Emerging from the Cold War
Stockpile Stewardship and Beyond

HISTORIES of the 20th century often celebrate the American spirit that united the country in 1941 after the bombing of Pearl Harbor. The heroism and sacrifice of U.S. citizens, whether fighting on the front lines, building equipment for the military, or rationing supplies at home, marked a great era for this country.

World War II was also a watershed for science and technology research in the United States. Before that war, most scientific research was funded privately. In the 1930s, Ernest O. Lawrence, who later cofounded Lawrence Livermore, built the Crocker Laboratory for housing his fourth cyclotron with contributions from several foundations and individuals, including $75,000 from William Crocker, chairman of the University of California’s Board of Regents. But in 1942, the U.S. government found its military ill-equipped for the kind of war it was entering. To bring the military up to date, the government funded an extensive science and technology effort, including the Manhattan Project—a top-secret project in Los Alamos, New Mexico, to build the world’s first atom bomb.

“The science of today is the technology of tomorrow.”

—Edward Teller

Reviewing the successes from the war-related research and development effort, President Franklin Roosevelt wrote in a letter to Vannevar Bush, director of the Office of Scientific Research and Development, that the lessons learned by the teams conducting this research could be applied after the war "for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national living standard." President Roosevelt asked Bush to recommend a new model for research and development that built on the achievements of the war effort.

In July 1945, Bush presented his recommendations to Roosevelt's successor, President Harry Truman, in a report titled *Science: The Endless Frontier*. The ideas presented in the Bush report shaped research and development activities for the remainder of the 20th century. In particular, government funding for research in support of national security increased dramatically, and improved designs for nuclear weapons continued to be developed at Los Alamos.

After the Soviet Union successfully tested its first atom bomb, the government responded by expanding nuclear weapons research. On September 2, 1952, a branch of the University of California Radiation Laboratory was opened at the deactivated Naval Air Station in Livermore, California.

"The founding of our Laboratory was a realization of the Vannevar Bush model," says physicist Kimberly Budil, who is the current scientific editor for *Science & Technology Review*. "Bush's report recommended that military research continue after the war, so the country would never again have to struggle to catch up technologically in a time of crisis. Also, to support industrial research plus help the economy and improve the American standard of living, the federal government was encouraged to fund basic research and provide educational opportunities—especially to returning soldiers—so the U.S. could renew its talent pool for future science and technology efforts."

The focus of the Laboratory in its early history was on meeting national needs for nuclear expertise. Experts in chemistry, physics, and engineering were encouraged to explore innovative solutions to the problems they faced in developing new weapon designs. Over time, not only did Lawrence Livermore achieve notable successes in its national security mission, but it also became one of the world's premier scientific centers—using its knowledge of nuclear science and engineering to break new ground in magnetic and laser fusion energy, nonnuclear energy, biomedicine, and environmental science.

Budil says that reviewing Livermore's history has given her a new appreciation for its founders. "In 1952, many of the first scientists who joined the Laboratory were young, especially to be taking on this kind of challenge. Herbert York was only 32 years old when he became the first director. The relative youth of our founders, along with their enthusiasm for a new challenge, drove the innovative spirit that we see throughout the Laboratory's history."

Innovative Solutions to Complex Problems

Innovation has been an integral part of Livermore's success. The military requirements for high-yield, low-weight weapons often led researchers to explore new design approaches. For example, in a 1950s project to design a warhead for the Navy's Polaris missile, the Laboratory's goal was to develop a small, efficient thermonuclear weapon that could be carried by submarine. Researchers came up with novel designs for the primary and secondary stages of the weapon to minimize the overall mass of the warhead.

These design improvements had far-reaching effects on future weapon designs. In Edward Teller's autobiography, *Memoirs: A Twentieth-Century Journey in Science and Politics*, he says that the warheads for Polaris greatly improved the nation's ability to deter attack. "That a portion of our retaliatory force would survive a surprise attack guaranteed that the Soviets would never find it advantageous to attempt a first strike."

The success of Polaris also set the tone for research at the Laboratory. Says Budil, "Part of our culture at the Laboratory is a willingness to explore creative solutions so we can find the best approach to the complex issues we need to resolve. That philosophy comes with enormous risk, both for the institution and for individual scientists, but it also offers the potential for enormous gain. Our history is filled with examples

of scientists putting their credibility on the line, risking failure in search of the best solution."

Livermore's multidisciplinary approach to problem-solving was bolstered by the work of scientists and engineers on progressively more complex weapon designs. Because designing a nuclear weapon is an iterative process, weapon researchers often found they had to understand concepts and processes outside their assigned disciplines or areas of expertise.

Test launches of three missiles with Livermore-designed warheads. (a) The Minuteman III intercontinental ballistic missile (ICBM) is equipped to carry the W62 warhead, and (b) the Peacekeeper ICBM is equipped to carry the W87 warhead. (c) The W84 warhead, now inactive, was designed for the ground-launched cruise missile.

For example, at the beginning of a weapons project, computer simulations were often used to evaluate design options. Then, once a new design was built, it had to be tested to ensure it worked as predicted. To acquire data on weapon performance, Laboratory engineers developed diagnostic equipment and techniques that would operate in the highly volatile environment of nuclear tests. These diagnostics had to record data in a fraction of a second, before the detonation vaporized the detectors, test apparatus, and cables.

In developing the elaborate setup for underground nuclear experiments, everyone involved in a test—engineers, physicists, code developers—had to understand the requirements of the other disciplines. According to Laboratory Director Michael Anastasio, this working relationship fostered an integral program of testing, simulation, and fundamental science. "Our work groups had those same permeable boundaries," he says, "where scientists from computation, design, and experimental science all contributed to achieving the goal of delivering a new device."

This multidisciplinary approach to research has provided added benefits to the nation's science and technology base—an advantage Vannevar Bush might have predicted. "To solve the problems encountered in designing nuclear weapons," says Budil, "Laboratory scientists often find themselves at the forefront of new technology. As a result, Livermore has an amazing history of technological firsts as well as spinoff applications that have benefits outside our national security mission."

For example, Livermore developed increasingly powerful lasers—Janus in 1975, Shiva in 1977, and Nova in 1984—so scientists could study thermonuclear physics in a laboratory setting. Data from laser experiments improved computer modeling capabilities for weapons research and were a valuable supplement to underground nuclear tests. But the benefits of laser science and technology extend well past the nuclear weapon community. Programs in inertial confinement fusion and laser isotope separation were begun as efforts to enhance the nation's energy supplies. Other laser research activities set the stage for improving medical treatments and studying the solar system.

"Such advances in scientific understanding and technology development do not happen merely by chance," says Budil. "They require strong capabilities for basic and applied scientific research. Livermore has stable funding, excellent research facilities, and outstanding researchers—factors that are essential to the success of big multidisciplinary science projects. They've contributed to the Laboratory's success both in weapons research and in other programs such as biotechnology and environmental restoration."

A New Course for Weapons Research

Nearly four decades after Lawrence Livermore was founded, the Berlin Wall was torn down, and the Soviet Union collapsed—the Cold War had been won. Today, the U.S. maintains a much smaller stockpile of weapons, but nuclear deterrence remains an integral part of its national security policy.

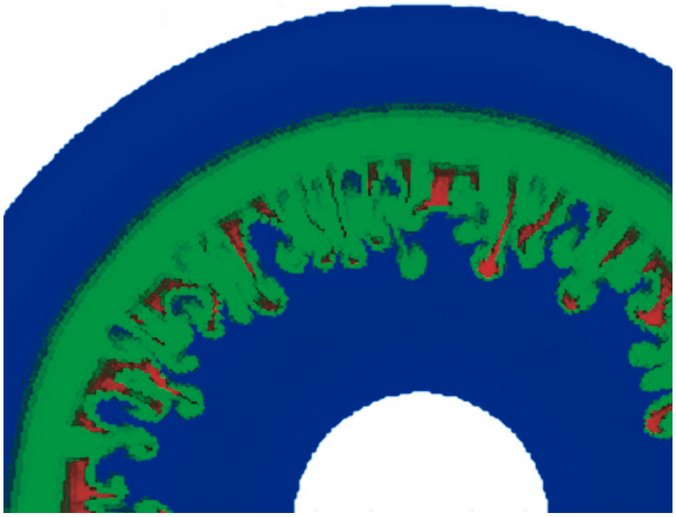
In 1992, President George H. W. Bush declared a moratorium on nuclear testing, and new weapons development ceased. The ending of the nuclear arms race dramatically affected the nation's three weapon laboratories—Livermore, Los Alamos, and Sandia—but their central missions still focused on national security science and technology.

In 1995, President Bill Clinton announced a new program called Stockpile Stewardship—an ambitious effort to improve the science and technology for assessing an aging nuclear weapons stockpile without relying on nuclear testing. For stockpile stewardship to succeed, all aspects of weapons must be understood in sufficient detail so experts can evaluate weapon performance with confidence and make informed decisions about refurbishing, remanufacturing, or replacing weapons as the needs arise.

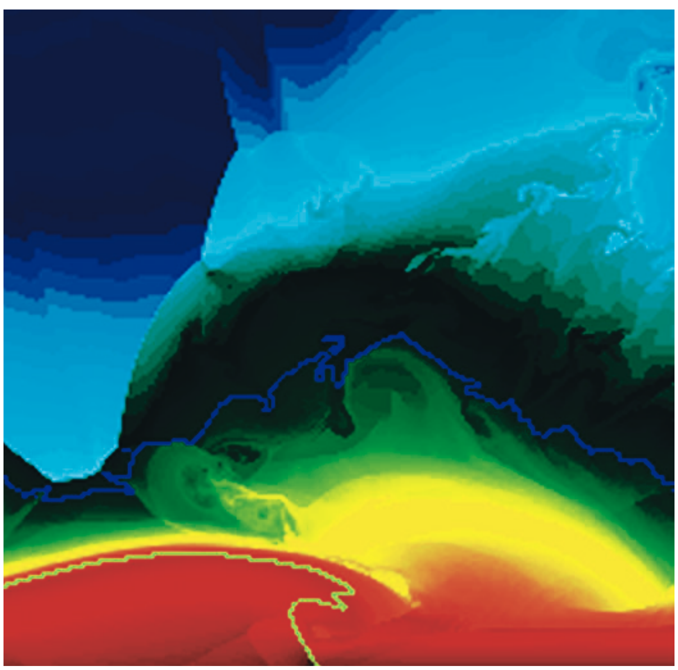
An Annual Assessment Review is conducted on the status of the stockpile. In this process, the secretaries of Defense and Energy receive formal evaluations of the stockpile from the three laboratory directors, the commander-in-chief of the U.S. Strategic Command, and the Nuclear Weapons Council. From those evaluations, the president makes a determination whether the weapons would perform as designed, should they ever be needed, or if nuclear testing is required again to certify performance. (See *S&TR*, July/August 2001, pp. 4–10.)

A view inside the target chamber for the National Ignition Facility (NIF), which is under construction at Livermore. Experiments with NIF will allow scientists to replicate various physical processes at the energy densities and temperatures approaching those in a weapon detonation. The first experiments are planned for 2003.

Aboveground diagnostic setup for an underground experiment at the Nevada Test Site. Data signals from a test explosion moved from the device, 300 meters downhole, up to the surface through cables, and the cables fanned out along the surface to trailers that housed instruments for reading the signals.



Simulation from a Laboratory-developed code run on ASCI Blue Pacific, one of the Advanced Simulation and Computing program's supercomputers at Lawrence Livermore. In this simulation, an arbitrary Lagrangian–Eulerian hydrodynamics code is used to model fluid motion as a function of increasing temperature, pressure, and density (or a Richtmyer–Meshkov instability) in an imploding inertial confinement fusion capsule.



Snapshot of a simulation run on ASCI Blue Pacific. This calculation modeled the density field of an x-ray burst on the surface of a neutron star. The yellow curve is the detonation front, racing across the stellar surface. The blue curve shows how the initial surface of the accreted atmosphere deforms.

Maintaining a safe and reliable stockpile without underground testing required a culture shift for the weapons program. "It changed the fundamental nature of our work," says Anastasio. "In the past, we asked ourselves whether a design would work. Now, with stockpile stewardship, we want to know when weapons fail. To certify reliability in this broader area, we must survey the state of a weapon periodically throughout its life cycle and try to predict when we'll lose confidence in its performance."

Stockpile stewardship was a radical departure for the weapons program in concept, but not in day-to-day activities. "Stockpile stewardship is an extension of how we were already doing business," Anastasio says. "Originally, in designing a weapon, Laboratory scientists would conduct tens of tests to put a weapon in the stockpile. But by 1980, we knew enough about how weapons worked that we could just test them at their performance margins. So we only conducted one to three nuclear tests before certifying a weapon. We also were developing simulation tools to answer questions that had been asked for decades. In effect, we were early pioneers of stockpile stewardship, even though such a program didn't officially exist at that time."

Keys for Successful Stewardship

The basic concepts for the Stockpile Stewardship Program were developed in the mid-1990s under the direction of Vic Reis, the assistant secretary for the Department of Energy's Defense Programs, with input from the Navigators Committee, a small committee of experts from the weapon laboratories. "We knew that certifying weapon performance without underground testing would be a hugely complicated task," says physicist George H. Miller, who represented Livermore on the Navigators Committee. "We'd need a much better understanding of the fundamental physics involved in a nuclear detonation if we were to determine when a weapon would fail."

According to Miller, the committee focused on defining the key features for a successful program of stockpile stewardship. "Experimental capabilities would be crucial. We'd need laboratories where scientists could scale nonnuclear experiments to closely match weapon physics conditions so they could examine properties at the microstructural level. We'd also need to dramatically improve the fidelity of our computer modeling capabilities, so we could more accurately simulate these complex interactions. And perhaps most important, we'd need a new methodology for certifying the judgment and credibility of future stockpile stewards."

From the Navigators Committee meetings and additional workshops led by Reis, DOE created a program that builds on the talent, resources, and capabilities available at the three weapon laboratories. Now administered by the National Nuclear Security Administration (NNSA), the Stockpile Stewardship Program integrates data from past nuclear tests with past and present nonnuclear tests, fundamental science and component-level experiments, surveillance of actual weapons withdrawn from the stockpile, and advanced simulations.

Previous highlights on the Laboratory's 50th anniversary have discussed the new facilities being built at Livermore in support of the Stockpile Stewardship Program. For example, the National Ignition Facility (NIF), a 192-beam laser designed to produce 1.8 megajoules of energy and 500 terawatts of power, will allow scientists to replicate various physical processes at the energy densities and temperatures approaching those that occur in a weapon detonation. (See *S&TR*, September 2002, pp. 20–29.) Miller, who is now associate director for NIF Programs, says, "In effect, NIF will allow us to break apart the physics of a weapon and examine the processes in isolation."

Experimental facilities alone would not provide a robust stockpile stewardship effort. To analyze the new data, scientists also needed vastly improved computer modeling capabilities so they could simulate a weapon in three dimensions from start to finish.

"Just to simulate the physical interactions that we understood," says Miller, "we estimated it would take computing speeds of 100 teraops," or 100 trillion operations per second—nearly 100 times the computer industry's top speed in 1994. "To develop that capability within one decade, we'd need to outstrip Moore's law." That is, Stockpile Stewardship could not wait for computer speed to double every 18 to 24 months—a computer industry standard first predicted in the 1970s by Intel Corporation's cofounder Gordon Moore.

To provide the necessary computing resources, DOE developed the Accelerated Strategic Computing Initiative (ASCI), a multilaboratory effort with strong partnerships in the computer industry designed to push computational power to the 100-teraops level. Now called the Advanced Simulation and Computing program and administered by NNSA, ASCI is producing remarkable results.

"We're seeing unexpected benefits from ASCI all over the scientific community," says Miller. "It's almost a new field—developing three-dimensional codes to run on the big computers, like the ASCI White machine here at Livermore. It's improving our scientific understanding in biology, chemistry, basic physics—every area of science." (See *S&TR*, June 2000, pp. 4–14.)

Miller believes NIF experiments, which are planned to begin in 2003, will also enhance scientific capabilities in many research areas besides weapon physics. For example, NIF will give astrophysicists their first laboratory setting for studying astronomy and should greatly improve their understanding of space physics. (See *S&TR*, May 2001, pp. 21–23.) "It's breathtaking science," Miller says. "Once again, we're reminded that when the federal government invests in high technology, there are surprising spinoffs that benefit the nation in many ways."

Training the Next Generation

As with Laboratory projects over the last 50 years, Livermore's stockpile stewardship work is a multidisciplinary effort, involving researchers from many directorates, including Defense and Nuclear Technologies, Engineering, NIF Programs, Chemistry and Materials Science, Computation, and Physics and Advanced Technologies. (See *S&TR*, March 2001, pp. 23–25;

Livermore's largest two-stage gas gun, which is 20 meters long. The gun's projectile flies down the barrel at speeds up to 8 kilometers per second and, upon impact, produces a shock wave millions of times the pressure of air at Earth's surface. Gas-gun experiments such as this one, which is being set up by technicians Leon Roper (left) and Keith Stickles, allow scientists to improve their understanding of the physics of shocked fluids and condensed matter—an important part of the nation's Stockpile Stewardship Program.

May 2001, pp. 24–26; July/August 2001, pp. 18–20.) Not only does the Stockpile Stewardship Program help the nation maintain its nuclear deterrent, but it is also helping Lawrence Livermore maintain its capability base to respond to future national needs. In particular, the program provides the technological challenges that scientists need to hone their problem-solving skills and build the scientific credibility that is a hallmark of the nation's weapon laboratories.

According to Anastasio, training the next generation of weapon scientists is imperative when the nation's nuclear deterrent is maintained in the absence of nuclear testing. "The test moratorium is 10 years old," he says, "and many of today's stockpile stewards have no experience designing a weapon or fielding a test. NNSA's Stockpile Stewardship Program is designed to help this generation of scientists gain the kinds of experience that we used to get with underground testing."

Multidisciplinary research is especially important for the program to succeed. By building new research facilities and computing capabilities, NNSA is combining experimental laboratories with computational laboratories so that physicists, code developers, engineers, and technicians can work in teams to solve stockpile-related problems. For example, ASCI code designers are working closely with physicists, chemists, material scientists, engineers, and others from the weapons program to validate the new codes used to model weapon physics. "We're working together to model real physics and to validate the codes against experimental data from our underground experiments," Budil explains.

NIF will provide the same cooperative research opportunities on the experimental end of stockpile stewardship. The power of NIF will allow scientists to perform weapon-relevant experiments in an aboveground nonnuclear environment. Nevertheless, setting up experiments and diagnostics will be an immense challenge, similar in many ways to preparing for a test at the Nevada Test Site.

"In the past, a designer's career record in the test program gave him or her credibility," says Budil. "For example, George Miller's opinions about nuclear weapons and how they work have the weight and credibility of his extensive experience. Without a test program, how does the Laboratory maintain its expertise and the public's confidence?"

To develop this experience and credibility, says Anastasio, Laboratory managers must allow scientists to once again follow the bold ideas that lead to innovation. "Livermore cannot become a risk-adverse institution if we are to maintain our creativity and flexibility in responding to the technical demands of national security. We must give scientists a chance to fail. We must let talented people put their technical reputations on the line—let them experience a few sleepless nights and confront the reality that an experiment might not work—so we can certify their credibility at making such critical decisions."

According to Miller, this need to challenge and test a scientist's judgment is one reason the nation has benefited from having competition between Lawrence Livermore and Los Alamos national laboratories. "When someone is diagnosed with a serious disease—a disease that, even with the best medical science, is still understood imperfectly—the patient wants to get more than one opinion." For the past 50 years, the nation has used this same approach with nuclear weapons. By having two independent weapon laboratories, the federal government has two sources of independent advice. And, Miller says, "Should the experts disagree—whether we're talking about medicine or

The U1a complex at the Nevada Test Site. The complex consists of several buildings and instrumentation trailers from which scientists can monitor experiments conducted underground. Today, the complex is used for subcritical experiments, which provide data to complement those from past underground nuclear tests.

weapon physics—it's possible that something is being missed." By building research facilities and new technology capabilities to be used by researchers at more than one laboratory, the Stockpile Stewardship Program ensures that the nation continues to have independent sources of expertise, each with credible histories in weapons research and the necessary research tools.

The Future of the Laboratory

Anastasio says that the future for Lawrence Livermore is both exciting and sobering. "September 11 reemphasized our mission. The nation is facing unprecedented security challenges. At Livermore, we must use our science and technology to build capabilities that serve the national interest."

As with the activities for stockpile stewardship, the Laboratory's role in research and development for homeland security is emerging from its ongoing work in nonproliferation and counterterrorism. "The scope of homeland security is daunting," says Anastasio. "The nation needs tools and technologies to prevent attacks, reduce threats, and manage the aftermath, areas we have long been working in to develop the relevant technical capabilities. Unfortunately, there's no silver bullet—no single technological widget—to solve this extraordinarily complex problem, and a layered, system-level approach is required."

An important part of this effort will be assessing the risks and balancing competing priorities while implementing solutions. In developing the nation's nuclear deterrent and maintaining the stockpile, researchers at Livermore have demonstrated the capability to work problems from end to end, and they build on this approach to problem-solving in projects for homeland security. "To focus our research in the right areas," says Anastasio, "we must understand not only what threats are facing the nation, but also what is needed to counter them." Researchers no longer focus solely on military applications for new technologies but rather are developing tools that can be used in various venues—from airports, hospitals, and post offices to theaters and sports arenas.

"We are developing real products that we can put in the hands of the end users," Anastasio says. "Once new technologies are developed, we'll transfer them to U.S. industry and then train the end users so these new tools can be deployed effectively."

Such activities are not new to the Laboratory. Many of Livermore's mission responsibilities and programs are relevant to homeland security and provide the Laboratory's scientists with an excellent overall perspective of the threats, technical opportunities, and user needs. "Homeland security will be an enduring national security mission for the Laboratory," says Anastasio, "With our successful track record of scientific innovation and technology development, we can provide effective solutions for this long-term endeavor."

Science and Technology in the 21st Century

Part of Livermore's 50th anniversary celebration has been to look at the future of science and technology in the context of national security and opportunities for the Laboratory. To foster this discussion, the Center for Global Security Research (CGSR) sponsored a 2002 Futures Project called "Science and Technology for National Security: The Next 50 Years—Pioneering the Endless Frontier," a series of workshops designed to examine the interactions and conflicts of science and technology, national security, and globalization. The CGSR workshops did not focus on predicting future technologies or national needs. Instead, participants were encouraged to identify the trends that intersect these three spheres of influence because the difficult challenges of the future will most likely involve issues at this interface.

Eileen Vergino, CGSR deputy director and cochair of the Futures Project, said, "Through these workshops, we not only wanted to examine the science and technology requirements imposed by national security. We also wanted to evaluate the inherent challenges and constraints to security that may be caused by science and technology breakthroughs and by globalization in the next 50 years."

One important goal of the Futures Project was to facilitate discussions between communities that rarely interact. Workshops included science advisors at federal agencies, fellows from the American Association for the Advancement of Science, other social scientists and experts in policy and national security, undergraduate honors students at Pennsylvania State University, and some of the younger scientists at Livermore, who may lead the Laboratory in the future. "We wanted to bring a lot of bright minds together and get them talking to each other," says Jay Davis, CGSR's first National Security Fellow and the other project cochair. "We asked a lot of questions and then gave the participants time to discuss the issues we brought up so they could examine problems and opportunities from multiple viewpoints."

Vergino notes that the terrorist attacks of September 11 serve as a cogent example of the interplay between the forces of globalization, national security, and science and technology. "Because of recent advances in communication technology, such as cell phones and the Internet, we can quickly correspond with people around the world," she says. "These new tools can also empower small, geographically dispersed groups, who can become a threat to national security merely by exploiting existing technology."

As a result, the U.S. can no longer focus its national security policy primarily on threats from one superpower or nation–state, as it did during the Cold War. Instead, it must plan for a complex world of competing smaller-scale threats, many of which can quickly inflict disastrous, long-term consequences.

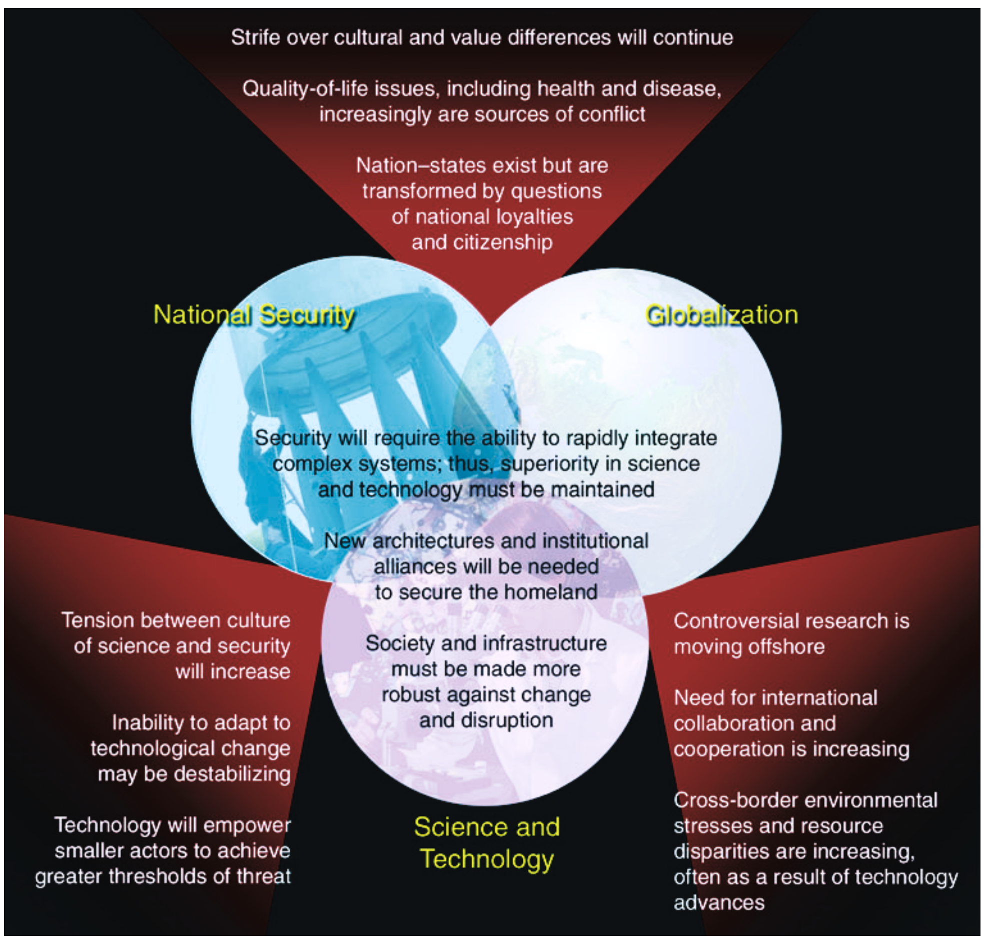
"A serious concern where science and technology threaten security is bioterrorism or even an outbreak of a naturally occurring disease," Budil says. "And this threat is not only to the United States, but to the global community. With the ease of international travel we have today, a disease outbreak in one country can quickly spread across the world."

Workshop participant Robin Newmark adds, "Many aspects of our lives have changed since September 11, and as a nation, we're trying to sort out the conflicts that arise between implementing an effective homeland security policy and protecting the personal freedoms that we hold dear. In a very short time, we've learned to accept that we might be searched before we enter a sports arena or board a plane to visit our grandmother."

Newmark, who leads Livermore's Geosciences and Environmental Technologies Division, says research laboratories such as Livermore have an important role to play in addressing these new security issues. "For the short term, we can modify our current tools and apply them to the security problems. But we also need to find better technologies for addressing these issues. By asking difficult, open-ended questions, the facilitators at the CGSR workshops are helping us consider these problems from many viewpoints."

Finding solutions to technically challenging problems requires devoted attention over the long term, and for that, researchers must have stable funding. Vannevar Bush's model for government funding of basic science research has been used effectively since World War II. But Newmark asks, "What would happen to research institutions like Livermore if our funding sources change in the next 50 years? What if universities must rely on corporate sponsorships? We also must consider how these changes might alter the focus of our research and what opportunities they might bring."

Of course, advances in any science can have unexpected social costs, and participants in the CGSR workshops were asked to consider the ramifications of future research and development efforts. For example, says Davis, "If we were to cure cancer or cardiac disease, what effect might that have on retirement plans



Example trends that intersect the three spheres of influence—national security, globalization, and science and technology—as identified by workshop participants in the Center for Global Security Research's Futures Project. The difficult challenges of the future will most likely involve issues that intersect the three spheres.

and health-care programs? Can we envision a way to protect our economy? Furthermore, in an increasingly globalized world, do our efforts to stop research in a particular area, such as stem-cell research, serve to simply move that research to another country where we can no longer benefit from it or provide ethical guidance on its application?"

Budil adds that this kind of brainstorming, where participants not only contribute ideas but also evaluate the consequences of each choice, allows scientists to exercise their skills at making connections across disciplines—a skill that often leads to innovative uses of old technologies. "One of the great innovations to come from the Laboratory's weapons program is PEREGRINE," she says. (See *S&TR*, June 2001, pp. 24–25.) "Who would have guessed 20 years ago that we could spin off a tool for planning cancer radiation treatments by combining our expertise in Monte Carlo modeling and radiation transport? But those are the connections that scientists can make in a multidisciplinary environment such as this Laboratory, and the CGSR workshops encourage the discussions that lead to such connections."

The final workshop was held in September 2002, in conjunction with Livermore's 50th anniversary celebration, and a report on the Futures Project will be issued in the next fiscal year. Says Vergino, "It's clear from the discussions we've had that U.S. national security depends on maintaining our lead in science and technology. The nation must continue to support a strong, flexible capabilities base, as it has since World War II. To respond quickly in times of crisis, our government needs talented scientists and engineers—people who can understand complex problems, rapidly analyze scenarios, and then integrate systems to implement strategic solutions, whatever that might be." (For more information on CGSR, see *S&TR*, June 1998, pp. 10–16, and September 2001, pp. 11–18.)

According to Lee Younker, associate deputy director for science and technology, the greatest success of the Futures Project is that it stimulated the thinking of the participants. The project also helped Livermore's senior managers to refine their ideas for how the Laboratory's role might evolve over the next 50 years. "The defining events for the United States affect national priorities," says Younker, "and they often refocus the nation's attention on its science and technology infrastructure. National laboratories must be prepared to respond quickly in critical times by devoting people and resources to the research areas where they can have an immediate effect on problems of national importance."

Innovative Science Is a Moving Target

In its 50th anniversary year, Lawrence Livermore faces new challenges. Nuclear weapons remain part of the nation's security policy, but the number of weapons in the stockpile has declined dramatically. The nature of national security is evolving, and the Laboratory must follow that evolution to maintain its vitality. Thus, Livermore's senior managers must determine how the Laboratory can best contribute to its evolving security mission and which capabilities will complement other national needs.

Younker says that part of Livermore's success stems from the stable funding it has received for weapons research. "We're a superb laboratory when we have resources to do what we do best." In today's economy, few industries can afford to work on large-scale basic science research or technology development because they need a quicker return on their investment as determined by market forces. Federal funding of science and technology projects, such as nuclear weapons research or the space program, typically has a much longer-term horizon and thus has provided a tremendous benefit for the country. But Livermore's senior managers know the Laboratory must continue to evolve, as it has under the Stockpile Stewardship Program, so the institution and its capabilities base can remain a vibrant national resource for the next 50 years.

"We can predict the future all we want and be wrong," Miller says. "What's important is for the nation to have a system that provides capabilities and flexibility so the country can respond to whatever threatens us. We can't sit back and wait—our enemies will find a way to attack us if we remain static. Instead, we must use periods of relative peace, as we've had more or less for the last 50 years, to try to push our knowledge and technology in a positive direction and prepare for times of crisis."

"In one sense," says Anastasio, "the future of Lawrence Livermore is to be the thing we've always been, and that is a laboratory of outstanding people who can get work done—who are flexible, responsive, and make great contributions to our country."

—*Carolin Middleton*

Key Words: Center for Global Security Research (CGSR) Futures Project, nuclear test moratorium, post–Cold War science and technology, stockpile stewardship, underground nuclear testing, Vannevar Bush.

For more information on the Center for Global Security Research:
www.llnl.gov/nai/cgsrjd/cgsr.html

For Vannevar Bush's complete report,* Science: The Endless Frontier*:
www.nsf.gov/od/lpa/nsf50/vbush1945.htm

For further information about the Laboratory's 50th anniversary celebrations:
www.llnl.gov/50th_anniv/