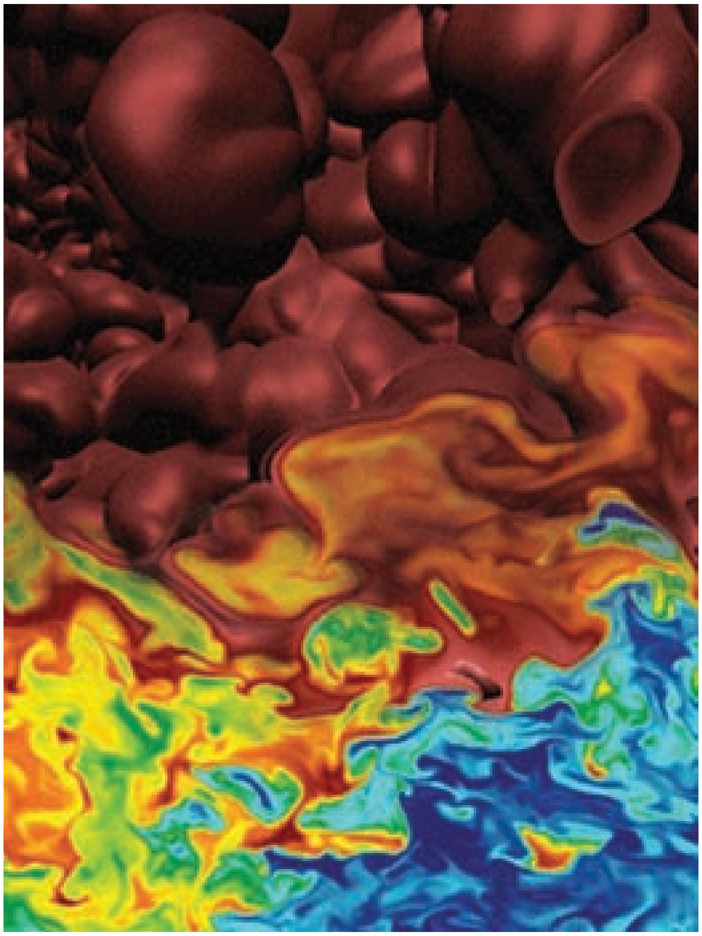
Livermore is contributing to a variety of efforts to better understand factors affecting global and regional climate. In May 2006, the U.S. Climate Change Science Program released *Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences*. Laboratory scientist Benjamin Santer, who was awarded a Distinguished Scientist Fellowship by the DOE Office of Science last year, was one of the report's lead authors and made important contributions to the underpinning research.

In 2006, Livermore scientists (including Santer) and collaborators showed that ocean warming and sea level rise in the 20th century were reduced substantially by the 1883 eruption of the volcano Krakatoa in Indonesia. Volcanic aerosols scatter sunlight and cause the ocean surface to cool. The more recent 1991 Mt. Pinatubo eruption in the Philippines, which was comparable to Krakatoa in size and intensity, resulted in minimal net cooling because it was countered by human-induced warming.

A team of researchers from Livermore and ten other institutions also studied sea surface temperature in hurricane "breeding grounds" of the Atlantic and Pacific oceans. Using 22 different computer models of the climate system, they showed that the warming of these tropical oceans over the last century is directly linked to human activities. These findings complement earlier work that uncovered compelling scientific evidence of a relationship between warming sea surface temperatures and increases in hurricane intensity.

California is another region of special interest. Research indicates that global warming may dramatically change river flows in the state. California's water infrastructure is efficient at providing

Research shows that the warming of the tropical oceans over the last century is linked to human activities, adding to evidence of a link between warming sea surface temperatures and increases in hurricane intensity, as exemplified by Hurricane Katrina.



Researchers used BlueGene/L for this high-resolution simulation of Rayleigh–Taylor instability in supernova thermonuclear burning.

an adequate water supply and minimizing flood risk when there are large amounts of mountain snow. If winter temperatures warm, more rain than snow will fall at higher elevations, and where snow does accumulate, it will melt sooner. Higher river flow rates during winter and lower rates during spring and summer would reduce the overall water supply for the entire year. Other studies examined the impact of temperature rises on California crops.

Astrophysics Discoveries through Simulation

Running advanced simulation models on some of the fastest computers in the world, Laboratory researchers are making exciting discoveries in stellar and planetary astrophysics. One puzzle in stellar evolution has been the fate of helium-3 produced in low-mass stars (one to two times the size of the Sun). The observed amount of helium-3 in the universe is less than that predicted to have been created by the big bang and stellar evolution. By modeling red-giant evolution with a fully three-dimensional hydrodynamic code, Livermore researchers identified a new mixing phenomenon that leads to the burning of excess helium-3. As reported in the October 26, 2006, edition of *Science Express*, predictions now agree with observations.

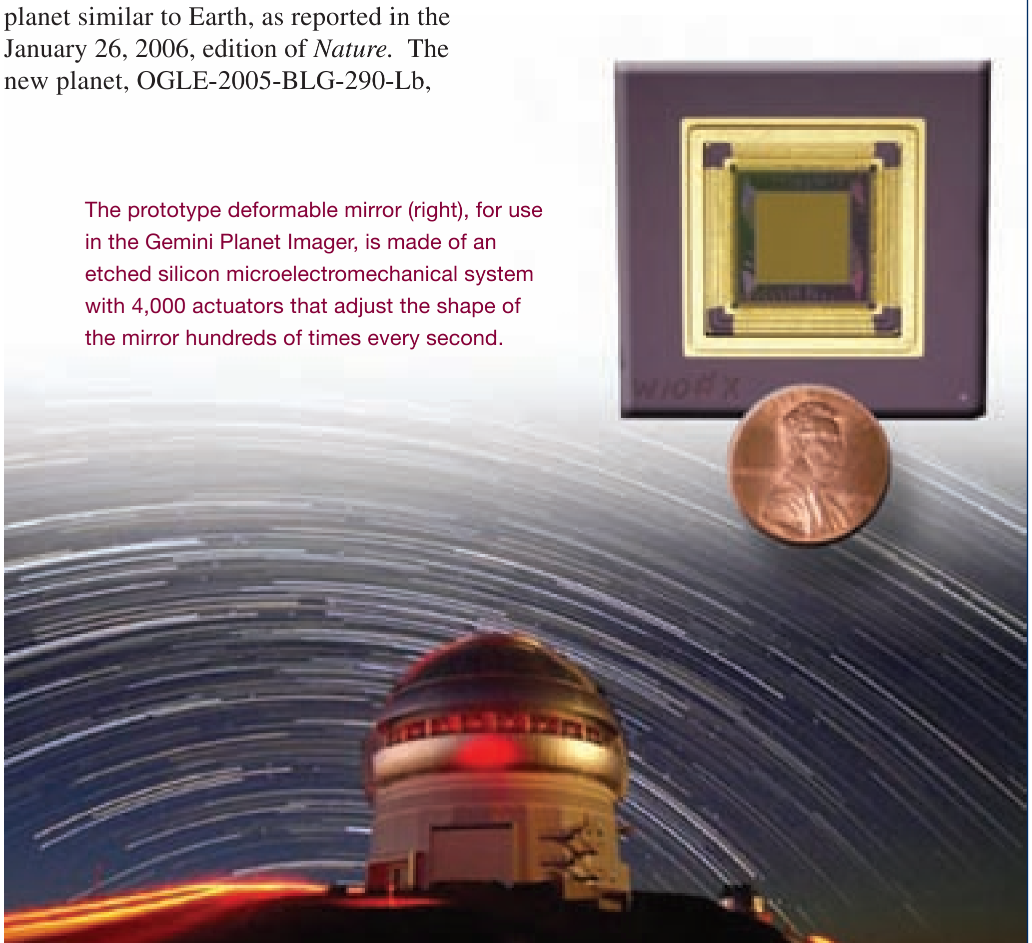
The cover of the August 2006 issue of *Nature Physics* featured a simulation of Rayleigh–Taylor instability—the same phenomenon that mixes a top layer of oil into water. The turbulence of a fluid flow is described by the Reynolds number; when it is above about 2,300, eddies of varying scales are present. The Livermore simulation achieved a Reynolds number of 32,000 and is the first to reach past the turbulent mixing transition at the necessary resolution. These results offer new insights into the dynamics of turbulent combustion in type Ia supernovae. Eddies affect the propagation of thermonuclear burning and the brightness of supernova “standard candles,” which are used to guide estimates of distances and the expansion rate of the universe.

Yet another set of simulations revealed important aspects of the behavior of carbon at high pressure and temperature. In particular, they showed the solid–liquid and solid–solid phase boundaries for pressures up to 20 million atmospheres and temperatures of more than 10,000 kelvin. The physical properties of carbon in this regime are of great importance for devising models of Neptune, Uranus, carbon-rich planets in other solar systems, and white dwarf stars.

Finding Distant Planets

An international collaboration of astronomers, including a Laboratory scientist, discovered a small, rocky or icy planet similar to Earth, as reported in the January 26, 2006, edition of *Nature*. The new planet, OGLE-2005-BLG-290-Lb, is the smallest planet yet detected outside our solar system. It has about 5.5 times the mass of Earth and orbits a dim star about 390 million kilometers away. The discovery was made by the Probing Lensing Anomalies Network (PLANET) using microlensing, a technique developed nearly two decades ago by Livermore astrophysicists as part of the Massive Compact Halo Object (MACHO) Project that searched for evidence of dark matter. PLANET observatories in the Southern Hemisphere tracked anomalies in the light from a more distant star. The gravitational pull of the red dwarf and the orbiting Earth-like planet caused the bending of light rays and indicated the presence of a planet.

Livermore scientists are also at the forefront of new technology to directly image distant planets. The Laboratory has been selected to lead the project to build the Gemini Planet Imager for the



The prototype deformable mirror (right), for use in the Gemini Planet Imager, is made of an etched silicon microelectromechanical system with 4,000 actuators that adjust the shape of the mirror hundreds of times every second.

8-meter-diameter Gemini South Telescope in Chile. The Gemini Planet Imager will be the most advanced adaptive optics system in the world. Through the use of adjustable mirrors, adaptive optics allow ground-based telescopes to produce clear images by correcting for atmospheric turbulence, which causes stars to twinkle and appear blurry to astronomers. The system will have a 2-centimeter-square deformable mirror with 4,000 actuators. Etched silicon microelectromechanical systems will adjust the mirror's shape to correct for atmospheric distortions 2,500 times per second with an accuracy of better than 1 nanometer. When the imager is operational in 2010, astronomers will be able to detect planets 30 to 150 light years from our solar system.

Imaging Biological Molecules at the Nanoscale

Laboratory scientists and collaborators for the first time have validated the idea of using an extremely short and intense x-ray pulse to capture an image of a biological object before absorbed energy from the pulse destroys the sample. At the same time, the team established a speed record of 25 femtoseconds (25 millionths of a nanosecond) for flash imaging. The research results were featured on the cover of the December 2006 issue of *Nature Physics*.

The experiment was performed at the free-electron laser at Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany. The pulse illuminated a nanostructured object, and the team recorded the pattern of diffracted x rays. A Livermore-developed computer algorithm then recreated an image of the object based on the recorded diffraction pattern. The flash images resolved features 50 nanometers in size, about 10 times smaller than what is achievable with an optical microscope.

The diffraction pattern of a short, intense x-ray pulse directed at a protein formed the basis for this image, which was featured on the cover of *Nature Physics*. Flash diffraction imaging is a new method for gaining atomic-scale information about complex biological molecules.

The new method, called flash diffractive imaging, will be applicable to atomic-resolution imaging of complex biomolecules when even more powerful x-ray lasers, currently under construction, are available. The technique will allow scientists to gain insight into the fields of materials science, plasma physics, biology, and medicine.

Experiments under Pressure

In experiments conducted at Livermore, an international team of researchers demonstrated a new kind of "creep," or flow, in a form of ice with the pressure, temperature, stress, and grain size of those in the deep interiors of large icy moons. The new research revealed a creep mechanism that is affected by the grain size of "ice II." Ice II is thought to exist in a 100-kilometer-thick layer in the interior of moons such as Saturn's Titan. The experimental results, presented in the March 3, 2006, issue of *Science*, imply that the ice II layer is significantly weaker than previously thought. The discovery will change scientists' thinking about the thermal evolution and internal dynamics of the medium- and large-size moons of outer planets, and about what was happening in the early solar system.

The same issue of *Science* reported the results of another international collaboration involving Laboratory scientists. They synthesized a novel class of nitrides made from noble metals under extreme conditions. Noble metals do not easily form compounds with other elements. With a diamond anvil cell creating high pressures and a laser creating high temperatures, the researchers made the first bulk nitride of the noble metal iridium. By combining experimental results with first-principles theoretical modeling, the scientists determined the structure of the known nitride of platinum. The semiconductor industry currently uses titanium nitrides because of their strength and durability. These new nitrides may prove to be even more durable than titanium.

At the European Synchrotron Radiation Facility, Laboratory scientists in an international team conducted x-ray scattering experiments to study the lattice dynamics of molybdenum samples. Experimental results combined with simulations enabled scientists to better understand a high-pressure anomaly in molybdenum. The simulations won the Gordon Bell Prize for 2006 (see p. 9).

Biological Discovery

Research has shown that many of the complex biochemical networks needed for the existence of advanced organisms could not have evolved without oxygen. Laboratory scientists used a Monte Carlo computer simulation and a large bioinformatics data base (the Kyoto Encyclopedia of Genes and Genomes, or KEGG) to study the effect of oxygen on metabolic networks—the biochemical systems that enable organisms to convert food and nutrients into life-sustaining energy. Starting with randomly selected seed conditions (a set of reactants), the simulations generated about 100,000 different reaction networks. Analysis showed that the largest and most complex networks require the presence of molecular oxygen, which offers organisms opportunities for respiration and the biosynthesis of entirely new classes of molecules. The results appeared in *Science* on March 24, 2006.

In another computational study, a Livermore chemist revealed the characteristics of the pigment in curcumin that give it the ability to prevent and even treat Alzheimer's disease. Experimental work on mice performed at the University of California (UC), Los Angeles, indicated that curcumin, the yellow pigment in the east Indian root plant turmeric, can penetrate the blood–brain barrier, the natural mechanism that protects the brain. It also can bind to and reduce amyloid plaque in brain cells, which is a cause of Alzheimer's disease. The Livermore study shed light on the hydrophobic and hydrophilic properties of curcumin that make possible both penetration and binding. The simulations further revealed the three-dimensional structure of the most stable form of curcumin, which may allow other drugs to be discovered through molecular similarity.

Laboratory scientists and collaborators took a small but valuable step toward understanding how cells function and how viruses interact with cells. They developed a method that can directly test for the existence of lipid rafts in cellular membranes. Lipids in the cell membrane are believed to form compositionally distinct domains, called lipid rafts, that serve a critical role in the organization of the cell membrane. The research team formed model cell membranes on a silicon chip, induced the formation of lipid-raft-like gel domains, and freeze-dried the membranes. Then, with NanoSIMS, the Laboratory's high-resolution secondary ion mass spectrometer, the scientists were able to detect gel domains and measure their size. Their work was reported in the September 29, 2006, issue of *Science*.

Accelerating Biomedical Research

At Livermore's Center for Accelerator Mass Spectrometry (CAMS), home to the most versatile and productive AMS facility in the world, a team of scientists developed an AMS technique for early detection of bone cancer, which could help physicians design methods to prolong a patient's life or even arrest the disease. Using calcium-41 as an isotopic tracer, AMS can measure small changes in the rate of continually occurring skeletal bone turnover in humans. A small dose of calcium-41 administered to a patient is enough to track skeletal calcium loss over a person's lifetime. Medical researchers know that skeletal disease correlates with bone turnover rate, and the amount of calcium-41 in urine samples can be carefully monitored with AMS. In experiments with mice, the technique has been shown to diagnose changes in bone turnover with high precision. Clinical trials will soon begin.

AMS also shows great potential as a diagnostic tool for determining how

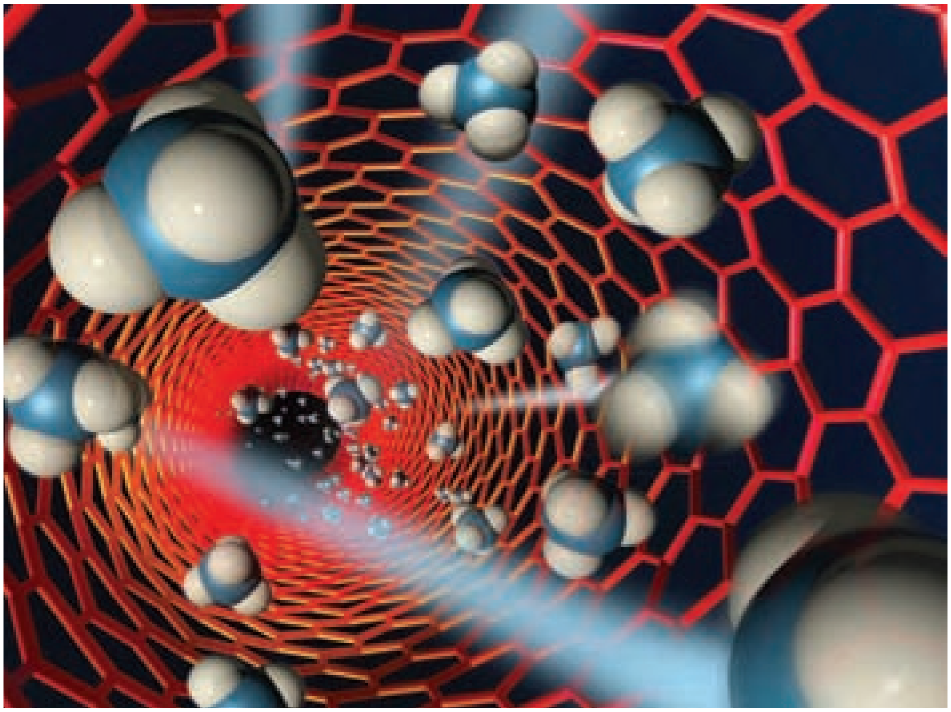
CAMS director John Knezovich explains the AMS process to Vince Stewart (left), director of Federal Government Relations at UC Davis and John Hamilton (center), deputy director of Federal Government Relations at UC's Office of the President. The CAMS accelerator is in the background.

people, especially the elderly, are able to absorb vitamin B12. An estimated 1 million Americans over the age of 65 have a condition known as pernicious anemia, which interferes with their ability to properly absorb the vitamin and puts them at risk for developing debilitating fatigue and neurological problems. Scientists at the Laboratory and UC Davis are developing a diagnostic procedure wherein a patient would take a small tablet of B12 labeled with carbon-14. Blood samples taken by pin prick would then be subjected to AMS analysis.

Uses of Carbon Nanotubes

Laboratory researchers have created a membrane with carbon-nanotube pores that may offer a less expensive way to remove salt from water, just one among many possible nanotube applications. In research that appeared on the cover of the May 19, 2006, issue of *Science*, the team reported that gas and water flows through the membrane are as much as 8,500 times faster than what classical models predict. Hollow carbon nanotubes are about 50,000 times thinner than a human hair— six water molecules can fit across their diameter. Larger molecules, such as contaminants in water, are blocked by the tubes' small size. The team measured the flow of gases and liquids through the membrane, composed of billions of nanotubes, and found the amazing results, which are consistent with quantum simulations of water flow through nanotubes.

Another surprising feature of carbon nanotubes was reported by a different team of Laboratory researchers and collaborators in the January 19, 2006, issue of *Nature*. They found that a single-walled carbon nanotube heated to more than 3,600 degrees Fahrenheit can be elongated by nearly 280 percent, compared to a theoretical maximum of 20 percent under normal conditions. Its diameter shrank by 15 times. This discovery of superplastic deformation could prove useful in helping to strengthen and toughen ceramics and other nanocomposites at high temperatures.



Artist's rendering of methane molecules flowing through a carbon nanotube less than 2 nanometers in diameter.

Fusion Advances

On November 21, 2006, seven parties, including DOE Undersecretary Raymond Orbach representing the United States, met in Paris to sign the agreement to establish the international organization that will implement the ITER fusion energy project. ITER, a large tokamak designed to produce 500 megawatts of fusion power, will be constructed at Cadarache, France. The Laboratory has been participating in the ITER project since its inception. Livermore scientists working at the DIII-D Tokamak at General Atomics in San Diego have led the effort to develop new methods for reducing the heat load on the walls of ITER, and they are developing advanced plasma diagnostics.

In September, the Laboratory was awarded contracts to work on two scoping studies for ITER diagnostic systems. One study will explore the use of infrared cameras to measure temperatures on a plasma wall where tremendous heat fluxes born from the fusion reactions will be deposited. The other study will deal with the design for an optical system that measures the plasma current density. The two diagnostic system designs will be patterned in part after systems deployed by the Laboratory on the DIII-D Tokamak.

A worker inside the DIII-D tokamak at General Atomics in San Diego, California. Diagnostic tools for the new ITER tokamak are based on ones Livermore developed for the DIII-D.

A New Addition to the Periodic Table

A team of researchers from Livermore and Russia's Joint Institute for Nuclear Research (JINR) discovered the newest superheavy element, element 118. They used the JINR U400 cyclotron in Dubna, Russia, to slam an intense beam of calcium-48 nuclei into californium-249 targets. In the gas-filled separator beyond the cyclotron, three atoms of element 118 were created and lived for about a thousandth of a second. Three similar decay chains were observed consisting of two or three consecutive alpha decays terminated by a spontaneous fission event. The Livermore–Dubna team previously discovered elements 113, 114, 115, and 116. Their findings were published in the October 2006 edition of *Physical Review C*.

The Livermore element 118 discovery team includes (from left) Jackie Kenneally, Jerry Landrum, Nancy Stoyer, and Ken Moody. Moody studied under Glenn T. Seabourg, who discovered plutonium and many other elements.

Hydrogen for Future Transportation

Hydrogen as a fuel can help replace imported oil and does not contribute to greenhouse emissions. As part of DOE's National Hydrogen Storage Project, a group of Laboratory researchers is taking an innovative approach to hydrogen storage for vehicles. Livermore's vessel is designed for high-pressure storage of hydrogen as a compressed room-temperature gas, a cryogenic gas, or as a liquid. Most other DOE researchers are concentrating on low-pressure options. The tank was tested on a Toyota Prius hybrid vehicle converted to run on hydrogen by Quantum Fuel Systems Technologies Worldwide of Irvine, California. The goal was to exceed DOE's target driving range of more than 480 kilometers. The team achieved a range of 1,050 kilometers.

The Livermore tank consists of a pressure vessel custom fabricated by Structural Composites Industries, of Pomona, California. Its many layers of insulation are enclosed within a vacuum vessel. Because the tank can hold hydrogen in different forms, the driver can choose a form that meets immediate priorities. The design builds on the success of Livermore's first-generation cryogen-capable vessel, which was tested in 2004 on a Ford Ranger. This successful technology demonstration could help pave the way for hydrogen-powered vehicles.

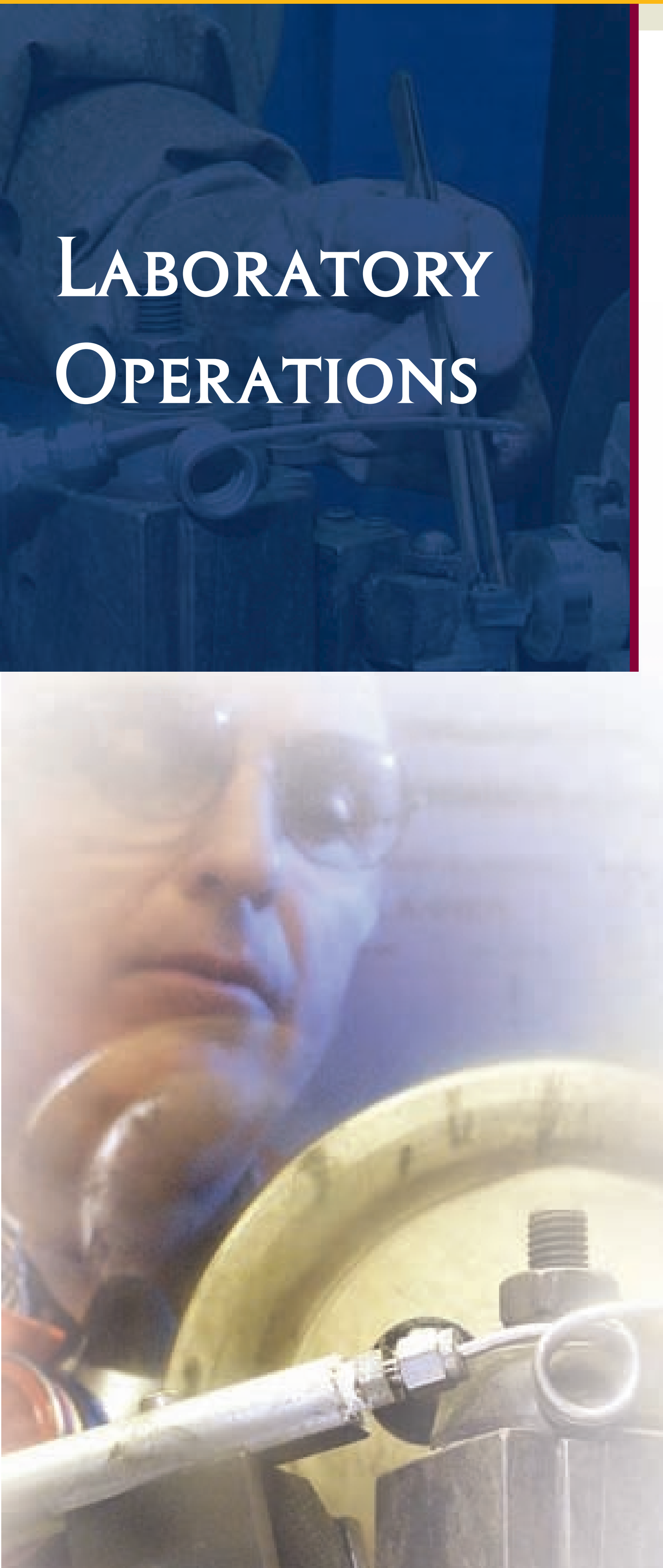
Vern Switzer and Tim Ross (top) work on a new hydrogen fuel tank for a Toyota Prius, shown below with (from left) Gene Berry, Francisco Espinosa-Loza, and Salvador Aceves.

Genome Sequencing and Biofuels

In May, DOE's Joint Genome Institute (JGI) celebrated the completion of its 100th microbial genome sequence. Scientists use information about the genomes of microbes and other organisms to study how microbes efficiently destroy toxic substances for environmental cleanup and break down plant materials to produce useful sources of energy. Sequencing has focused on microbes that are efficient at ethanol conversion and on a rapidly growing poplar tree, the black cottonwood (*Populus trichocarpa*), which could serve as feedstock for biofuel. The work was featured on the cover of the September 15, 2006, edition of *Science*. Among the JGI's major discoveries is the identification of more than 45,000 protein-coding genes, more than any other organism sequenced to date. The research team identified 93 genes associated with the production of cellulose, hemicellulose, and lignin, the building blocks of plant cell walls.

The JGI unites the expertise of five national laboratories, including Lawrence Livermore, along with the Stanford Human Genome Center. As a national user facility, the JGI has sequenced or is in the process of sequencing more than 380 organisms, more than any other institution in the world.

It was cover news for *Science* when the JGI sequenced the genetic code of plants that could serve as sources of energy.



Laboratory Operations

Responsible stewardship of the Laboratory entails setting and meeting high standards in all aspects of operations. Safe, secure, and efficient operations are an integral part of Livermore's research and development programs. Together, quality operations and scientific and technical excellence make possible Livermore's programmatic accomplishments and sustain public trust in the Laboratory.

Safety and security are the most important considerations in day-to-day operations. The Laboratory provides employees and neighboring communities with a safe and healthy environment in which to work and live. A personal commitment by all employees to the safety of their work—and of the individuals around them—is indicative of a deeply rooted safety culture. The Laboratory is continually improving systems in place to ensure that proper safety practices are learned and followed by all. Security, also the responsibility of every employee, requires vigilance. Nuclear materials, sensitive information, and other valuable assets must be protected against new and evolving threats.

Business processes and systems, infrastructure management, and administrative functions are continually being improved to achieve best-in-class performance among high-technology research organizations. The demand is greater than ever before to improve efficiency and cut costs while also maintaining compliance in an increasingly complex regulatory environment. Contract performance measures help to gauge operational effectiveness and provide quality assurance to Laboratory and contract managers, government officials, and the general public.

Safety is Paramount

Livermore's Integrated Safety Management (ISM) system provides a framework through which safety procedures and practices are continually improved. A focus on safety by each individual, sound implementation of ISM, and a commitment at all levels of management are critical to success. First on the Laboratory Director's A List for 2006 is "Make a personal commitment to our collective safety and security," and Director George Miller stresses this theme in all of his Laboratory-wide talks to employees.

Injury and illness rates are stable after a decade-long decline that brought the statistics to more desirable levels. For 2006, the rate for recordable cases (number of cases per 100 employee-years) was 2.37, while the rate for cases with days away, restrictions, or job transfers was 1.04. The Laboratory is committed to reducing injury and illness rates. Excellence in safety is exemplified by the National Ignition Facility (NIF) Programs Directorate. In 2006, both the NIF project site and NIF laboratories received "Perfect Record" awards from the National Safety Council for working more than 12 consecutive months without injury or illness involving days away from work. The Council also awarded NIF Programs a "1 Million Work Hours" award for working 1 million hours without an injury or illness that resulted in days away from work.

The institution and each of the directorates continue to improve their ability to identify their own weaknesses, analyze safety implementation, and take effective corrective actions. Line managers conduct observations of work-level activities for the ISM self-assessment process, and each directorate certifies ISM implementation annually. Areas for improvement are identified and addressed. Livermore has improved the management of corrective action plans to deal with deficiencies. The overall on-time completion rate is high and has dramatically improved over the last year for nuclear-related institutional corrective actions—from 43 percent to 84 percent.

In June, the Laboratory completed the Compliance Management Plan for the Safety Basis Requirements (10CFR830, Subpart B) for its Category 2 and 3 nuclear facilities. All milestones were met to achieve compliance with 10CFR830, Subpart B. This is the culmination of a five-year effort reflecting the development, submittal, and approval of seven 10CFR830-compliant Documented Safety Analyses. Through corrective action plans and process improvements, Livermore is taking vigorous steps to improve safety in all areas to move to a self-identifying, self-correcting program.

The Laboratory has also established a robust emergency management program to ensure that employees and the public are protected from potential consequences of an incident involving hazardous materials. In fiscal year 2006, Livermore met all deliverables in its Emergency Readiness Plan for the National Nuclear Security Administration (NNSA) Livermore Site Office. Emergency Preparedness Hazard Assessment reviews were completed for appropriate facilities,

Ed Moses (left), associate director for NIF Programs, celebrates the directorate's "Perfect Record" award from the National Safety Council with the Materials Storage and Handling team.

Livermore staff worked together with the Livermore Police Department on the SecurEX 07 emergency preparedness drill.

and the Laboratory significantly increased the number and quality of its emergency drills and exercises. Altogether during the year, 26 drills, one annual exercise, and one Department of Energy (DOE) Headquarters-sponsored "no-notice" exercise were held. These efforts have greatly improved how staff work with emergency responders and how access is controlled to an emergency response area.

Security Improvements

Security was enhanced after the September 11 attacks, and the Laboratory now operates routinely at a heightened security level. An extensive security infrastructure is in place. However, in fiscal year 2006, the Laboratory faced a declining budget for safeguards and security together with increasing requirements and ever-growing threats. Nevertheless, Livermore was able to meet the challenge through continuous improvement of its Integrated Safeguards and Security Management (ISSM) system and judicious application of risk management principles to optimize security investments and scale back some services. The LLNL Site Safeguards and Security Plan was approved by the Livermore Site Office and described by the NNSA Associate Administrator for Defense Nuclear Security (NA-70) as "well done."

Effective implementation of 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 in annual training. Line management is accountable for performance, and each directorate conducts an annual self-assessment—this year focusing on security incident prevention, cyber security, and selected other topics that present risk to the directorate.

Technology investments in 2006 included new physical protection systems, the incorporation of security features in the design of new information technology systems, and an extensive upgrade of the central alarm station. The station serves as the central nervous system for Protective Force operations, including alarm monitoring and site video surveillance.

Livermore is also making continual improvements in cyber security, including extensive cyber security training, inventory and reduction of Classified Removable Electronic Media (CREM), and the Diskless Conversion Project to eliminate local system disks from classified workstations. Immediately after a widely publicized security incident at Los Alamos National Laboratory, Director George Miller launched a thorough self-assessment of compliance with DOE/NNSA orders and directives, Laboratory policies, and each directorate's procedures for implementing classified cyber security. He also tasked all employees who deal with classified materials to review cyber security training information as well as security plans and procedures. In addition, the Laboratory is studying several options for further improving its cyber security posture.

Responsible Environmental Management

In 2006, the Laboratory completed the last of 87 milestones in the Livermore Site Remedial Action Implementation Plan. This completes "build out" of the regulatory-required infrastructure needed to clean up groundwater, which was contaminated with volatile organic compounds (VOCs) by activities in the 1940s, before the Laboratory was established. Since remediation began in 1989, more than 3 billion gallons of groundwater and 225 million cubic feet of soil vapor have been treated, removing a combined total of over 2,200 kilograms of VOCs. The established network of extraction wells and treatment systems is confining the plumes of contaminated groundwater within Laboratory boundaries, and these systems are attacking source area contamination using available technology.

At Site 300, the Laboratory's remote experimental test site, 20 groundwater and soil vapor-treatment facilities are being operated, and work is under way

20 Years of SAFE

In February 1986, Livermore launched the Security Awareness for Employees (SAFE) program, and for 20 years SAFE has been identifying and countering foreign intelligence threats against the Laboratory and its employees. SAFE is widely acknowledged as the model counterintelligence program for DOE. Employee awareness is key to an effective counterintelligence program, and SAFE provides help to staff in dealing with foreign contacts and protecting information. The program also sustains employee awareness of security threats by bringing in speakers from the intelligence and counterintelligence communities—even former KGB officers.

20th Anniversary
SAFE
1986-2006

to complete construction of other new facilities. Considerable effort is being devoted to preparation of documents to meet Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requirements as part of the process to evaluate and establish remediation needs. Livermore is working closely with all stakeholders to negotiate effective and cost-efficient remedies that will protect human health and the environment from unacceptable risk.

Laboratory meteorologist Brent Bowen (left) and Gary Bear monitor weather at the 52-meter meteorological tower. Meteorological data support emergency preparedness and response, regulatory atmospheric modeling, and essential environmental sampling.

The TSF project management team celebrates their award from DOE. Project manager Anita Zenger is holding the TSF sign on the left.

In fiscal year 2006, Livermore also declared conformance with International Standard ISO 14001, Environmental Management System (EMS), after ISO 14001 requirements were effectively integrated into the Laboratory's ISM system. EMS promotes responsible environmental stewardship practices and focuses on continuous improvement through pollution prevention and conservation measures. As part of EMS, the Laboratory has set or is developing specific targets to reduce various categories of energy consumption, materials use, and waste generation. The declaration of conformance was based on an internal audit and an independent audit conducted by the Livermore Site Office, which found no major nonconformances and 22 noteworthy practices. Minor nonconformances were addressed through a corrective action plan.

Best Practices in Project Management

The Laboratory's Terascale Simulation Facility (TSF) won the DOE Secretary's Project Management Award in 2006, which is presented annually to three teams that demonstrate outstanding performance based on overall management and successful completion of a project. The $100-million, 253,000-square-foot TSF houses two of the world's fastest supercomputers (see p. 9) and more than 250 staff members. The facility was completed in 2004, eight months ahead of schedule and $1.2 million under budget.

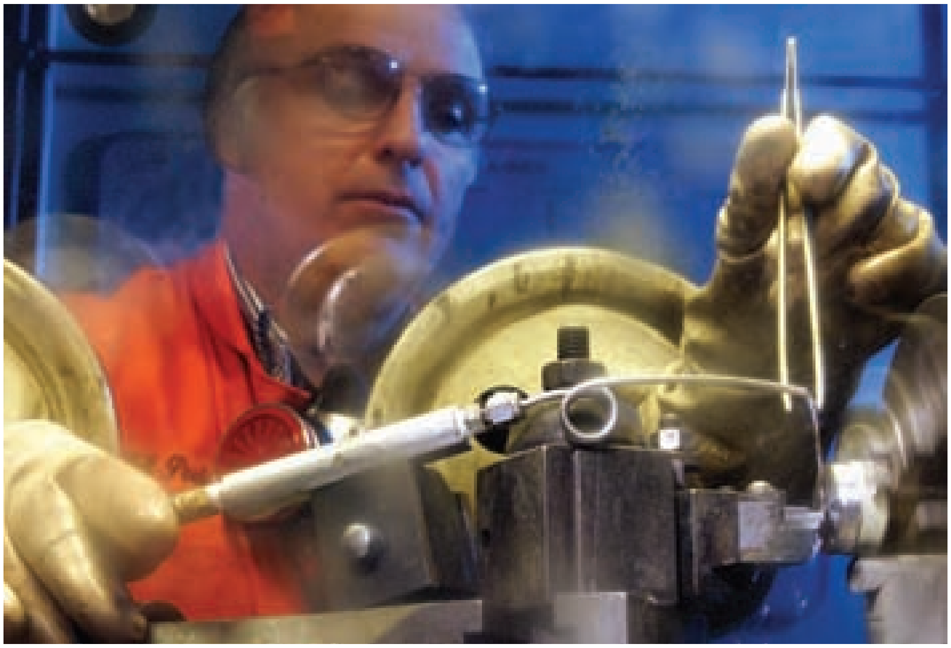
TSF construction and the ongoing NIF and Engineering Technology Complex Upgrade projects benefit from the use of an Earned Value Management System. EVMS is also being used for a growing list of projects within the Stockpile Stewardship Program. This best-practices tool provides an effective means for evaluating how well a project is being executed with respect to technical requirements, cost, and schedule. EVMS gives sponsors, Laboratory managers, and those engaged in the project a clear view of status and progress. By bringing formality to project management, EVMS enhances project planning and execution, and it reinforces clear roles, responsibilities, and accountability.

In May 2006, DOE's Office of Management certified the Laboratory's EVMS. To achieve site-wide certification, Livermore had to demonstrate that the system was compliant with the 32 guidelines in the American National Standards Institute/Electronic Industries Alliance Standard 748-A. Certification is important because DOE recently began requiring that the method be used for managing earned value for capital asset projects budgeted at more than $20 million. The University of California is the first DOE contractor to certify EVMS at all of its sites, and it is the only contractor that has site-wide certification for each site.

Superblock Back to Normal Operations

With the approval of the NNSA Livermore Site Office, the Plutonium Facility (Building 332, also known as the Superblock) returned to normal operations in May. The Laboratory decided in January 2005 to stand down operations in the facility so that the management team could turn its full attention to safety improvements. An intense effort ensued to assess all activities, develop new tools and processes, and implement rigorous protocols for resuming work. The Superblock returned to partial operations in October 2005, with activities limited to less than 5 kilograms of plutonium.

An Operational Excellence program, begun in 2005, is increasing efficiency,



Certified fissile material handler Bill Poulos machines plutonium for an experiment in the Plutonium Facility.

Criticality Safety Training for NNSA

Criticality safety is an essential element in training NNSA workers who handle or otherwise deal with special nuclear material. At the request of NNSA, Livermore expeditiously developed a nuclear criticality training curriculum, got it approved, and graduated the first class of students, who came from various NNSA sites. Training modules include classroom sessions on regulatory and safety issues as well as hands-on experiments in the Superblock involving fissile materials, supervised by senior Laboratory certified material handlers. Participants are also trained to deal with criticality accident scenarios.

Barbara Krögfuss of Y-12 places her gloved hand on a uranium test assembly as part of a nuclear criticality training exercise at Livermore. Certified fissile material handler Nolan Lomba (right) and Mark Lee of the Livermore Site Office look on.

lowering costs, and increasing safety in Superblock operations. The initial effort focused on improving the Unreviewed Safety Question Determination (USQD) process for determining and documenting whether DOE approval is required for a proposed activity or whether an operation is outside of the Safety Basis. Implementation of recommended improvements has led to a 80-percent reduction in the USQD approval cycle time, better documentation, and cost avoidance by reducing the number and duration of USQD-related meetings.

Efficient and Effective Business Practices

The Laboratory's business systems—procurement, property management, and finance—are designed to meet best-in-class business practices and applicable federal regulations. Each area has performance management programs in place that include metrics and performance thresholds, developed in concert with NNSA and UC. Business processes and systems are continuously improved to increase effectiveness and lower institutional administrative costs. Livermore is re-engineering many processes by taking advantage of information technologies. In addition, the Laboratory uses internal audits—and is subjected to external audits—to ensure that business systems are in full compliance and follow best practices.

A Process Improvement Initiative is serving as a catalyst to stimulate continual improvement. Livermore staff members trained in process improvement methods are assisting organizations that have identified opportunities and needs for process improvement. More than 60 process improvement projects are completed or well underway, spanning every directorate at the Laboratory. Among many examples, projects are improving the processes for revisions to the Laboratory's *ES&H Manual*, workflow in the Plutonium Facility, employee termination, configuration management and security of computer systems, and determination and approval of ES&H roles and responsibilities as work projects, facilities, and organizations change.

LAPIS gives employees and staff secure online access to personal data.

Livermore is also investing in business and financial management projects that will transform the way work is done. As an example, the multi-year Enterprise Project Accounting and Reporting (EPAR) Program aims to replace Livermore's current financial system and provide capabilities to track project costs, budgets, funding, and schedules, and perform earned value management within a single-source system. To ease the transition, EPAR is organized to be a series of releases. The first, called Financial System Upgrade, was completed in January 2007. The Financial System Upgrade entails implementation of a new project-costing module and accounting format changes.

In addition, the Laboratory's system for managing employee information, the Livermore Administrative People Information System (LAPIS), was significantly upgraded in 2006. The upgrades enhance self-service capabilities and automate the process for updating, approving, and routing modifications to personnel information. The system makes it easy for employees to view and update their personal information online and for Laboratory directorates to validate and update personnel data so that timely and accurate people information can be provided to the new Laboratory contractor.

Outreach and Partnering

With outstanding scientific and technical capabilities and an important national security mission, Lawrence Livermore National Laboratory is a national resource. The Laboratory's continuing success depends on engaging sponsors and actively participating in the broad scientific community to understand emerging national needs and technical opportunities. Success in the Laboratory's research programs depends on strong ties to research universities and partnerships with U.S. industry.

The Laboratory's closest academic ties are with the campuses of the University of California (UC). In addition to more than 500 ongoing collaborations between Laboratory scientists and UC colleagues, joint research centers foster interdisciplinary collaborations. These academic partnerships strengthen research programs at Livermore and the campuses. University ties also serve as a valuable pipeline for recruiting new talent to the Laboratory. Partnerships with U.S. industry bring valuable research tools to Livermore programs—from the world's fastest computers to the world's largest laser. Industrial partnerships also facilitate the transfer of the Laboratory's technological advances to the marketplace.

Lawrence Livermore is an important regional resource, too, contributing to the intellectual vitality of the San Francisco Bay Area and California's Central Valley. The Laboratory provides Californians with information and expertise on issues ranging from homeland security to groundwater management. Partnerships also abound through educational, business development, and diversity outreach programs. The Laboratory supports a wealth of science education programs and works with local universities and colleges to provide high-technology workforce training.

Being a good neighbor is important to the Laboratory and its employees. Lawrence Livermore's 8,000-plus staff members and their families contribute generously to the well-being of neighboring communities through charitable contributions and volunteer work.

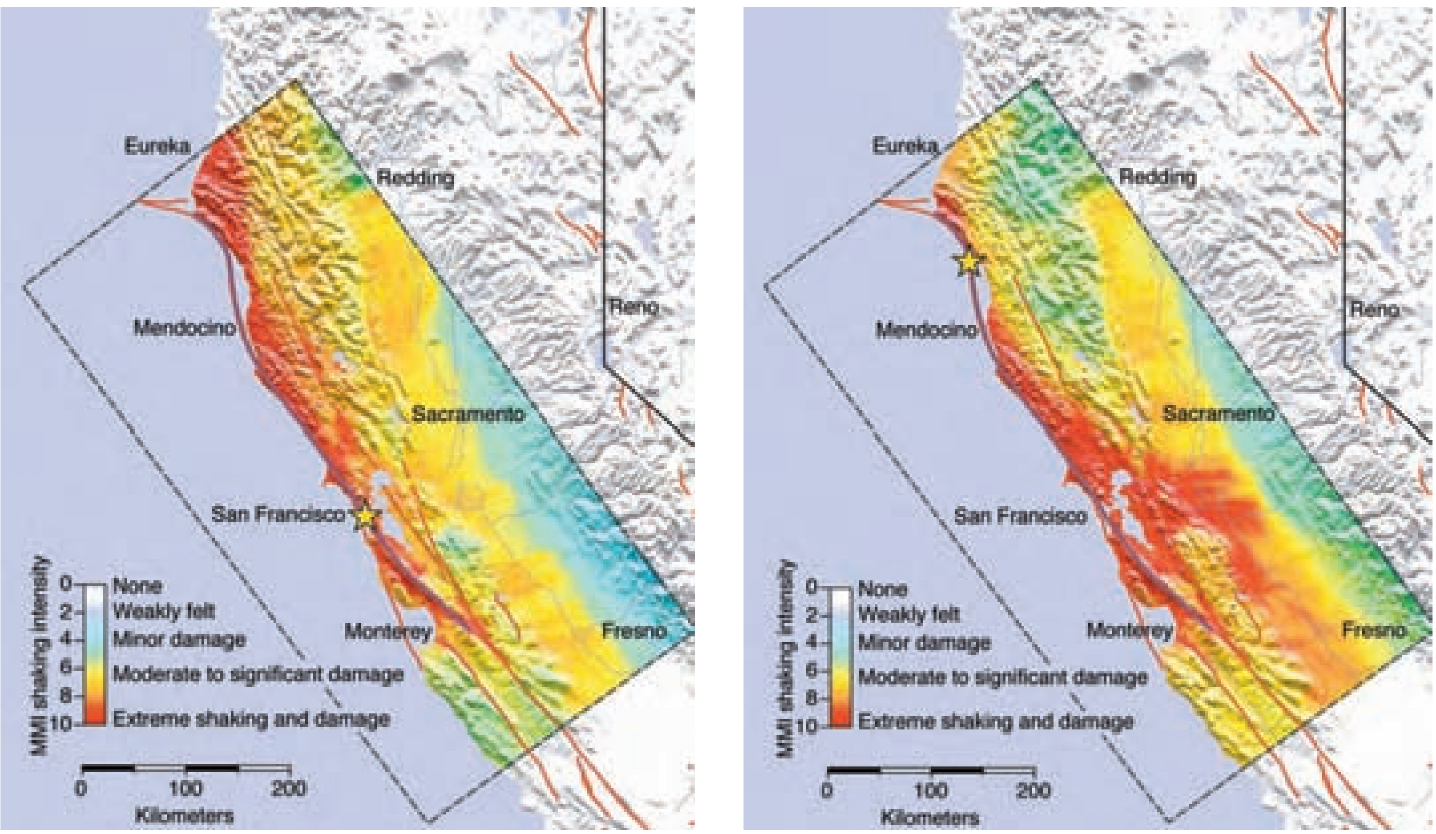
Science and Technology for California

The Laboratory marked the centennial of the 1906 San Francisco earthquake with presentations in April by two invited experts, who discussed historic and potential future earthquakes in the Bay Area. During the day of activities, members of the media were invited to a session where Livermore researchers unveiled detailed simulated re-creations of the 1906 earthquake as well as simulations of temblors along other local faults that could have devastating effects on the Bay Area, Central Valley, and Delta regions of California.

The simulations, performed with the U.S. Geological Survey, made use of high-performance computers, three-dimensional models of geology, and a seismic velocity model to assess damage. The earthquake simulations along the Bay Area's major faults showed the potential for severe damage to major transportation corridors, power lines, and water pipelines. Impacts in the Delta region include possible damage to levees, buildings, and bridges.

The Laboratory is also working with the State Water Resource Control Board in the Groundwater Ambient Monitoring Assessment (GAMA) project. Livermore is applying its state-of-the-art facilities for age-dating tritium (helium-3) and methods for low-level detection of tracers to pinpoint the sources and determine the migration of groundwater contaminants. The GAMA project focuses on 116 priority groundwater basins that account for 90 percent of the state's groundwater use. Laboratory scientists are analyzing and interpreting the results from samples taken from selected municipal water supply wells and providing the results to the State Water Resource Control Board and the U.S. Geological Survey.

In 2006, the Laboratory completed a study that identified the sources of



A simulation of the 1906 San Francisco earthquake (left) shows the perceived shaking experienced from Eureka to Fresno, with the historical epicenter along the San Andreas Fault, denoted by the star. A second simulation shows a hypothetical earthquake of the same magnitude with an epicenter much farther north and rupturing to the south. Although the epicenter is farther away, the shaking experienced in the San Francisco and Central Valley areas is much greater than during the 1906 quake. These simulations used the Laboratory's Thunder and MCR supercomputers and Japan's Earth Simulator. The simulations are displayed at http://earthquake.usgs.gov/regional/nca/1906/simulations/.

nitrates in the groundwater in a portion of Alameda and Contra Costa counties. The region has a long history of agricultural activity and is increasingly urbanized. Nitrate contamination poses a threat to using groundwater to meet the growing demand for drinking water. Nitrates can come from application of synthetic fertilizer, confined animal operations, septic system discharge, or oxidation of nitrogen in the soil. In this case, naturally occurring nitrogen in the soil is the most likely source of the high levels of nitrate in the groundwater.

Other applications of the Laboratory's science and technology that are important to the State of California include regional climate modeling (see p. 26) and many projects to strengthen homeland security. Laboratory researchers are also helping to control animal diseases that could be a threat to agriculture (see p. 20) and developing emergency-response capabilities and procedures in projects with the Port of Oakland and San Francisco International Airport.

Educational Outreach

The Laboratory's science education programs and activities reach students and teachers in local communities, the San Francisco Bay Area, and the Central Valley. More than 12,000 students in kindergarten through junior college as well as hundreds of educators participate in a range of activities.

Programs for students are many and diverse. For example, "Science on Saturday" is a five-week series of free lectures and demonstrations by top Livermore researchers on topics at the forefront of science and technology. Targeted at middle- and high-school students, the series is so popular that it was expanded in 2006 to better accommodate the large attendance of the previous year. The lectures were recorded for broadcast by the University of California Television Network, and the series was repeated for students in the Central Valley.

Now in its third year, "Got Science?" is a popular one-day family-oriented event held at the Robert Livermore Community Center. More than 3,000 visitors filled the center for hands-on science and engineering activities, displays, and fun. The event offered approximately 30 exhibits staffed by Laboratory volunteers.

Livermore's Edward Teller Education Center (ETEC) is home for a variety of professional development programs for kindergarten through junior college educators. Sponsored by the Laboratory, the UC Office of the President, UC Davis, and UC Merced, the center aims to improve the quality of science instruction and technology applications in the classroom. ETEC hosted computer technology workshops as well as the seventh annual Edward Teller Science & Technology Education Symposium, a two-day event held in September. More than 200 California teachers received the latest topical science information as well as lessons and activities for use in the classroom.

Another outstanding ETEC activity is the Teacher Research Academy in biotechnology, biophotonics, and fusion/astrophysics. The academy is co-sponsored by UC Davis and held as 12 regional workshops. It introduces teachers to breakthrough science and concludes with a six- to eight-week internship in a Livermore research laboratory. A unique opportunity for educators, the Teacher Research Academy was featured in the American Physical Society summer *Newsletter*.

At "Got Science?," Mike Revelli (left) and Don Nelson show local children how magnets work.

Tri-Valley Science and Engineering Fair

The Laboratory is the organizing sponsor of the Tri-Valley Science and Engineering Fair, which was in its tenth year in 2006. The fair stimulates interest in science and technology among middle school and high school students from the Dublin, Livermore, Pleasanton, San Ramon, and Sunol school districts. The Tri-Valley Fair is affiliated with the Intel International Science and Engineering Fair (Intel ISEF), the world's largest pre-college celebration of science. A middle-school winner at the 2006 fair took first place at the California State Science Fair, and the high-school winners took awards at Intel ISEF.

A middle school student demonstrates "Effect of Mass and Length on Time Period of Pendulum" in the Tri-Valley Science and Engineering Fair's junior category.

A Good Neighbor

Laboratory employees actively 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. The Laboratory's Public Affairs Office provides a listing at its website (www.llnl.pao) of community outreach activities, public events, and available tours as well as on-line copies of its *Community Newsletter*.

The Laboratory's Helping Others More Effectively (HOME) campaign raised nearly $1.5 million for Bay Area and San Joaquin Valley charitable organizations in 2006. Livermore employees marked their eighth straight year of contributions totaling more than $1 million. The Laboratory is the largest single workplace supporter of the Tri-Valley Community Fund, which is dedicated to raising and distributing local charitable contributions to human service, educational, cultural, and recreational organizations.

Employees also generously support programs such as Toys for Tots and the Laboratory's Brighter Holidays for local families in need during the holiday season. Each spring, Livermore employees buy thousands of daffodils as part of the American Cancer Society's Daffodil Days®. Lawrence Livermore topped the list of fundraisers for Daffodil Days in 2006 for the San Francisco Bay Area and for all of northern California.

Research Collaborations with the University of California

Collaborations between the Laboratory and UC campuses strengthen research programs at Livermore and provide the campuses with access to Livermore's multidisciplinary capabilities and special research facilities. More than one-quarter of the roughly 1,000 peer-reviewed journal articles produced each year by

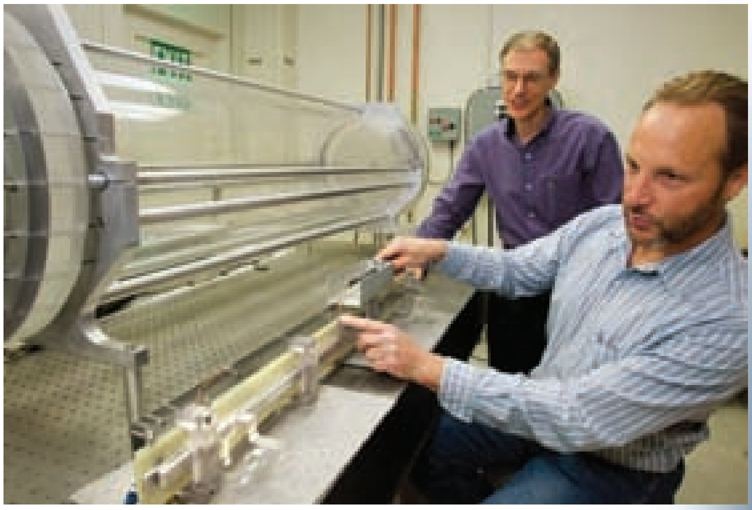
Laboratory firefighters Aaron Horn (left) and Mike Hamilton gathered toys, stuffed animals, and games for the annual Toys for Tots drive.

Laboratory scientists are coauthored by colleagues at UC campuses. Larger-scale collaborations take place through partnerships in research institutes on campuses and at the Livermore site.

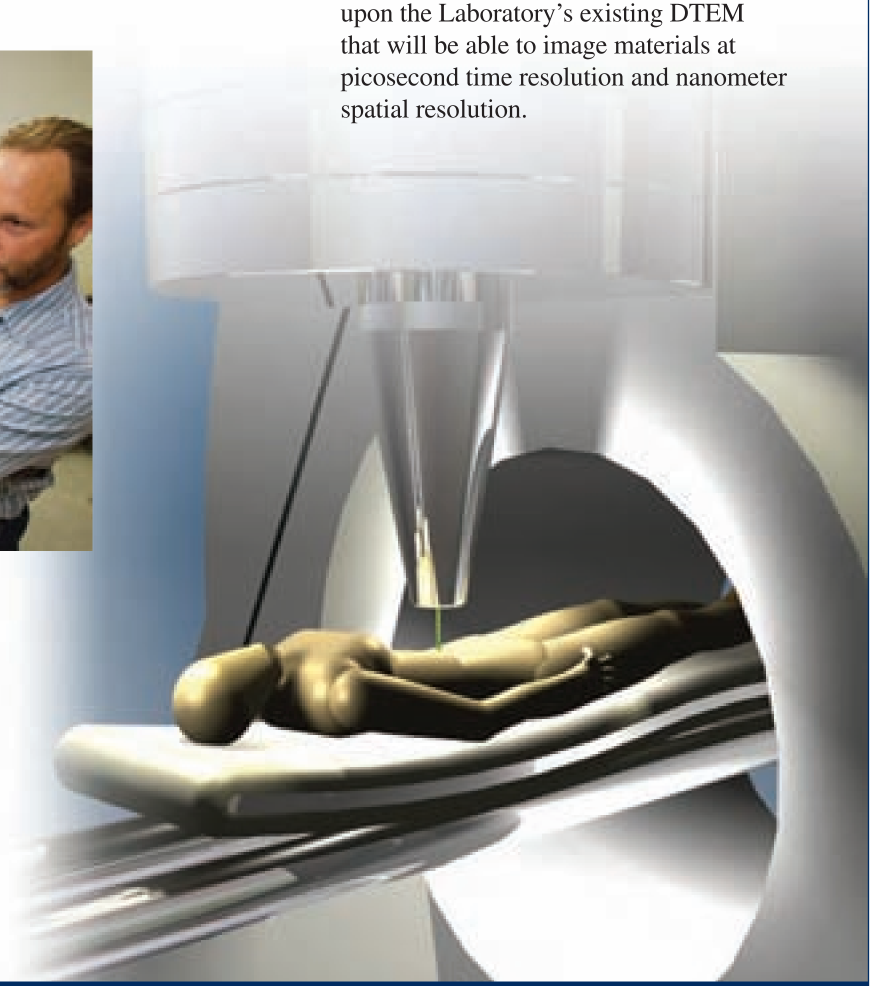
One of the Laboratory's many strong ties with UC is the UC Davis Cancer Center, a National Cancer Institute-designated center. The center's program includes about 180 scientists at work on more than 300 cancer projects on three campuses, including the Laboratory. In the partnership, physicians and scientists work to turn technology developed for national security applications into new cancer therapies, detection methods, and prevention strategies. Laboratory contributions to the fight against cancer include optical imaging techniques to differentiate malignant cells from healthy ones, the use of accelerator mass spectrometry for medical applications (see p. 29), and development of a new device to deliver proton radiography to cancer patients.

With UC support and reinvested contract management fees, scientists from Livermore and UC San Diego are collaborating on global climate change and cosmology projects and supporting computational tools. The focus of the climate change research is the regional impact of change on water supplies—with a particular interest in the western United States. Another team is performing high-resolution simulations of the evolution of galaxy clusters in the early universe. These results will be combined with data to come from the Large Synoptic Survey Telescope (another project with major Laboratory participation) to map the distribution of matter in the universe. In both areas, vastly improved scientific data management technologies are needed to organize, analyze, and manipulate large sets of observational and simulation data, from hundreds of terabytes to petabytes. Researchers in many fields will benefit from the development of the new tools.

The Laboratory is also a key participant in the Institute for Material Dynamics at Extreme Conditions (IMDEC), a newly formed UC Multicampus Research Program that is based at UC Berkeley. IMDEC will bring campus and national laboratory scientists together to examine fundamental issues in the ultrafast dynamics of materials at extreme conditions (see p. 10). Tools used by IMDEC researchers will include Livermore's Jupiter Laser Facility. One proposed major project is to build a laser and target chamber for the Linac Coherent Light Source at the Stanford Linear Accelerator Center for ultrafast imaging. Another proposal is to build a next-generation dynamic transmission electron microscope (DTEM)—an improvement upon the Laboratory's existing DTEM that will be able to image materials at picosecond time resolution and nanometer spatial resolution.



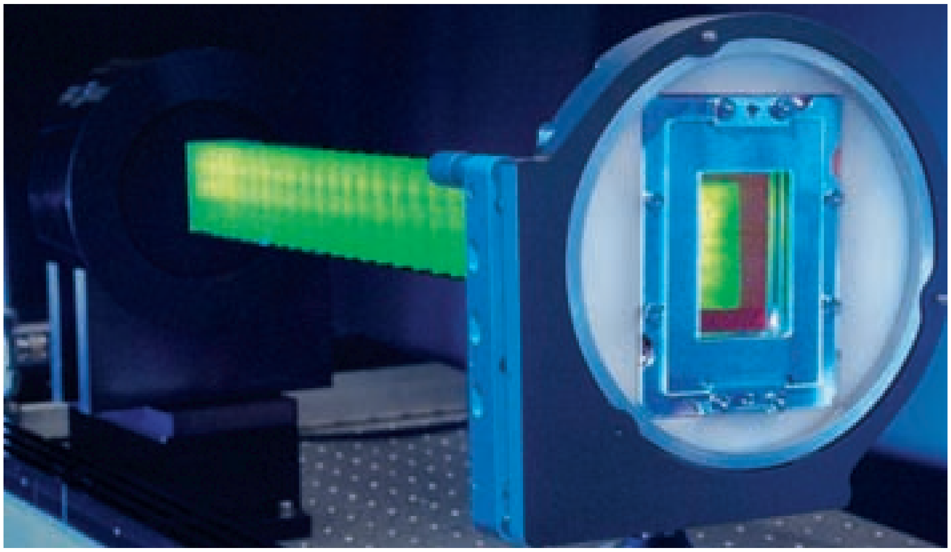
Mark Rhodes (right, above) and George Caporaso adjust a prototype Blumlein transmission-line generator, which will generate power inside the compact proton accelerator for cancer treatment.



Laboratory Technologies Reap Awards

In 2006, Livermore scientists and engineers—and their research partners—earned seven R&D 100 awards, more than any other institution. Each year, *R&D Magazine* presents awards to the 100 top technological advances of significant potential benefit to society.

Since 1978, Laboratory researchers have won 113 R&D 100 awards, and many of these inventions were developed in partnerships or have been transferred to U.S. industry for commercial development. Laboratory-developed technologies contribute to U.S. economic competitiveness in world markets. The transfer of technology to industry also promotes economic development both locally and throughout the United States.



The award-winning single yttrium-calcium-oxyborate crystal in the center of the holder shifts incoming invisible infrared light on the right to green light on the left, a task that formerly required four crystals.

This year's R&D 100 award winners include three systems applicable to homeland and national security: the Sonoma Persistent Surveillance System (see p. 17), the Easy Livermore Inspection Test for Explosives (E.L.I.T.E.) pocket-sized explosives detector (see p. 21), and the UltraSpec ultra-high-resolution spectrometer that can be configured to detect either gamma rays or neutrons. Two additional R&D 100 awards were granted for computer software: Babel, which allows software modules written in different programming languages to seamlessly pass scientific data to each other, and Sapphire, a sophisticated tool for mining scientific information from terabytes of data.

A technique called Externally Dispersed Interferometry, which will assist in the search for distant planets, also won an R&D 100 award. The seventh winner is the yttrium-calcium-oxyborate (YCOB) crystal plate for efficient frequency doubling of laser light. The advantages of YCOB crystals over other methods of wavelength conversion will greatly boost laser research and the development of future high-power systems.

People and Management

The Laboratory stays vibrant by attracting and retaining a high-quality workforce inspired by "passion for mission" and dedicated to excellence. Highly motivated individuals and exceptional multi-disciplinary teams are responsible for achieving program goals, advancing science and technology, and continually improving operations. Laboratory staff are carrying forward a long tradition of scientific and technological innovation to meet pressing national needs. The strength of the current workforce is demonstrated by the many awards they received for their scientific accomplishments and quality operations.

Strong ties to world-class research universities—in particular many partnerships with the various campuses of the University of California (UC)—serve as a vehicle for bringing new talent to the Laboratory. Much of Livermore's work requires special skills. Scientists gain essential expertise through years of training, working with senior staff, and access to unique computational and experimental capabilities. The Laboratory's continuing success depends on providing employees with abundant career development opportunities, a quality work environment, and the chance to work on projects that make a difference to the nation.

Livermore's long-standing ties with UC have also fostered a tradition of intellectual independence and integrity as well as a focus on the long-term interests of the nation. Laboratory researchers strive to anticipate future national needs and security threats. Science and technology investments and exploratory research and development efforts are targeted accordingly. Visionary technical leadership and effective management of research programs and operations underpin Livermore's achievements and sustain public trust in the Laboratory.

Contract Competition for Livermore

In May 2007, the Department of Energy (DOE) Secretary Samuel W. Bodman announced that Lawrence Livermore National Security, LLC (LLNS) was awarded the contract to manage and operate Livermore. Laboratory director George Miller, who led the competition for LLNS, will continue as director and be president of LLNS. LLNS is a limited liability corporation made up of Bechtel National, Inc., the University of California, BWXT Technologies, Inc., and the Washington Group International, Inc. Battelle Memorial Institute, four small business subcontractors, and Texas A&M University are also members of the team. The new contract begins on October 1, 2007, and continues for seven years. Up to an additional 13 years can be earned through successful performance under an award-term provision.

DOE had announced in 2003 its intention to open the management of Los Alamos to full competition at the expiration of the current contract. Subsequent congressional legislation required open competition for the management of all three UC-managed national laboratories: Lawrence Livermore, Los Alamos, and Lawrence Berkeley. In April 2005, DOE awarded a new five-year contract to UC to manage and operate Lawrence Berkeley. In December 2005, Los Alamos National Security, LLC was named the contractor for Los Alamos.

The competition for the Lawrence Livermore contract began in January 2006 with a DOE request for an Expression of Interest. In March, the National Nuclear Security Administration (NNSA) issued a formal Acquisition Plan. The May draft Request for Proposal (RFP) was followed in July by the final RFP. The proposal deadline was October 27, having been extended from October 12. Oral interviews took place in December.

LLNS proposed an approach to sustain exceptional science and technology and innovation at the Laboratory, to implement enhanced business and Laboratory operations, to deliver strong mission performance while also expanding the amount of work for customers outside of NNSA and the Department of Energy, and to be a leader in achieving the objectives of NNSA's Complex 2030 Initiative.

Laboratory Management Changes

The UC Regents selected George Miller in March 2006 as interim director of the Laboratory, to serve through the remainder of the University' s current contract to manage Lawrence Livermore. Miller has been a Laboratory employee since 1972, and he brought to the assignment invaluable expertise in nuclear weapons and national security as well as experience as an associate director in many programs. Miller succeeded Michael Anastasio, Livermore's ninth director, who became director of Los Alamos National Laboratory on June 1, 2006. Friends, colleagues, former Laboratory directors, and dignitaries took the opportunity to say goodbye to Anastasio and wish

Ed Moses (left), associate director for National Ignition Facility (NIF) Programs, explains NIF to visiting UC regents.

Laboratory director George Miller wishes former director Michael Anastasio a fond farewell.

him well in ceremonies held at Livermore on May 25, 2006.

Soon after Miller became director, he announced the appointment of new members of his senior management team. Dave Leary became acting deputy director for Operations in April. Leary joined the Laboratory in 1973, and his long career has spanned numerous management positions, including head of the Security Department, head of the Innovative Business and Information Services Department, and National Ignition Facility Programs deputy director for Operations. In 2003, he was appointed associate director of Laboratory Services and director of Safeguards and Security. Leary replaces Wayne Shotts, who retired from the Laboratory after a long and distinguished career.

Bruce Warner was appointed acting associate director at large to support the director and deputy directors in the management of Laboratory operations. In addition, Larry Ferderber was named the director's chief of staff, and Barbara Peterson was appointed transition manager to lead Laboratory efforts for a smooth transition to the new contractor.

Preparing for the Transition

A pre-transition team was formed in May 2006 to prepare for the process of transferring people, property, and procedures to the new contractor, who will begin managing and operating the Laboratory on October 1, 2007. The team, composed of subject matter experts, first identified all the work required to ensure a smooth handover with minimal disruption to the work-force and Laboratory programs. The information was compiled and documented in a detailed project plan—with a complete work breakdown structure to ensure accuracy and thoroughness. Team leaders, working with subgroups, then began the task of reviewing materials ranging from Laboratory contracts and agreements to facilities and property to assess potential impacts that must be addressed during transition.

The pre-transition team (now the transition team) has also been keeping employees informed about the contract and transition processes. The Laboratory debuted a special Web site in May 2006, which includes frequently asked questions, up-to-date news, a monthly newsletter, archival material related to the selection process and transition, and links to relevant UC and NNSA Web sites. The team leader and members also "made the rounds" in 2006, giving all-hands presentations—with opportunities for questions and answers—to directorates and other organizations at the Laboratory. In addition, employees from the Administration and Human Resources Directorate briefed employees about their current benefits to prepare them for evaluating choices and changes that may occur when the contract changes.

Attention to Workforce Management

In 2006, the Laboratory's Workforce and Communications Working Group

Then NNSA administrator Linton Brooks thanks Wayne Shotts for his years of dedicated service upon Shotts's retirement.

A team of subject matter experts under Barbara Peterson (standing) is working to ensure a smooth transition to the new management contractor on October 1.

conducted a comprehensive assessment, concluding that the directorates have been effectively managing skill-mix needs and that staffing levels are manageable through normal attrition. Retention rates remain high for employees that perform tasks related to NNSA Defense Programs as well as those who have mission-critical skills. Special emphasis is being given to managing recruitment and retention challenges that may arise during the transition to the new contractor. Exciting career opportunities and an inclusive, collegial work environment are key to effective recruitment and retention as Livermore works to create a more diverse workforce.

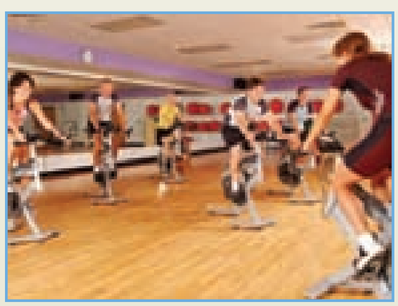
Ongoing activities with UC campuses (see p. 42) and other major research universities act as a pipeline to fill the need for critical skills and greater diversity. One of many special opportunities for graduate and undergraduate students is the Department of Homeland Security (DHS) Scholars and Fellows Program, which places outstanding young scholars at national laboratories for 10 weeks during the summer. Of the 130 award recipients in 2006, 33 students identified Lawrence Livermore as their first choice laboratory. Altogether, Livermore is host to over 600 summer students who work side by side with Laboratory scientists.

Cherry Murray, deputy director for Science and Technology, reviews a poster by Aaron Fisher, a participant in the Student Employee Graduate Research Fellowship Program.

The Laboratory's continuing success also depends on developing future leaders. Livermore's comprehensive programs in leadership and management development are recognized as among the "best in class" within the UC system and the DOE complex. These programs includes two training courses that are required for supervisors, a variety of technical and administrative leadership training courses, and a two-and-a-half-day Management Institute presented by Laboratory senior managers to help prepare next-generation leaders. Nearly 1,200 current supervisors have been trained, and more than 760 emerging and current supervisors and managers have participated in the Laboratory's various leadership succession development programs. The representation of women and minorities in these succession development programs has steadily increased and is now at a high level in support of diversity objectives.

A Healthy Heart

Started as a pilot project in 2003, the Laboratory's Healthy Heart Program has doubled each year in its outreach. Its goals are to prevent, identify, and mitigate cardiovascular diseases and diabetes through comprehensive screenings, education, and programs that create a healthier work environment. More than 1,500 employees have participated in assessments for risk of heart disease, stroke, diabetes, and other chronic diseases. The Healthy Heart Program has demonstrated statistically significant reductions in such risk factors as high blood pressure and elevated cholesterol.



Exercise classes for employes have been held for many years. Now they are an important part of the Healthy Heart Program, which encourages sedentary individuals to join in.

People and Programs in the News

The scientific and technological accomplishments of Livermore employees are recognized by prizes, awards, and front-page publicity. But 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 158 invention disclosures, 144 U.S. patent applications, 19 first foreign patent applications, 63 issued U.S. patents, and 24 issued foreign patents in fiscal year 2006.

The American Physical Society honored James R. Wilson with their Hans A. Bethe Prize. The award is presented annually to an individual in recognition of outstanding accomplishments in theory, experiment, or observation in the areas of astrophysics, nuclear physics, nuclear astrophysics, or closely related fields.

Masaru Takagi received the 2006 Larry Foreman Award for Excellence and Innovation in Inertial Confinement Fusion (ICF) Target Fabrication at the 17th Target Fabrication Meeting. Takagi is the inventor of the chemical processes used to make extremely round and smooth plastic shells that are the starting point for ICF capsule fabrication.

Scott Wilks (left) and Max Tabak were awarded the 2006 Award for Excellence in Plasma Physics Research by the American Physical Society, along with two physicists from Japan and one from Great Britain. They were cited for developing the fast ignition inertial fusion concept and for demonstrating key aspects in a series of experiments that have catalyzed the worldwide effort on fast ignition.

Richard Christensen was awarded the Nadai Medal from the American Society of Mechanical Engineers for contributions to mechanics of materials and heterogeneous media, theory of viscoelasticity, properties of polymers and non-Newtonian rheology and wave propagation.

Stanford professor and former Laboratory postdoc Wendelin Wright and Stony Brook University assistant professor and Livermore collaborator Michael Zingale received Presidential Early Career Award for Scientists and Engineers honors. Both were nominated by the Laboratory for work performed at Livermore.

Cherry Murray, deputy director for Science and Technology, has been elected vice president of the American Physical Society for 2007. She will successively serve as president-elect, president, and then immediate past president.

Steven R. Patterson, associate director for Engineering, was elected president of the American Society for Precision Engineering.

Tomás Díaz de la Rubia, associate director for Chemistry, Materials, and Life Sciences, was elected as vice president and president-elect for the American Physical Society's Division of Computational Physics.

The 2006 Gordon Bell Prize for Peak Performance (see p. 9) was awarded to Laboratory scientists and collaborators for "Large-Scale Structure Calculations of High-Z Metals on the BlueGene/L Platform." In addition, the BlueGene/L Supercomputer and Quantum Chromodynamics project team, which included a Livermore scientist, earned a Gordon Bell Prize for Special Achievement.

Robert Budnitz and Karl van Bibber were elected fellows of the American Association for the Advancement of Science. Budnitz was honored by the section on engineering for contributions to understanding the safety of nuclear power reactors and deep geological radioactive waste repositories, with emphasis on probabilistic safety analysis. Van Bibber was recognized by the section on physics for contributions to the field of astrophysics and particle accelerator physics, particularly for his efforts in the dark matter axion search.

The Laboratory won seven R&D 100 awards among the 100 granted by *R&D Magazine* for the top industrial innovations worldwide (see p. 44). The Laboratory won more awards than any other institution. This brings the Laboratory's total to 113 awards. The seven winning technologies were:

- An explosives detector known as E.L.I.T.E., the Easy Livermore Inspection Test for Explosives, which can be used by airport screeners, military personnel, and others to detect more than 30 different explosives.
- A new high-precision radiation detector called UltraSpec that operates at very low temperatures and can assist security officials in identifying even small amounts of nuclear material.
- The Sonoma Persistent Surveillance System, which offers the first integrated, broad-area, high-resolution, real-time motion imagery system for surveillance applications.
- A high-average-power wavelength conversion device that can change the color of laser light, permitting large-aperture high-average-power lasers to operate at half the wavelength of the laser crystal's natural emission wavelength.
- A technique called Externally Dispersed Interferometry for conducting precision measurements of the Doppler velocities of stars or sunlit targets.
- Analysis algorithms allowing the exploration of large, complex, and multidimensional data sets. The technology has been dubbed Sapphire.
- A tool called Babel, which addresses the problem computer scientists face in developing simulation codes that have language incompatibilities among the software libraries they must use.

Two Laboratory researchers were named fellows of the American Physical Society. Peter Amendt was honored for contributions to the development of indirectly driven single- and double-shell inertial confinement fusion physics necessary for the demonstration of laboratory-scale ignition. Gilbert (Rip) Collins was lauded for contributions to the field of high-energy-density physics related to the development and application of novel laser-compression capabilities to measuring ultra-high-pressure material properties.

Grace Clark was elevated to fellow of the Institute of Electrical and Electronics Engineers, based on her pioneering contributions to block adaptive filtering.

Scot Olivier was named fellow of the International Society for Optical Engineers for achievements in adaptive optics.

Maya Gokhale became a fellow of the Institute of the Electrical and Electronics Engineers for contributions to reconfigurable computing technology.

David Keyes was elected vice-president-at-large of the Society for Industrial and Applied Mathematics. Keyes is also Fu Foundation Professor of Applied Mathematics in the Department of Applied Physics and Applied Mathematics at Columbia University.

Jim Seward was elected president of the Western Occupational and Environmental Medical Association.

Dean Williams and Hope Ishii won the 2006 *Science Spectrum* Top Minorities in Science "Trailblazer" award. The award recognizes outstanding Hispanic, Asian American, Native American, and black professionals in the science arena whose leadership and innovative thinking on the job and in the community extend throughout and beyond their careers.

Robert Shepard was honored with the 2006 Emerald Honors Educational Leadership Award.

The Terascale Simulation Facility Project won the DOE Secretary's Project Management Award of Achievement (see p. 36).

Gerald Kiernan was awarded the NNSA Silver Metal for "distinguished career accomplishments and outstanding contributions" including service as the NNSA assistant deputy administrator for Nonproliferation R&D.

The Easy Livermore Inspection Test for Explosives (E.L.I.T.E.) won an Excellence in Technology Transfer Award from the Federal Laboratory Consortium for Technology Transfer (see p. 21).

The National Ignition Facility Program won a "Perfect Record" award from the National Safety Council for a year of accident-free work (see p. 34).

An NNSA Defense Programs Award of Excellence was given to the Startup Team for the Device Assembly Facility at the Nevada Test Site.

Laboratory waste minimization efforts garnered four DOE annual pollution prevention awards, three of them "best in class" awards and the fourth in the "environmental stewardship" category. Awards were given to teams representing the Flash X-Ray and Contained Firing Facility at Site 300, the JASPER gas gun at the Nevada Test Site, and the Space Action Team at Livermore main site.

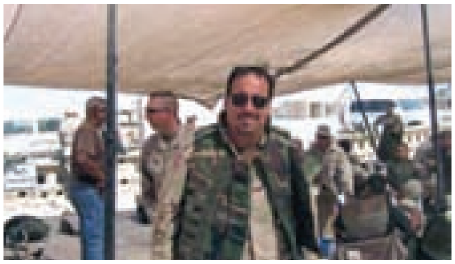
John Wolf was appointed to a two-year term as a director of the Academy of Certified Hazardous Materials Managers.

A paper co-authored by Bill Glassley was cited by the Danish science magazine *Ingeniøren* as one of the five most important scientific achievements of 2006. The paper is "The Rise of Continents: An Essay on the Geologic Consequences of Photosynthesis."

At the 2006 IEEE Visualization Conference, Dan Laney, Peer-Timo Bremer, Ajith Mascarenhas, Valerio Pascucci, and Paul Miller were honored with the Best Application Paper Award for "Understanding the Structure of the Turbulent Mixing Layer in Hydrodynamic Instabilities."

A paper on bioaerosol mass spectrometry by a team that included several Laboratory employees won honorable mention from the National Institute for Occupational Safety and Health in its annual Alice Hamilton Awards.

Ken Bogen and Ed Jones received the Society for Risk Analysis Best Paper Award in its Decision Sciences category.



Mike Newman (above), who has made three trips to Iraq, and Jim Trebes were feted by the U.S. Army for a surveillance system they developed, considered one of the Army's ten greatest inventions for 2005.

Tom Isaacs, director of the Office of Policy, Planning, and Special Studies, was appointed to a new international advisory board for Japan's Nuclear Waste Management Organization.

Anantha Krishnan was selected as co-chair of the National Academy of Science Committee on Testing and Evaluation of Biological Standoff Detection Systems.

The U.S. Army Joint Forces Command and the U.S. Secret Service honored Mike Uzelac (right, with his wife, center) for his work on the Joint Conflict and Tactical Simulation (JCATS), the most widely used conflict simulation model in the world.

Cary Spencer received a Meritorious Unit Citation from the Central Intelligence Agency.

DOE lauded Dave Brown for his leadership of the Laboratory Classification and Export Control Office, for responding to the needs of the nuclear weapons community while building trust with environmental, safety, and health advocates.

Susan Allen was honored by DHS for her role in preparing the federal government's first biennial bioterrorism risk assessment.

Two of the Laboratory's technical publications were honored in the 2005 Society of Technical Communication international competition. The Chemistry and Materials Science Directorate *2004 Annual Report* won an Excellence Award and the *Quantum Simulations Group Brochure* won a Merit Award.

Jerry Schweickert won an Outstanding Mentor Award from DOE.

Becky Failor was chosen by the Department of State to represent the U.S. at the first conference on Arab State Women Leaders in Science, Engineering, and Technology.

The 2006 Houtermans Award winner was Jimi Badro, who has been collaborating with Laboratory researchers for years. The Houtermans Award is given annually by the European Association of Geochemistry in recognition of an outstanding publication or series of publications by a young scientist under the age of 35.

A video produced at the Laboratory, "Contractors Construction Safety Orientation at LLNL," earned awards from AEGIS and *Digital Video Magazine*. The video also has a Spanish language version and is required viewing for all subcontractors performing construction work on site.

"From the Laboratory to the Marketplace," a video about technology transfer and commercialization successes, won an Award of Distinction from the Communicator Awards and an award from *Digital Video Magazine*.

Steve Homann was honored with the Laboratory's first Distinguished ES&H Contributions Award for his work in radioactive dispersion consequence assessment.

The Laboratory's six-member team of protective security officers captured second place in the annual Best of the West SWAT competition for law enforcement special-response teams.

Retiree George Michael was lauded during the opening ceremony of Supercomputing 2006, the premier international supercomputing conference he was instrumental in founding in 1988.

The Frost & Sullivan Emerging Technology of the Year Award was presented to a team of Laboratory scientists for the development of the carbon nanotube membrane.

Two teams won Lawrence Livermore's annual Science and Technology awards, the Laboratory's highest award for achievement in science and technology: the Nuclear Car Wash Team, which developed a drive-through detector system for cargo inspection, and the Non-Equilibrium Warm Dense Gold Team, which achieved the highest energy density ever observed for a solid heated at constant volume.

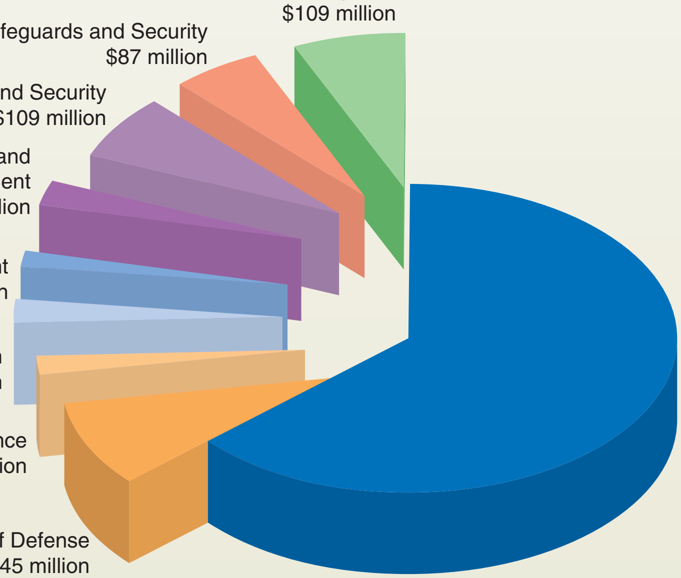
Laboratory Budget

Most of Livermore's approximately $1.6 billion budget for fiscal year 2006 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.

As a multiprogram laboratory, Livermore applies its special capabilities to meet important national needs. Activities sponsored by non-NNSA parts of DOE include work for the Office of Environmental Management as well as research and development projects for the Office of Science and many other program offices. Non-DOE sponsors include federal agencies (such as the National Aeronautics and Space Administration, Nuclear Regulatory Commission, National Institutes of Health, and Environmental Protection Agency), State of California agencies, and industry.

Many of the Laboratory's research and development activities are pursued for sponsors as partnerships that combine special expertise and capabilities of the Laboratory with those of other DOE laboratories and research universities.



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 each month in our award-winning magazine, *Science and Technology Review*. The Laboratory's flagship publication is available on the Web, and you can use the Web site to order a free print subscription.

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