Commentary by Penrose (Parney) C. Albright

Honoring the Past with a Look to the Future

THE Laboratory at Livermore opened for business 60 years ago, on September 2, 1952, as a branch of the University of California Radiation Laboratory led by Ernest O. Lawrence. Herbert York, then only 31 years old, was tasked by Lawrence to draw up a mission statement and organizational plans for the new laboratory and to serve as its first director. The founding 75 staff members were in their 20s and 30s except for senior scientist Edward Teller, who was 44.

Establishment of the Laboratory was triggered by the Soviet Union's successful test of an atomic bomb. Its founding was an experiment by the U.S. government at a time when the Cold War was raging and nuclear security was a preeminent concern. Lawrence and Teller urged decision makers in Washington, DC, to create a second design laboratory to augment the ongoing efforts of the Los Alamos laboratory in New Mexico. They believed the nation would benefit from having a second, independent source of nuclear design expertise to spur design innovation. The two renowned physicists had the credibility to convince Washington that, as York later said, "the youngsters could make the Lab work."

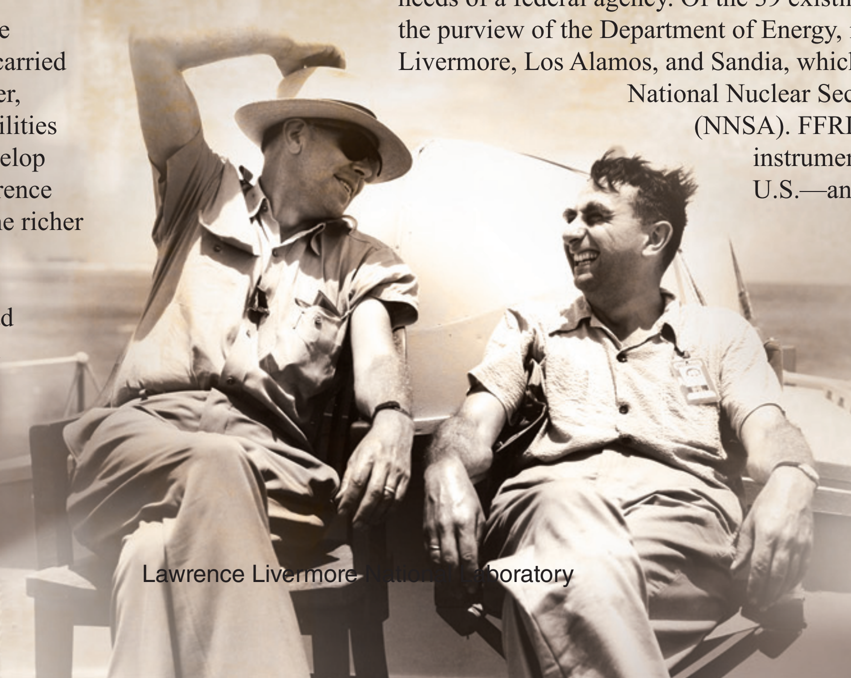
Those youngsters set out to build a "new ideas" laboratory, focusing on novel approaches to nuclear design that were not being pursued at Los Alamos. Success did not come right away. The Laboratory's first test of a fission device failed, as did the second. So did the first test of a hydrogen bomb design. But during the 1950s, critical breakthroughs led to compact strategic warheads, small enough to place inside missiles that could be launched from submarines. The fielding of these Polaris-missile submarines offered the nation a survivable nuclear deterrent at sea. These technological breakthroughs led to the intercontinental ballistic missile portion of the deterrent and to air-carried standoff weapons. Having a broader, more varied suite of nuclear capabilities allowed the nation's leaders to develop a more sophisticated nuclear deterrence strategy and provided them with the richer set of options they desired.

The novel design and rapid development of the Polaris warhead established Livermore's reputation for innovation. And that first group of talented scientists and engineers created the Laboratory's culture, which we share and benefit from today. They pursued multidisciplinary "team science" to solve multiyear, large-scale problems. This approach, pioneered by Lawrence, has been key to the Laboratory's many successes. Our founders set a remarkably high standard for innovative scientific and technical excellence, product delivery, and dedicated service to the nation.

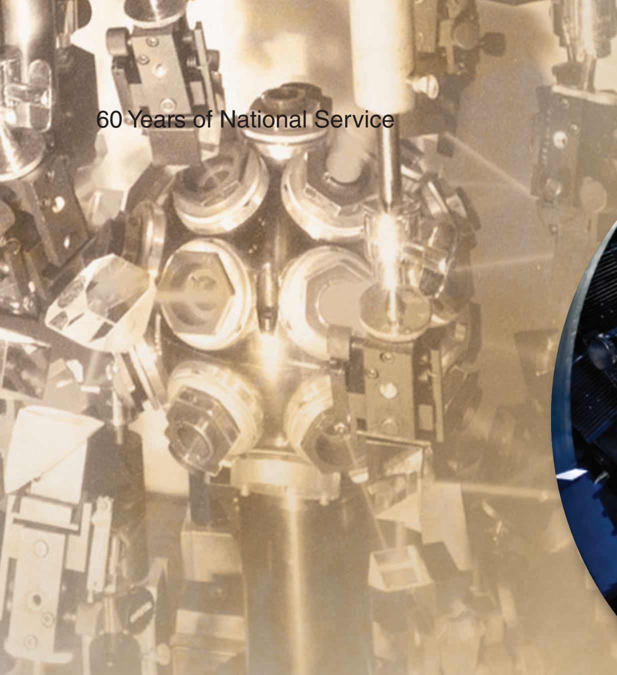
Independent Centers of Expertise

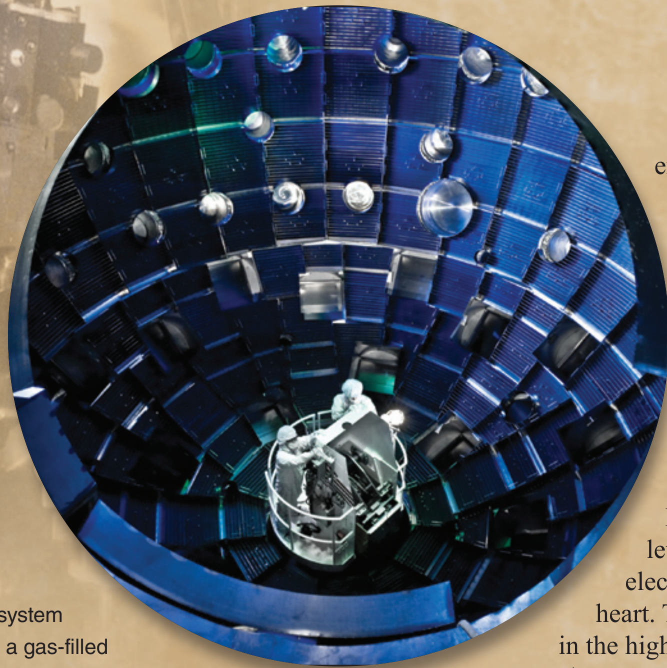
The government's "experiment" in cooperative competition of ideas has paid off. Throughout the Cold War, Livermore and Los Alamos provided key innovations in weapons effectiveness, safety, and security, and working with Sandia National Laboratories, they met the demanding military requirements for the entire weapons package. These independent centers of expertise are proving to be equally essential after the Cold War. In the absence of nuclear testing, peer review between the nuclear design laboratories and their different approaches to problem-solving provide a crucial safeguard in carrying out the U.S. policy to "sustain a safe, secure, and effective nuclear arsenal as long as nuclear weapons exist."

Lawrence Livermore and Los Alamos were also part of a grander national experiment in how best to pursue large-scale, long-term research and development to meet important national needs. After World War II, U.S. decision makers identified a capabilities gap between the basic research conducted at universities and the product-directed work in private industry. To fill that need, they created a system of federally funded research and development centers (FFRDCs). Managed and operated by a private entity, each FFRDC is focused on meeting the special needs of a federal agency. Of the 39 existing today, 16 fall under the purview of the Department of Energy, including Lawrence Livermore, Los Alamos, and Sandia, which are part of the National Nuclear Security Administration (NNSA). FFRDCs have been instrumental in propelling the U.S.—and its national security



Ernest O. Lawrence (left) and Edward Teller founded the Laboratory at Livermore in 1952, with Herbert York (not pictured) serving as the first director.





In the 1960s, Livermore scientists built the 4-pi system (left) with 12 ruby laser beams arranged around a gas-filled target chamber about 20 centimeters in diameter. A concerted Laser Program, started in 1972, has led to the National Ignition Facility, where 192 laser beams are directed toward the center of a 10-meter-diameter target chamber (right).

capabilities—to a position of scientific and technical leadership for more than half a century.

The long-term relationship between an FFRDC and its federal sponsor provides the continuity an institution needs to attract and retain talented personnel, construct and operate large research facilities, and develop capabilities for national use. The bargain between an FFRDC and its government sponsors is a simple one: The center commits to sustained excellence in supporting the sponsors' missions, and the sponsors commit to a sustained relationship with specific centers, investing in infrastructure and new capabilities. An FFRDC embeds itself in the sponsors' mission and culture and serves as a trusted partner to these agencies.

Livermore, for example, not only shares mission goals with NNSA but also offers objective and independent technical advice when needed to inform programmatic and national policy decisions. The three NNSA laboratories have provided technical support to arms-control negotiations from the earliest discussions on nuclear-test bans to the current strategic arms-control agreement, called New START. Our input has helped shape successive nuclear posture reviews and key decisions about nuclear nonproliferation policy.

Innovation and Excellence in Science and Technology

At Livermore, we have greatly benefited from our close ties to the University of California (now a parent organization for our managing contractor, Lawrence Livermore National Security, LLC). Through this working relationship, we have consistently explored new ideas and pushed at the frontiers of science and technology in areas central to the success of NNSA's missions.

For example, Lawrence, Teller, and York recognized that the key to making more rapid progress on nuclear weapons design was high-performance computing and simulations. The most powerful existing computer in 1952—the UNIVAC I—was ordered before the Laboratory even opened. We continue to lead in high-performance computing and are home to Sequoia, which is now the world's most powerful supercomputer. To test the new machine and demonstrate its utility for breakthrough research, we collaborated with IBM researchers to develop cell-level simulations that examine the electrophysiology of a beating human heart. This astonishing effort is described in the highlight beginning on p. 22.

Laboratory engineers needed to make advances to meet stringent requirements for our early weapon designs. Parts had to be manufactured with an accuracy of 25.4 micrometers (0.001 inches)—a much higher precision than was possible at the time. Through this work, a Livermore engineer, Jim Bryan, became widely recognized as being "the founding father of precision engineering." Concurrently, we demonstrated prowess in systems engineering through many successful large-scale projects in weapons and fusion energy research. From the earliest days, our expertise in high-performance computing has been applied to diverse engineering applications. The highlight beginning on p. 26 features our state-of-the-art engineering simulations that address challenging national security issues.

We have made groundbreaking advances in many other areas, perhaps most notably in research on lasers and fusion. In 1960, calculations performed by John Nuckolls and colleagues showed that fusion might be achieved by imploding a small capsule of fuel with intense radiation. Coincidentally, a possible source for the required level of radiation was demonstrated elsewhere: the first working laser. With sponsor support, Livermore launched efforts to develop high-energy lasers and explore inertial-confinement fusion because both concepts offered potential benefits for the Laboratory's nuclear weapons research.

Today, researchers at the National Ignition Facility (NIF) are on the verge of creating fusion ignition and burn for the first time in a laboratory setting. NIF offers researchers the unique opportunity to design experiments that explore the energy, pressure, and density regimes occurring within an operating nuclear weapon. Results from those experiments provide the data needed for model development and validation. When combined with our high-performance computing simulations, these data allow us to determine how changes contemplated for stockpiled systems—for example, to improve a weapon's safety and security features or to extend its service lifetime—will affect weapon performance. The article beginning on p. 14 features experimental work at NIF and explains the importance of this research in sustaining the nation's nuclear deterrent.

Serving as a Broad National Security Laboratory

Collectively, the FFRDCs are an invaluable resource for the U.S. They are needed today, now more than ever, to help address the many difficult challenges that so broadly affect national security. A National Academy of Sciences panel studying the three NNSA laboratories recently recommended that these laboratories be recognized more explicitly as broad national security laboratories and their capabilities put in the greater service of multiple sponsors. Such work builds on and strengthens the extensive scientific and technological capabilities applied to the laboratories' core mission in nuclear security.

Readers of *S&TR* appreciate the Laboratory's contributions to national security, broadly defined. Current programs in defense and international security include work on advanced conventional munitions, cybersecurity, space situational awareness, intelligence assessments, directed-energy weapons, enhanced protection for soldiers, and countermeasures against the use of chemical and biological weapons and improvised explosive devices.

Our nation also faces major challenges in energy and environmental security, public health, and economic competitiveness. Livermore has a long history of innovative accomplishments in these areas, as well. For example, expertise in nuclear fallout modeling led to analyses of stratospheric ozone depletion in the 1970s; radioactive material dispersion predictions after nuclear reactor events at Three Mile Island, Chernobyl, and Fukushima; and our current leadership in assessing climate change. Similarly, expertise in geophysical science to ensure containment of nuclear tests now supports field experiments on carbon capture and sequestration as well as computer modeling of induced fracturing to enhance geothermal energy systems and natural gas extraction.

The article beginning on p. 6 provides another remarkable example of our innovative research to address an important national need: an exciting new approach to rapidly develop vaccines that target infectious diseases or biological agents. Our work in biosciences began in the 1960s with efforts to understand the effects of ionizing radiation on human health. The research evolved to focus on DNA analysis and technologies, such as flow cytometry and fluorescent tagging, to study chromosome damage and repair, and the use of our unique high-performance computing resources, to develop advanced capabilities in bioinformatics and molecular modeling. This pioneering work helped lead to the Human Genome Project and current efforts in biosecurity.

Future Filled with Challenges and Opportunities

Our Laboratory continues to look forward, working to meet a broad set of national needs. The challenges are daunting. It is vitally important that we focus our innovative skills on anticipating and then meeting the needs of our sponsors, with a thorough understanding of their requirements and constraints. As the stories in this and other issues of *S&TR* report, the possibilities are endless for creative scientists and engineers who want to make lasting contributions.

Anniversaries are an appropriate time to celebrate the past and cast attention on future challenges. They are also a time to thank Livermore's outstanding staff—past and present—for their new ideas and dedicated hard work. Carrying on traditions established by the Laboratory's founders, we look forward to the next 60 years of excellence in mission-directed science and technology, delivering innovative solutions in service to the nation.

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The Laboratory has often been home to the nation's most powerful computers. The Sequoia system (below left), which can perform 20 quintillion floating-point operations per second, is currently ranked number 1 on the Top500 list of supercomputers. The Laboratory's first computer was the UNIVAC I (below right), the most powerful computer available in 1952 with a performance capability of 1,900 operations per second.