Science & Technology REVIEW

January/
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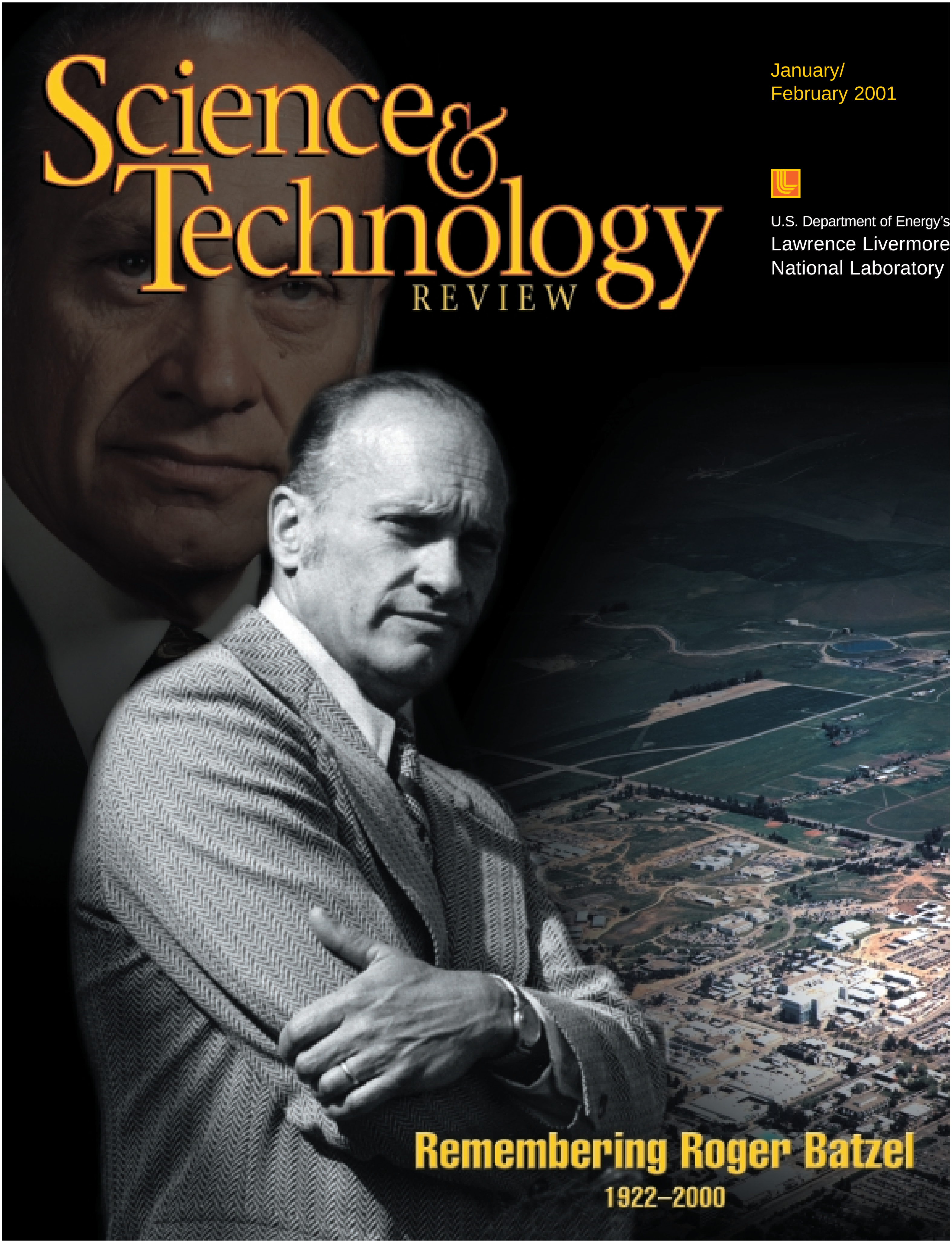
U.S. Department of Energy's
Lawrence Livermore
National Laboratory

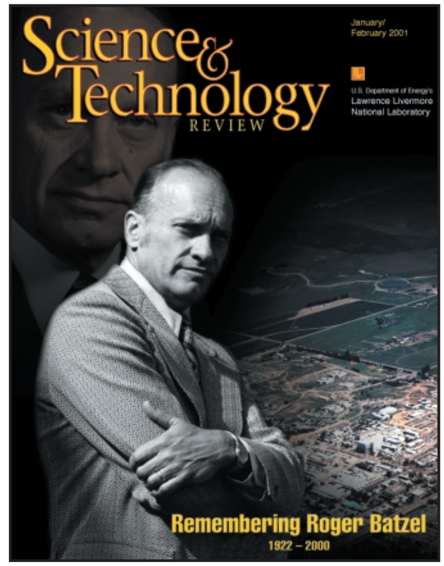


Remembering Roger Batzel

1922–2000

About the Cover

This issue of *S&TR* pays tribute to Roger Batzel, the Laboratory's sixth and longest-tenured director (1971–1988). Batzel died on July 29, 2000, at the age of 78. He was an extraordinary leader, deeply respected personally and for the significant growth and achievement he fostered in Laboratory missions. The issue features an overview of Batzel's long and distinguished career at Livermore (1953–2000). It also focuses on the particular achievements of his directorship. Among them are the growth of a strong biomedical capability, innovations in alternative energy sources, and significant progress in the science that supports deterrence and nonproliferation of nuclear weapons and contributed to the end of the Cold War.



Cover design: George Kitrinos

About the Review

Lawrence Livermore National Laboratory is operated by the University of California for the Department of Energy. At Livermore, we focus science and technology on assuring our nation's security. We also apply that expertise to solve other important national problems in energy, bioscience, and the environment. *Science & Technology Review* is published 10 times a year to communicate, to a broad audience, the Laboratory's scientific and technological accomplishments in fulfilling its primary missions. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

Please address any correspondence (including name and address changes) to *S&TR*, Mail Stop L-664, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, California 94551, or telephone (925) 423-3432. Our e-mail address is str-mail@llnl.gov. *S&TR* is available on the World Wide Web at www.llnl.gov/str/.

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January/February 2001
Lawrence Livermore National Laboratory

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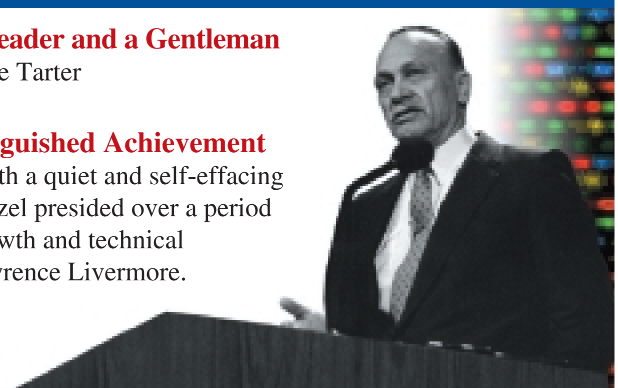
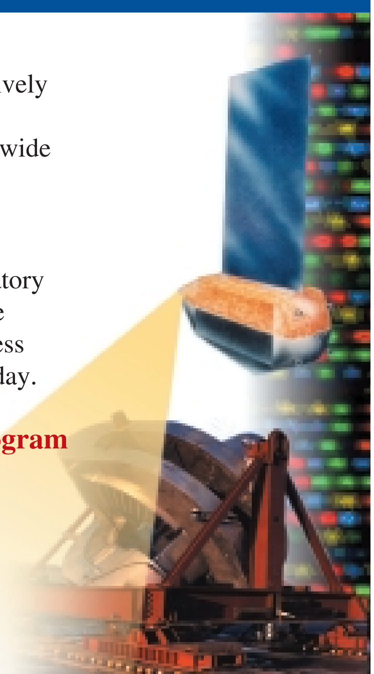


Research Highlights



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Lab, UC Davis team for cancer research

The Laboratory and the University of California at Davis Cancer Center have announced a major collaboration to fight cancer. The institutions have created an integrated cancer research program to accelerate discoveries that help prevent, diagnose, and treat cancer, the nation's second leading killer. The affiliation brings together the research and development strengths of Lawrence Livermore scientists and engineers, particularly in biomedical technology and genomics, with the basic science capabilities of patient-centered clinical researchers at the UC Davis center.

At least a dozen projects are under investigation, including:

- Studies of plant chemicals that may affect the development of cancer.
- Studies using ultrasensitive accelerator mass spectroscopy to analyze how drugs are absorbed in the body.
- Development of new light diffusion sensors that can detect cancer by measuring how light scatters when it is reflected inside tissue.
- Development of an ultrashort-pulse laser to use the light scattered off tissue to create images showing melanomas and other cancers on the skin.

Contact: James Felton (925) 422-5656 (felton1@llnl.gov).

Lab technology revises estimate of meteor's size

Using an innovative three-dimensional imaging technique, a team of Laboratory researchers has revised the size estimate of Kleopatra, an unusually elongated metallic asteroid.

In May 2000, researchers at the Jet Propulsion Laboratory in Pasadena, California, reported Kleopatra's length at about 217 kilometers. More recently, Livermore's Mark Hammergren and his colleagues used an image-layering technique called speckle interferometry (*S&TR*, April 2000, pp. 17–18) to revise that estimate to about 250 kilometers. Using the 10-meter Keck telescope in Hawaii equipped with a special high-speed infrared camera, they snapped about 100 images in a single night of the near-infrared light reflected from the asteroid to sample a set of 22 positions in Kleopatra's rotation. The high-speed imaging technique negates the Earth's rapidly changing atmospheric effects, which can distort distant objects in space.

Kleopatra is unusual because of its shape. Most asteroids are spheres. Researchers hope that Kleopatra's odd shape, which is believed to result from the gentle collision of two asteroids, will offer insight into the composition of asteroids.

Contact: Mark Hammergren (925) 423-5523 (hammergren1@llnl.gov).

Going fishing in the gene pool

Researchers at the Joint Genome Institute (JGI) in Walnut Creek, California, are leading an international effort to map the genetic code of the puffer fish. The JGI is a Department of Energy collaboration of Lawrence Livermore, Lawrence Berkeley, and Los Alamos national laboratories.

The puffer fish (known as Fugu in Japan, where it is a delicacy) is an ancient species with 400 million base pairs of DNA, compared to the 3 billion bases that make up human DNA.

The puffer fish is being mapped because its genome is considered simpler and more pure than the human genome, which is muddled by genetic "noise" resulting from millions of years of evolution. Scientists reason that they can learn much about the fundamental structure of the cluttered human genome from the puffer genome. This knowledge will help fill in the details of the completed draft of the entire human genome.

The same principle that drives the puffer fish research is also leading genetic researchers to investigate the genome of other simpler organisms such as the mouse, fruit fly, yeast, and nematode.

Contact: Elbert Branscomb (925) 296-5700 (branscomb1@llnl.gov).

Cancer research yields cooking tips

Researchers at Lawrence Livermore's Biology and Biotechnology Research Program have found that cooking hamburgers at specific temperatures and to specific internal temperatures and flipping them frequently not only kills harmful bacteria but also reduces the formation of chemicals that may cause cancer.

According to an article by these researchers in the November 2000 issue of the *Journal of the National Cancer Institute*, frying hamburger patties at a pan temperature of 160°C and turning the patties every minute speeds the cooking process and reduces the formation of harmful, potentially cancer-causing compounds.

Before being cooked, the burgers were also inoculated with a strain of *E. coli* bacteria but were found to be essentially bacteria-free after being cooked to an internal temperature of 70°C, regardless of pan temperature and frequency of turning.

The researchers conclude that their cooking method could ensure a microbiologically safe food product and might lower human cancer incidence due to dietary carcinogens. Their research is part of a larger investigation into the role of cooking in the formation of compounds that, when metabolized, may cause cancer (see *S&TR*, July 1995, pp. 6–30, and September 1995, pp. 6–23).

Contact: Cynthia Salmon (925) 423-4700 (salmon6@llnl.gov).

Roger Batzel
A Leader and a Gentleman

IN this issue of *Science & Technology Review*, we pay tribute to the distinguished career of Roger Batzel, Lawrence Livermore's sixth director and one of its most respected scientists and leaders. Roger embodied the best attributes of a national laboratory director—rigorous scientific training and broad technical know-how combined with a talent for administering and a superb people sense.

During Roger's directorship, from 1971 to 1988, the Laboratory thrived and expanded. Dozens of new office buildings, laboratories, and research facilities were erected. Biomedical, energy, and environmental programs blossomed. And laser science grew dramatically with the dedication of the Shiva and Nova lasers.

Despite the Laboratory's substantial diversification, Roger kept our main focus on strengthening the nation's forces for nuclear deterrence. Weapons research ranged from the more traditional design and testing of nuclear devices to the pursuit of strategic defense technologies.

Through it all, Roger was a steadying influence. His level-headedness, integrity, and sound judgment earned him the respect and affection of employees. He had a particular genius for choosing the right leaders for the Laboratory's major research efforts and supporting them in attaining the resources they needed to succeed.

I consider myself fortunate to have worked at the Laboratory under Roger's leadership for more than two decades. One of the most important things I observed was that Roger was always looking ahead to assure a vigorous Laboratory far into the future. For example, he appointed Associate Director-at-Large Carl Haussmann and former Laboratory Director Mike May to head long-range planning at the Laboratory. Together, Roger, Mike, and Carl set the course for Laboratory research programs into the 1990s and the new century.

Roger's reputation shone brightly in Washington, DC, where people trusted his plain-speaking advice and counsel. Over the years, he advised presidents, senators, Pentagon generals, and leaders of the Atomic Energy Commission and its successors, the Energy Research and Development Agency and the Department of Energy.

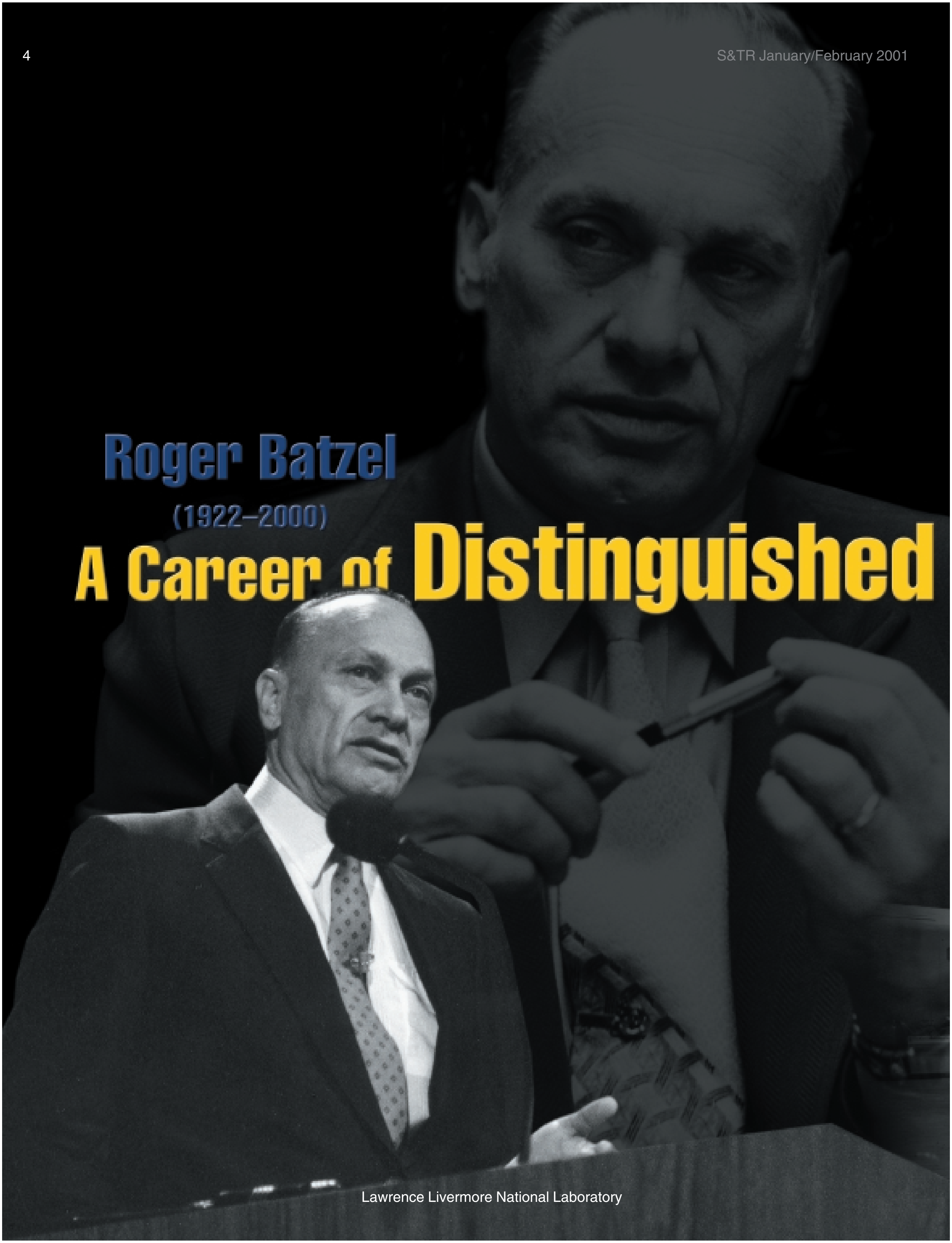
Roger's contributions did not start with his directorship nor did they end with it. He joined the Laboratory in 1953, a year after it began operation, and quickly made a name for himself in the Chemistry Department as an able scientist. His managerial talents soon became evident, and he assumed increasingly responsible positions in nuclear testing, space reactors, and biomedicine as well as chemistry.

When he stepped down as director, he was named associate director-at-large, a post that gave him significant responsibility in the Laboratory's national security and intelligence programs. When I became director in 1994, I found Roger a ready resource of knowledge, experience, and well-reasoned judgment.

As was plainly evident from the eloquent words spoken at a memorial service at the Laboratory last September, some two months after his death, Roger will be sorely missed. His style was much different from that of E. O. Lawrence, but he, too, will be remembered as an outstanding leader.

■ Bruce Tarter is Director of Lawrence Livermore National Laboratory.

Roger Batzel
(1922–2000)
A Career of Distinguished



With the full confidence of employees and Congress, Lawrence Livermore Director Roger Batzel

Achievement

presided over nearly 17 years of unprecedented growth and remarkable accomplishments.

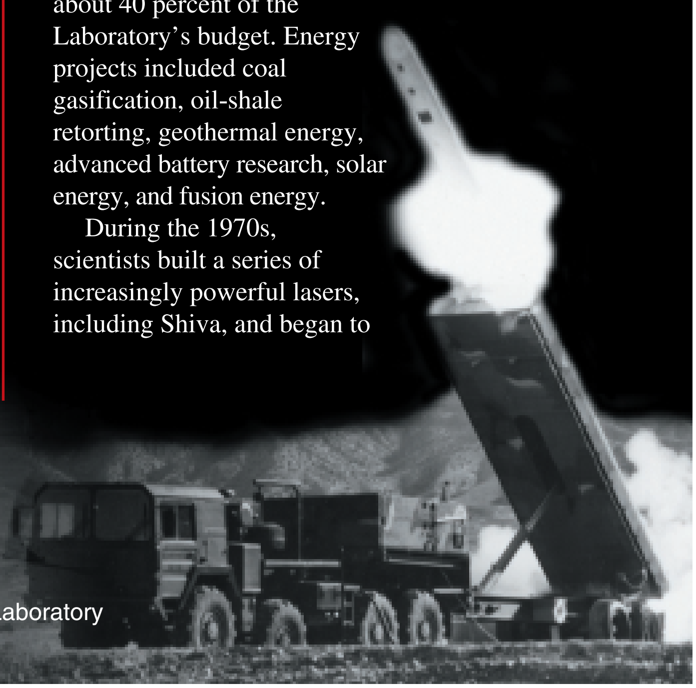
NUCLEAR chemist, presidential adviser, and accomplished square dancer, Roger Elwood Batzel redefined what a national laboratory could be during his tenure as director of Lawrence Livermore National Laboratory. Batzel died on July 29, 2000, at the age of 78, to the great sorrow of countless friends and colleagues.

Batzel was director from 1971 to 1988, or nearly one-third of the Laboratory's history. For almost 17 years—by far the most for a Lawrence Livermore director—he presided over enormous technical achievements that contributed greatly to the eventual end of the Cold War. In the process, he demonstrated that a quiet, self-effacing manner was no obstacle to greatness in leadership or to earning the genuine affection and respect of colleagues and senators alike.

"Roger shepherded the Laboratory through a time of great growth and transition from a defense and nuclear facility to a multiprogram institution dedicated to solving the important scientific issues of our time," says Lawrence Livermore Director Bruce Tarter. From fiscal year 1971 to 1988, Lawrence Livermore's total operating, equipment, and construction budget climbed more than twofold to over $1 billion. At the same time, the full-time staff rose from 5,300 to 8,200, about what it is today.

Laboratory Associate Director Emeritus Phil Coyle, who served as Batzel's executive officer for several years, notes that the concept of a multiprogram laboratory, one that pursued excellence in applied research in many different fields, blossomed to its full potential under Batzel. Nonweapons work grew to account for about 40 percent of the Laboratory's budget. Energy projects included coal gasification, oil-shale retorting, geothermal energy, advanced battery research, solar energy, and fusion energy.

During the 1970s, scientists built a series of increasingly powerful lasers, including Shiva, and began to



develop laser isotope separation technology for enriching uranium. Biomedical and environmental work, including nuclear waste storage technology, expanded significantly. The Laboratory gained expertise to analyze seismic events, and research in atmospheric sciences and global climate modeling grew.

National Security Advancements

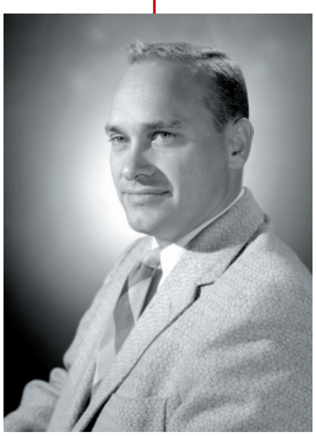
Although the 1970s saw reduced federal funding for defense, Laboratory weapons scientists made significant achievements, including the successful underground nuclear test of the Spartan antiballistic missile at Amchitka, Alaska. Weapons support facilities such as diamond-turning machines for unprecedented machining accuracy were built at Livermore. Increases in computational capabilities led to major improvements in simulating weapon performance and other physics phenomena in extreme environments.

During the Reagan administration, from 1980 to 1988, the Laboratory saw funding for energy and the environment decline and support for national security climb significantly. New weapons projects for Laboratory scientists included warhead designs as well as research on ballistic missile defense, which included particle beams, free-electron lasers, x-ray lasers, and Brilliant Pebbles, part of the strategic missile defense initiative. New research facilities such as the Advanced Test Accelerator and the Flash X-Ray Facility—the latter a key component of today’s Stockpile Stewardship Program—were also built.

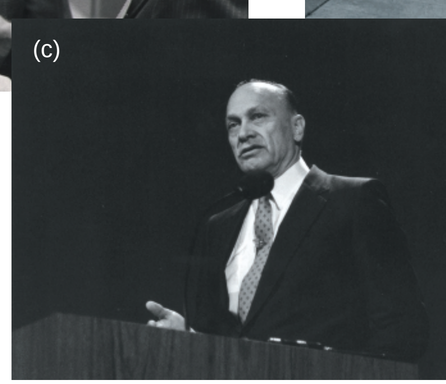
Computer modeling affected nearly all fields, providing a foundation for its essential role today. The Laboratory’s Atmospheric Release and Advisory Capability tracked the Chernobyl radioactive cloud, and combat simulation programs designed at Livermore became vital training tools to the military. A new generation of supercomputers allowed Laboratory scientists to significantly improve simulating weapons and other phenomena with advanced codes.

Laser research expansion continued aggressively. The 10-arm Nova laser debuted in 1985 as the world’s largest. Successful plasma and implosion experiments over the next decade pointed the way to the giant 192-beam National Ignition Facility, now under construction at Lawrence Livermore. Biomedical research made major strides in genetics, biodosimetry, and other areas and laid the groundwork for the Laboratory’s major role in the Human Genome Project.

Laboratory Director Emeritus Edward Teller credits Batzel with



In 1959, Batzel was appointed head of the Chemistry Department.



(a) With Vice President Nelson Rockefeller in 1977, (b) with Dixie Lee Ray, Director of the Atomic Energy Commission, in 1973, and (c) during one of his annual State of the Laboratory presentations.

positioning Lawrence Livermore to help the nation win the Cold War through research in support of the Strategic Defense Initiative, specifically the development of Brilliant Pebbles. "Roger Batzel fought and won the Cold War when the battle had to be fought. His contributions to the nation are just as important as those of E. O. Lawrence or Robert Oppenheimer," says Teller.

Kept Up to Date on Research

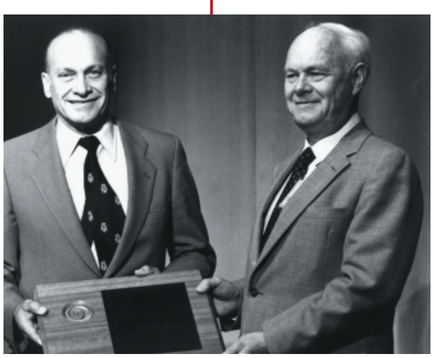
Batzel made sure he was current on research programs, both large and small. Jack Kahn, who served as Batzel's deputy director for many years, cites his "extraordinary grasp" of Livermore's widely diverse research efforts, including programs such as biomedicine and fusion energy that were not immediately related to his specialty of nuclear chemistry.

Duane Sewell, who also served under Batzel as deputy Laboratory director, notes that when Batzel visited scientists around the Laboratory to learn more about their research, they would often marvel that "this guy knows a lot about my experiment."

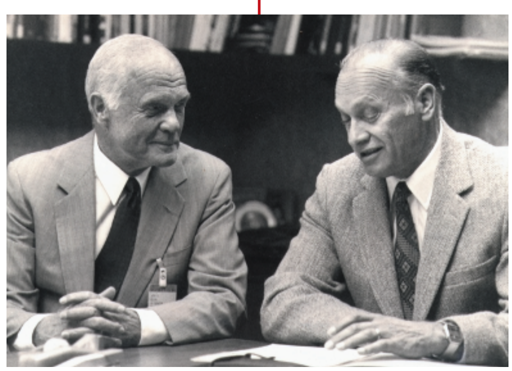
"I make sure I understand what's going on in the various parts of the weapons program, in magnetic fusion energy, in the laser area, in energy and biomed," Batzel said in the mid-1980s. "That is a challenge in its own right, one which gives me a great deal of satisfaction."

Batzel started two programs that strengthened overall research. The first, a formal postdoctoral program, broadens the training for individuals who recently received a Ph.D. and is, today, a vital part of Lawrence Livermore's multidisciplinary research efforts. The second evolved into the current Laboratory Directed Research and Development program of independent research, which Livermore Director Emeritus Michael May terms "a great asset to the Laboratory and to science in general."

Batzel's directorship was also marked by important progress in people issues. Educational programs, in particular, blossomed. Lawrence Livermore scientists visited local schools and devised math and science lesson plans designed to capture the imagination of schoolchildren and teachers alike. Batzel strengthened educational assistance for employees and greatly expanded collaborations with universities and other laboratories. Interactions with industry and local communities and government agencies soared. The Visitors Center debuted as one of many outreach efforts.



In 1982, Batzel received the Distinguished Associate Award from W. Kenneth Davis, Deputy Secretary of Energy. The award citation said Batzel "has proven to be a catalyst for success through his technical insight and his management style that fosters creativity and the pursuit of excellence."



Batzel enjoyed the confidence of congressional representatives and senators, including Senator John Glenn.

Batzel counseled his successor, John Nuckolls, shortly after he stepped down as the Laboratory's sixth director. (At the far right is Carl Haussmann.)

Transformed Social Fabric

Kahn says that Batzel did not receive enough credit for helping to transform the social fabric of the Laboratory, from a top-down structure characteristic of the 1950s and 1960s to a more egalitarian structure that encouraged two-way communication. “Roger was a true agent of change,” he said.

Discussions about Batzel’s directorship typically turn into fond recollections of Roger Batzel the man. Mort Mendelsohn, whom Batzel convinced to take over the biomedical research program in 1972 (see related article on pp. 10–13), described him as a “tall, lanky, cowboy-booted man” who was also a “superb manager.” He was, Mendelsohn says, “the Gary Cooper of the nuclear world. Roger was a man of few words, but he had the strongest convictions.”

Sewell characterizes him as “calm, thoughtful, and very caring about people.” He says that Batzel had the confidence of Laboratory employees as well as Congress “because he was such a quiet, kind, and good individual.” Sewell says that Batzel “was not what I would call a flamboyant or dynamic leader. But he got things done.” He adds, “When he spoke to you, you listened.” Sewell, the Laboratory’s deputy director emeritus, continued to share an office with Batzel until his death. “He was a wonderful man who touched my life,” he says.

Coyle cites Batzel’s influence on Washington contacts. “He had a way of reassuring any customer, whether it was the Navy, Department of Defense, or whoever, that when the Lab took on a

An American Success Story

Roger Batzel’s life was “an American success story,” says Lawrence Livermore Director Emeritus Michael May. He cites Batzel’s steady rise from modest beginnings in Weiser, a small town in Idaho where he was born and reared. In the midst of World War II, he left his studies at the University of Idaho and joined the U.S. Army Air Force, where he served as a navigation instructor. After the war, he returned to the University of Idaho, earning his bachelor’s degree in chemical engineering in 1947.

His first job after college was as a chemist with General Electric Company’s Hanford facility in Richland, Washington. In 1948, he left to attend the University of California at Berkeley, studying under famed nuclear chemist Glenn Seaborg. After receiving his Ph.D. in 1951, Batzel spent two years as a senior chemist with the California Research and Development Corp., which as a contractor for the Atomic Energy Commission conducted defense research at Lawrence Livermore’s current site.

He joined Lawrence Livermore as an assistant division leader with the Chemistry Department in 1953, a year after the Laboratory opened its doors. His work involved the radiochemical analysis of nuclear-device performance. Batzel became Chemistry department head in 1959 and associate director of Chemistry two years later. His responsibilities increased significantly shortly after when he was also named associate director of Nuclear Testing, a position he held until 1964.

He went on to serve as associate director of Chemistry and Space Reactors from 1966 to 1968 and associate director of Chemistry and Biomedical Research from 1969 until his appointment as the Laboratory’s sixth director on December 1, 1971, his 50th birthday.

He served as director until early April 1988. “I have found challenge, stimulation, and satisfaction in my position,” Batzel said.

An inscription on a plaque, presented to Batzel by John Nuckolls, Batzel’s successor, cites Batzel’s “vision and leadership during the years of growth and diversification that have made Livermore an internationally esteemed center of excellence for defense, energy, and biomedical and environmental science and technology.”

Nuckolls appointed him associate director-at-large. In that position, he served on the Laboratory’s Executive and Weapons committees and oversaw the Intelligence Program. Although he retired in 1989 as director emeritus, he still kept a desk in the Director’s Office and worked on a regular basis as a consultant.

Batzel was a fellow of the American Physical Society and the American Association for the Advancement of Science. He received the esteemed Distinguished Associate Award, the Department of Energy’s highest award, in 1982.

On September 30, 2000, two months after Batzel’s death, longtime friends, family members, and former colleagues gathered for a special tribute hosted by current director Bruce Tarter. Three former directors—Mike May, Edward Teller, and John Nuckolls—attended, as did many other current and former senior Laboratory managers. Joining them were Edwina (Eddy) Batzel, Batzel’s wife of 54 years, daughters Stella and Stacy, and grandsons Chris and Sam. Batzel’s son Roger could not attend.

Following the ceremony, Tarter announced that the Laboratory would dedicate Building 132, the national security building, in Batzel’s memory for his “legacy of excellence in support of national security.”

job, the best people would be assigned and those projects would be successful—always."

John Nuckolls, who succeeded Batzel as director, says "Roger had special strengths and resources that facilitated Livermore's evolution into the nation's leading applied science laboratory. He created and led a team of extraordinary senior scientist–managers. He gave our national security programs top priority. His strong support never wavered, notably during the major controversies related to our leading Strategic Defense Initiative program when it was criticized by the scientific community and investigated by Congress.

"Roger followed Lawrence's example (as characterized by Edward Teller), 'generously supporting all who had the ability and determination to take a step forward.' Each of us who personally experienced this generous support has an enduring appreciation for Roger's leadership."

Built Home for Leaders

"Roger built a home for colorful, creative leaders," says Coyle, who is presently Director, Operational Test and Evaluation in the Department of Defense. "It was a rainbow of talent that any institute would treasure." He adds, "Roger had the ability to support diverse programs and talents so each person felt like part of a whole." The accomplishments that Batzel nurtured, Coyle says, "thrive to this day."

Despite his crowded schedule and frequent trips to Washington, Batzel spent as much time as possible with his family—his wife Edwina and their three children, Stella Lynn, Roger Jr., and Stacy. The Batzels' recreational pursuits included horseback riding, swimming, skiing, vacations at the family home in Idaho—and, of course, square dancing.

Daughter Stella, who was born the day Batzel joined the Laboratory in 1953, recalls how her father always took her phone calls, even when he was meeting with important visitors. "I never felt like an inconvenience," she says. "The mark of a good manager is not how he treated the special people, but how he made everyone feel special."

For Director Bruce Tarter, "Roger left as his legacy a strong and diverse Lab, and he continued to provide advice and counsel during the past decade. He will be missed."

—Arnie Heller

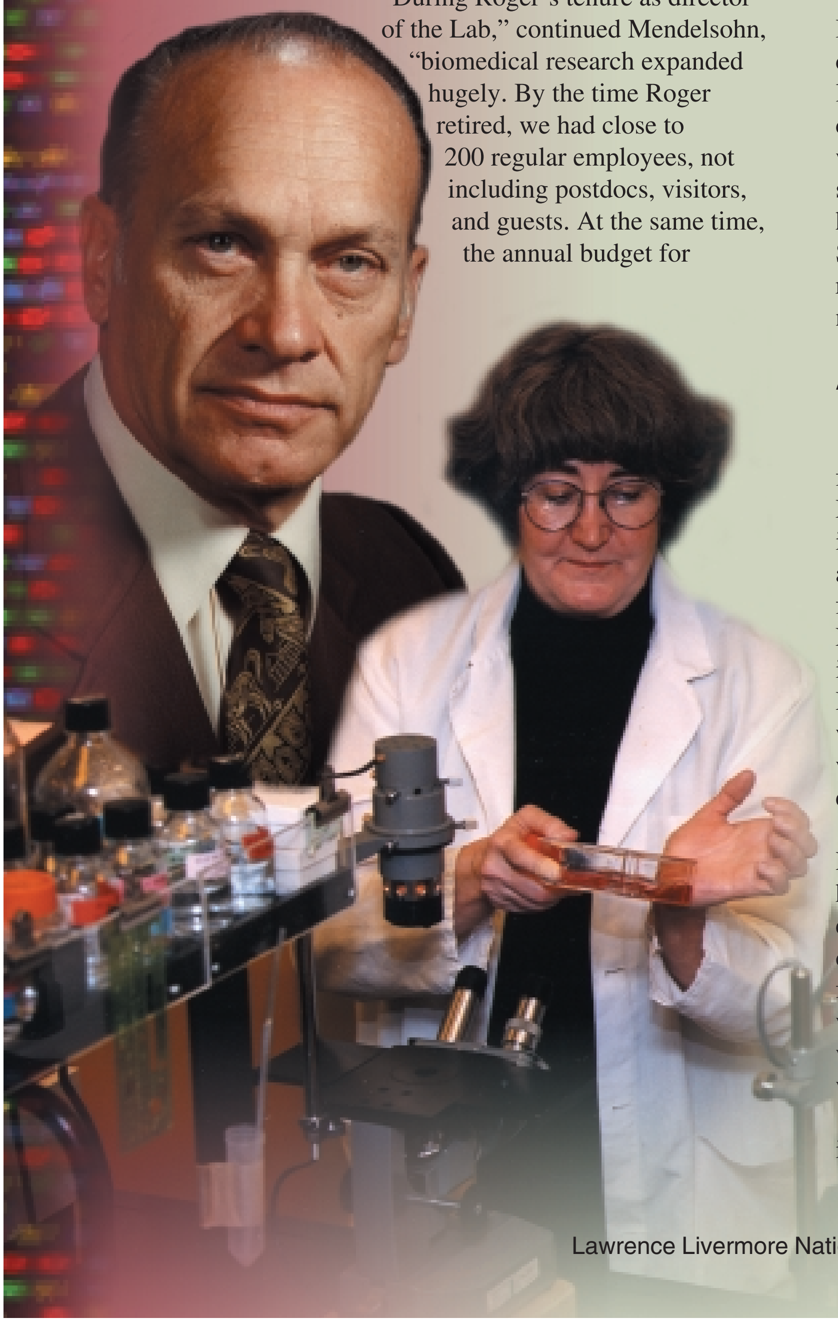
Key Words: Advanced Test Accelerator, Atmospheric Release and Advisory Capability, biodosimetry, biomedical research, Brilliant Pebbles, DOE Distinguished Associate Award, Flash X-Ray Facility, Laboratory Directed Research and Development program, Nova laser, postdoctoral program, Roger Batzel, Spartan antiballistic warhead.

For further information contact John Nuckolls, (925) 422-5435 (nuckolls2@llnl.gov).

From Dosimetry to Genomics

ROGER BATZEL was the strong, silent type, just what the doctor ordered back in the early 1970s when Livermore's biomedical research program began to grow substantially. According to Mort Mendelsohn, associate director for Biomedical and Environmental Research from 1972 to 1992, "Roger was always there with whatever resources I needed to advance the program. He didn't talk a lot, but he was supportive in every way possible. And that's what mattered.

"During Roger's tenure as director of the Lab," continued Mendelsohn, "biomedical research expanded hugely. By the time Roger retired, we had close to 200 regular employees, not including postdocs, visitors, and guests. At the same time, the annual budget for biomedical and environmental research increased from $3.2 million to almost $30 million. The range of our research broadened and diversified just as much while he was in charge."



Roger Batzel brought Mort Mendelsohn to Livermore from the University of Pennsylvania. Mendelsohn had visited Livermore around 1970 as part of a site visit team. He met Batzel at that time as well as John Gofman, who had founded the biomedical and environmental programs at Livermore in 1963. Both Gofman and Mendelsohn were M.D.–Ph.D.s doing research on carcinogenesis and on radiation and its effects on chromosomes. In 1971, even before Batzel became director of the Laboratory, Gofman decided to leave Livermore. He recommended Mendelsohn to Batzel as his replacement.

Mendelsohn chuckles remembering his early meetings with Batzel. "Roger was a weaponeer, a Westerner, always wearing cowboy boots. I was very much the Eastern academic with long hair and a strong antiwar position. But Roger was very convincing when he talked about what a great place Livermore was to work and what opportunities were available. He was a super-salesman, which might sound negative. But everything he said was absolutely true. I started at Livermore in September 1972. Here I am, almost 30 years later, semi-retired, with almost no hair left, but still at Livermore. I've never regretted a moment of it."

An Emphasis on Biodosimetry

Biological research at the national laboratories began in 1954 with studies to determine the biological consequences of fallout radiation from the Bravo test at Bikini Atoll, in which Marshall Islanders and Japanese fishermen were seriously irradiated. As the need grew for a bioenvironmental presence at the Nevada and Pacific test sites and in Project Plowshare for peaceful applications of nuclear weapons, the Atomic Energy Commission mounted a small program at Livermore in 1963. John Gofman, a professor of medical physics at the Donner Laboratory of the University of California at Berkeley, was recruited to set up the new program. His initial charge was to study the dose to humans of radioisotopes in the environment.

Not long after Mendelsohn took over the program, Project Plowshare was discontinued, in part because of the potential health concerns associated with peaceful use of nuclear explosives. Researchers at Livermore continued to study the dose to humans. But the program became oriented toward finding biological measurements that indicated the dose to which subjects had been exposed. Prominent in this effort was developing a set of biological dosimeters for humans and, with it, the study of human radiation biology and toxicology.

With Batzel's encouragement, Mendelsohn became involved in the Radiation Effects Research Foundation

(RERF) in Hiroshima and Nagasaki, Japan, the primary organization that keeps tabs on the health of A-bomb survivors. Livermore invented the glycophorin-A assay and transferred it to RERF. The assay detects residual mutations in human red blood cells from exposure to radiation from nuclear bomb explosions decades earlier. No other mutation assay, before or since, has been able to reach back so far in time. Livermore and RERF researchers found that, on average, the mutant cells increase linearly with radiation dose.

A second Livermore discovery in the mid-1980s greatly reinforced the use of chromosome aberrations as a dosimeter. It grew out of the human chromosome library project that Livermore and Los Alamos worked on jointly. With gene libraries for each human chromosome, researchers could paint chromosomes specifically. An otherwise obscure translocation (sharing of parts) between a painted and unpainted chromosome (or two chromosomes painted different colors) shows up as a two-color chromosome and can be viewed easily. Translocations could be identified 10 to 100 times faster than before, with greatly increased reliability. These chromosome aberrations also respond to radiation exposure and persist long enough to provide good dosimetry on A-bomb survivors.

And what of people who may be subjected to extremely small doses of radiation and have habits or participate in a lifestyle that may affect DNA? For example, nurses and x-ray technicians in hospitals or workers at nuclear reactors may receive regular miniscule doses. These people may also smoke or eat large quantities of red meat, both of which may affect DNA. In a 1992 interview, Mendelsohn expressed concern about whether biodosimetry methods would be able to sort out the results of such mixed exposures. This difficulty remains a problem. However, methods to attribute effects from chemical exposures are rapidly improving. With the use of accelerator mass spectrometry for biomedical research, scientists can now detect minute changes in human DNA (see *S&TR*, July/August 2000, pp. 12–19).

Beginnings of Biotechnology

The first successful molecular biotechnology project at Livermore took place in the late 1970s with the production of made-to-order monoclonal antibodies. (Antibodies are nature's defender molecules, and monoclonal means that they are produced by a single clone.) A scientist can select for and form single clones or copies of immunologically active cells. Such cells make only one antibody, and when isolated, they can be produced infinitely with complete purity and remarkable specificity. Two of Livermore's products are the monoclonal antibodies that recognize the subtle distinction

The foresight of Laboratory management in the 1970s and 1980s led to Livermore's major contributions to the Human Genome Project. Shown here is a scientist completing an early step in the gene sequencing process at the Joint Genome Institute in Walnut Creek, California, a collaboration of Livermore, Berkeley, and Los Alamos national laboratories.

Roger Batzel (center) with Dixie Lee Ray (left), head of the Atomic Energy Commission, and Mort Mendelsohn in 1973.

between normal and mutant red blood cells in the glycophorin-A assay. Other Livermore monoclonal antibodies can indicate whether a blood stain is human or whether a child has sickle cell anemia. Still others are useful for making the individual proteins involved in the complex process of repairing DNA.

Perhaps the most important antibodies to come out of this work were those to bromodeoxyuridine in DNA, a substance that can substitute for a normal building block of DNA. A small amount injected into a subject or in a culture will be synthesized into the DNA of any cells that are dividing. When this monoclonal antibody is coupled to a fluorescent marker, all the cells in division become fluorescent and can be seen under a microscope or detected and measured in a flow cytometer. A Livermore team used this technique and Livermore's work in cell kinetics to develop methods that revolutionized the study of cell growth and that today are standard procedure worldwide. Cancer patients are routinely evaluated by these methods to see how fast their cancer cells are dividing.

Birth of the Human Genome Project

Says Mendelsohn, "My arrival at Livermore with new people, new equipment, and a new orientation coincided with a Laboratory-wide cutback. That was a difficult time at Livermore. But Roger was committed to the whole process and made my transition happen as smoothly as possible."

One of the new people was Marv Van Dilla, a leading expert in flow cytometry, a technique for measuring and separating cells. From that beginning grew Livermore's expertise in flow cytometry, which exploited the Laboratory's knowledge of lasers and engineering as well as the biological sciences. Two years later, in 1974, Livermore scientists for the first time performed an experiment that successfully measured and sorted Chinese hamster chromosomes using flow cytometry. Not until 1979 did scientists learn how to do the same with human chromosomes, which are much smaller and more varied. By 1984, says Mendelsohn, "We had increased our proficiency and confidence in the method such that we could separately identify and study each of the human chromosomes. This ability, combined with worldwide developments in recombinant DNA technology, led to the Livermore–Los Alamos project to build human chromosome-specific DNA libraries."

At about the same time, in 1984, Mendelsohn organized a meeting of molecular geneticists from around the world to brainstorm the potential for DNA-oriented methods to detect human heritable mutation in A-bomb survivors. It became clear to those at the meeting that despite the enormous scale of this effort, analysis of the entire human genome was feasible. In 1986, the Department of Energy was the first federal agency to launch a major initiative to completely decipher the human genetic code. A year later, Livermore researchers began to study all of chromosome 19, which they had earlier learned was the home of several genes important for DNA repair. In 1990, two years after Batzel retired, the Department of Energy joined forces with the National Institutes of Health

Early ground-breaking Livermore work in flow cytometry, a technique for separating specific cells from other cells that has come to have numerous medical research applications. Some biosensors to detect the specific agents used in biological weapons are based on flow cytometry.

to kick off the Human Genome Project, the largest biological research project ever.

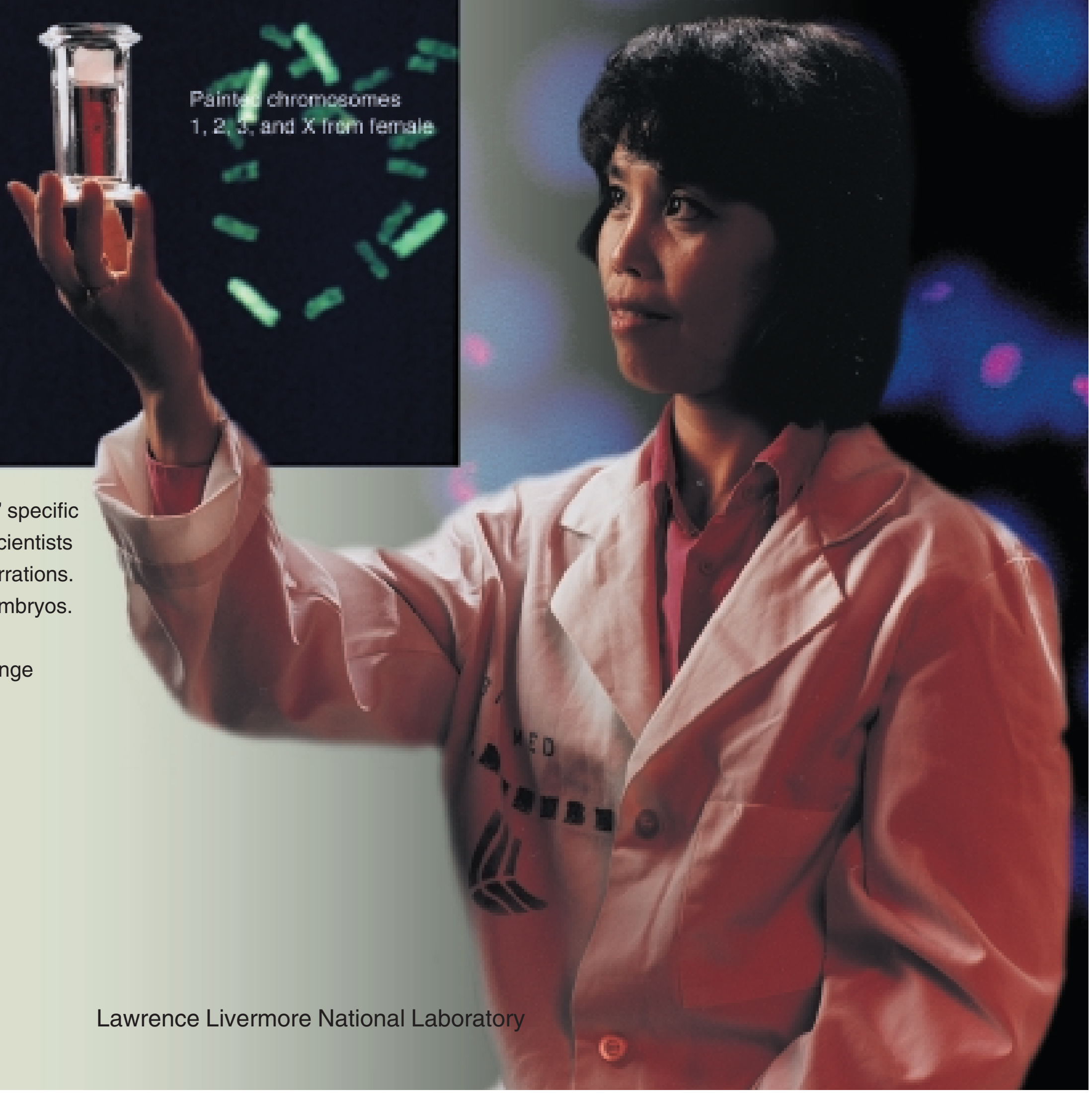
Free Rein for Creativity

It is easy to wonder where Livermore's biomedical research program would be today if Roger Batzel had not been director during those formative years. Mendelsohn says, "When Roger chose people, he then gave them their own reins. Roger was a textbook example of a primary principle of Tom Peters: to never let management interfere with creativity."

—Katie Walter

Key Words: biotechnology, chromosome libraries, chromosome painting, dosimetry, flow cytometry, Human Genome Project, Roger Batzel.

For further information contact Mort Mendelsohn (925) 422-5765 (mendelsohn2@llnl.gov).



Livermore developed a way to "paint" specific chromosomes. With this technique, scientists can quickly identify chromosome aberrations. This photo is of one-day-old mouse embryos. The bright green chromosomes are chromosomes 1, 2, 3, and X. The orange one is chromosome Y.

Swords into Plowshares and Beyond

LOOKING back 25 years at the nation's energy situation and comparing it to today's, one might be tempted to mutter, "*Déjà vu*." In the mid-1970s, the nation was in the middle of an energy crisis: oil shortages, long lines at the gas pumps, uncertainties over our energy future. Today, gasoline prices in some areas of the country are frequently over two dollars a gallon, rolling "brown-outs" are all too frequent during a hot California summer, and energy prices are rising as the deregulation of California power companies begins.

In the seventies, the first decade of Roger Batzel's nearly two-decade term as director of Lawrence Livermore, finding ways to enhance the nation's energy supply was a national priority. The year Batzel became director, Congress amended the charter of one of the Department of Energy's predecessors, the Atomic Energy Commission (AEC), to support nonnuclear energy research.

Bob Schock, who spent much of the 1970s, 1980s, and 1990s managing one aspect or another of the Laboratory's energy efforts and is now with the Center for Global Security Research, recalls: "In the 1970s, the Lab was already in the energy business through Project Plowshare, which was exploring the peaceful uses of nuclear explosions. When the energy crisis hit in 1972 and 1973, Lawrence Livermore and Oak Ridge were the two leading AEC national laboratories in energy-related research."

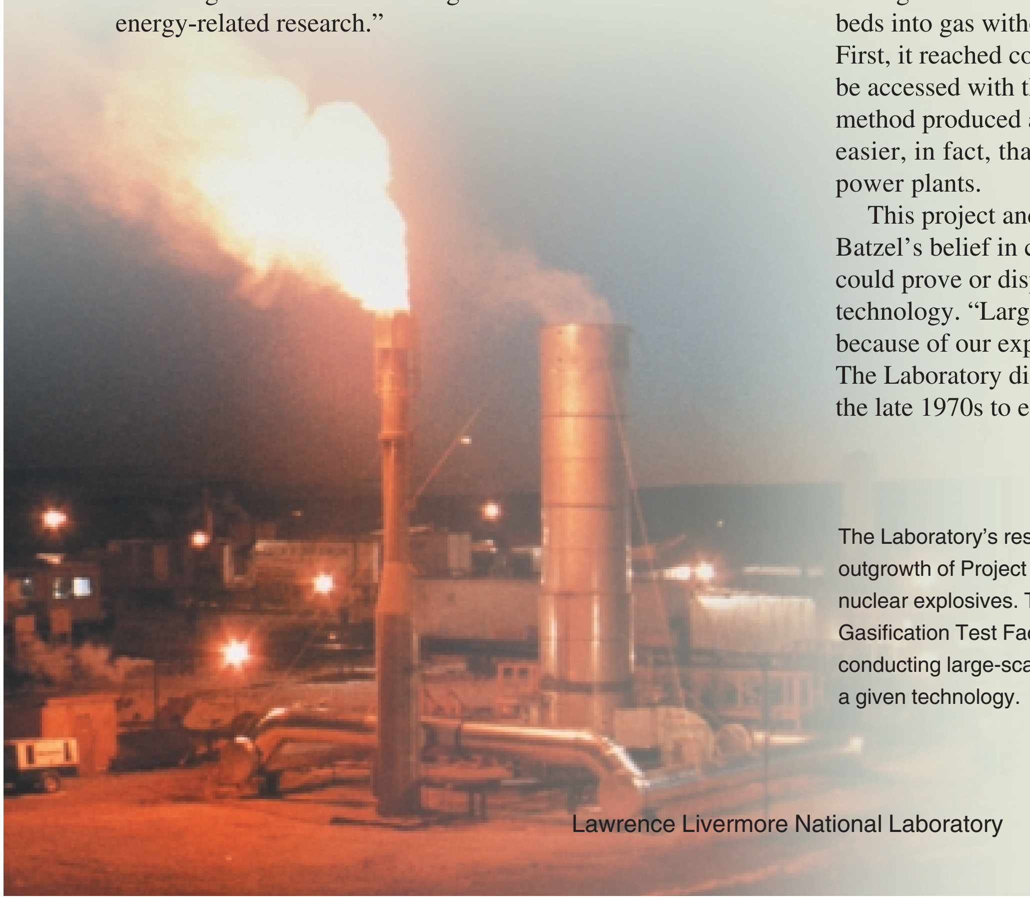
Along with Plowshare, two other large-scale energy-related efforts at the Laboratory that predated the energy crisis were laser fusion and magnetic fusion. In the 1970s, the Laboratory also became active in researching how to safely dispose of radioactive waste from nuclear power plants—an activity that continues to this day. Finally, with the country's attention turned toward alternate energy supplies, Lawrence Livermore's scientists and engineers researched energy sources such as coal, oil shale, geothermal energy, solar power, electric roadways, and advanced batteries.

The Plowshare Energy Legacy

In 1957, the AEC officially established Project Plowshare to explore the use of nuclear explosives for peaceful purposes. "Plowshare had two parts," explains Schock. "There was a civil engineering component—using nuclear explosives to make canals, dams, and such—and an energy component—using nuclear explosives to stimulate natural gas reservoirs, process underground oil shale into oil, and so on." Even though Plowshare was terminated in 1977, its legacy lived on into the 1990s through energy projects in these areas and others.

From 1974 through 1988, the Laboratory developed an underground coal gasification process that converted coal beds into gas without mining. This method had two benefits. First, it reached coal that, for economic reasons, could not be accessed with the usual mining techniques. Second, the method produced a combustible gas that was easy to clean—easier, in fact, than the stack gas produced by coal-fired power plants.

This project and others, Schock notes, benefited from Batzel's belief in conducting large-scale demonstrations that could prove or disprove the commercial viability of a given technology. "Large-scale demonstrations were the Lab's forte because of our experience in nuclear testing," adds Schock. The Laboratory did some large experiments in Wyoming in the late 1970s to early 1980s to gasify coal seams in-place.



The Laboratory's research into underground coal gasification was an outgrowth of Project Plowshare, which explored the peaceful uses of nuclear explosives. The Rocky Mountain Underground Coal Gasification Test Facility in Wyoming reflected Roger Batzel's belief in conducting large-scale demonstrations to test the economic viability of a given technology.

"We started by using high explosives—we'd forgone nuclear explosives by then—and then came up with a technique that gasified the coal without explosives. It uses the natural fractures in coal and controls the burn zone through a movable oxygen injector.

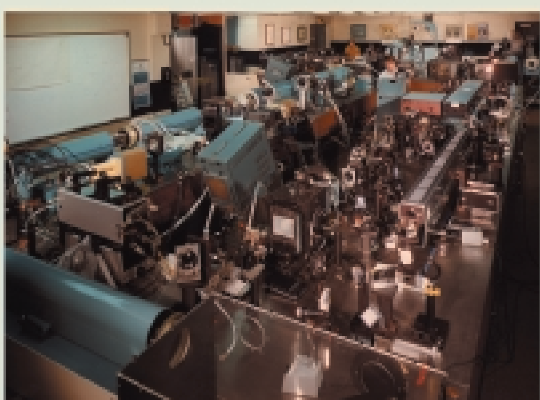
"In situ coal gasification is still a good idea," says Schock. "If the technology is ever implemented, it could double or triple the accessible U.S. coal reserves and has the advantage that the carbon dioxide produced by the process can be separated out and captured."

In another Plowshare offshoot, the Laboratory investigated the feasibility of using nuclear explosives—and later, high explosives—to fracture oil shale. As Schock explains it, one can convert oil shale to oil by subjecting it to high temperatures and high pressures—in other words, by speeding up the geologic clock. Laboratory researchers envisioned using explosives to fracture the vast oil-shale reserves in the western U.S. so that the oil could be processed in place, which would provide an important alternative to imported oil. This effort evolved in the early 1980s into a surface oil-shale retorting process that used hot oil-shale particles as the heat carrier. It also produced a model of how oil is formed that is today used for exploration by every major oil company in the world.

Lasers and Energy

Part of what drove the Laboratory's early research into lasers was the prospect of creating fusion energy as a virtually

(a)



(b)

(c)

A series of large laser systems developed during Batzel's term as director helped researchers gain understanding of the inertial confinement fusion process, in which small targets containing deuterium–tritium fuel are compressed using the energy of a laser beam. (a) The two-beam Janus laser (1975) was used to demonstrate laser implosion and thermonuclear burn of primitive targets. (b) The two-beam Argus (1976) increased understanding of laser–target interactions and helped researchers develop technologies for the next generation of systems. (c) The one-beam Cyclops (1975) demonstrated radiation implosion targets and tested optical designs for the Shiva laser. The 20-beam Shiva (1977), shown in the background above, was the most powerful laser at that time, delivering more than 10 kilojoules of energy in less that a billionth of a second in its first full-power firing. Thermonuclear fuel was imploded to 100 times liquid density in Shiva experiments.

inexhaustible, low-cost, safe, and environmentally attractive energy source. Laboratory researchers envisioned doing this through inertial confinement fusion (ICF), in which small targets of fuel are imploded by laser beams until the fuel reaches temperatures that induce fusion. Beginning in 1972, the Laboratory pursued this vision in a series of increasingly powerful laser systems—each five to ten times more powerful than its predecessor. Janus (completed in 1975), Shiva (1977), and Nova (1984) gave laser researchers the tools to expand scientific understanding and to take the nation a step closer to achieving the fusion process. The latest of these systems—the National Ignition Facility—will be an important component of the Department of Energy's Stockpile Stewardship Program (see related article on pp. 18–20), and will, in addition, provide the most powerful system yet for exploring the ICF energy conversion process.

Another energy-related laser effort that continued into the 1990s was the Laboratory's development and refinement of laser isotope separation (LIS) technology. Atomic vapor laser isotope separation (AVLIS) was first developed to separate uranium-235, needed to fuel fission reactors, from the common isotope uranium-238. LIS began in 1973, culminating in enrichment demonstrations in 1980. The technology was then expanded to a large-scale experiment by 1985. The success of these demonstrations led DOE to select U-AVLIS over other enrichment technologies for commercial development. Although the AVLIS program was scaled back in the late 1990s, the LIS process may find other important applications in medicine, astronomy, energy, and industry. (See *S&TR*, May 2000, pp. 13–21.)

Magnetic Fusion Energy

Another early energy effort was research on magnetic fusion energy. This research had been part of the Laboratory since its founding in 1952 and grew under Batzel's directorship. In the magnetic confinement concept, the fuel is trapped in a magnetic force field long enough to achieve fusion. These systems use large electric currents traveling through huge magnet coils to produce the immensely strong magnetic fields needed. The Laboratory experimented with confining the fuel with giant magnets in experiments such as Levitron, Baseball I and II, TMX (Tandem Mirror Experiment), 2XIIB, and MFTF (Mirror Fusion Test Facility), culminating in the MFTF-B, initiated in 1981. The magnet system for MFTF-B was the largest superconducting system ever built. Shortly after the system was completed in 1986, DOE, faced with budget reductions, decided to focus its magnetic fusion energies on a different technology—the tokamak. The Laboratory then became a contributor to the International Thermonuclear Experimental Reactor (ITER) project to design and build the world's first full-scale magnetic fusion reactor.

More recently, Livermore fusion energy scientists are revisiting the spheromak concept. A tokamak's magnetic fields are generated by large, external magnetic coils surrounding a doughnut-shaped reactor, with other magnets in the hole in the donut. A spheromak, as Schock explains, "takes the hole out of the doughnut." In the spheromak configuration,

During Batzel's tenure as director, the Laboratory explored a number of energy options, including capturing energy from solar ponds. Researchers determined that adding a 1.8-meter reflector panel to this shallow solar pond test module increased its efficiency by about 25 percent annually.

the plasma fuel produces some of its own confining magnetic fields, requiring only an external set of coils and making for a much more compact machine capable of producing a higher-temperature and higher-density plasma. (See *S&TR*, December 1999, pp. 18–20.)

Closing the Fuel Cycle

With nuclear fission still an important source of electric power in the United States and throughout the world, a way must be found to satisfactorily close the fuel cycle—that is, a method for safely disposing of the radioactive waste produced by nuclear power plants. Beginning in 1977, the Laboratory participated in studies of a candidate site for a U.S. high-level waste repository that culminated in the choice of the Yucca Mountain site in Nevada.

In 1987, Congress directed DOE to study the Yucca Mountain site for its feasibility as a permanent repository for high-level nuclear waste. The Laboratory was responsible for designing the waste package and barrier system for the proposed repository. As part of this responsibility, Laboratory scientists designed a computer code that would run on the world's most powerful computers and show how buried nuclear wastes would affect the Yucca Mountain geology. (See *S&TR*, March 2000, pp. 13–20.)

From 1980 to 1984, Livermore scientists and engineers also designed, built, and operated the only experiment to retrievably store commercial spent-fuel underground at the Climax Mine in Nevada. At the time, Climax was the first place in the world where high-level radioactive waste from fission reactors was stored underground for any length of time. The successful demonstration of this concept paved the way for future repositories.

One of the magnets for the Mirror Fusion Test Facility-B, the Laboratory's most ambitious magnetic mirror fusion experiment. Two pairs of these enormous magnets were needed to confine the fusion fuel plasma. Cutbacks in energy and environmental work in the 1980s caused this test facility to be mothballed shortly after its completion in 1986. However, Livermore stayed involved in magnetic fusion energy research through the International Thermonuclear Experimental Reactor and, more recently, the spheromak.

A Plethora of Smaller Projects

Although the Laboratory had many large demonstration projects during the 1970s and 1980s, smaller energy projects also flourished. For instance, the Laboratory explored the feasibility of using shallow ponds to store solar energy to produce domestic heat and run chemical processes. And on their own, several engineers rigged up a surrey—basically a golf cart—with solar panels to test the feasibility of using solar energy in transportation.

Battery research, starting with aluminum–air batteries, was also a consequence of the Laboratory's emergence in the 1970s as a powerhouse in DOE energy research. The current incarnation of the battery research is the refuelable zinc–air fuel cell, an alternative to the standard lead–acid batteries now powering most cars and other vehicles. The fuel cell promises trouble-free, nearly 24-hour-a-day operation for numerous kinds of electric vehicles, from forklifts to delivery vans and possibly personal automobiles.

Batzel Stood Back, Let Ideas Blossom

Batzel was well known for standing back and letting people follow their inclinations. But, as Schock is quick to point out, that didn't mean he was not aware of what was going on within the programs. "When you had a review, it was quickly apparent that he was technically on top of his game. He didn't wait for you to tell him about the technical aspects. He *knew*. He understood the details, but didn't try to run the programs, instead focusing on the big picture. He developed a tremendous number of leaders at the Laboratory. He did it with a hands-off style and didn't try to micromanage. It was a time when people, programs, and ideas blossomed, in energy research as well as throughout the Laboratory."

—Ann Parker

Key Words: battery research, Climax Mine, coal gasification, energy program, fuel cell research, International Thermonuclear Experimental Reactor (ITER), laser fusion energy, magnetic fusion energy, Mirror Fusion Test Facility-B (MFTF-B), National Ignition Facility (NIF), oil-shale retort, Project Plowshare, Roger Batzel, solar surrey, spheromak, uranium atomic vapor laser isotope separation (U-AVLIS), Yucca Mountain.

For further information contact Bob Schock, (925) 422-6199 (schock1@llnl.gov).

Adapting to a Changing Weapons Program

THE successful Spartan antiballistic missile test at Amchitka in the Aleutian Islands got Roger Batzel's tenure as director started with a bang. The test also produced a story that epitomizes his supportive, hands-off managerial style. Phil Coyle, who was later deputy director of the Laboratory, was in charge of the test and asked Batzel if he should send in daily or weekly reports while preparations for the test were under way. Batzel replied that they wouldn't be necessary. "How about monthly reports?" asked Coyle, unable to believe what he was hearing. "No," Roger replied. "You don't need to submit any reports. Just know that we want you to succeed, and we are here to help."

The large nuclear buildup of the late 1960s was over by the time Batzel started as director. The Vietnam War ended not long after, and the entire nuclear weapons complex was soon caught in a budgetary squeeze. Emphasis was on small, tactical warheads with less collateral damage, enhancing the safety of nuclear weapons and continuing the development of strategic deterrent forces. Considerable progress was also made in conventional weapons, including a new conventional hard-structure munition specifically designed to destroy or seriously damage massive reinforced concrete structures such as bridge piers and underground control centers.

Says George Miller, who came to Livermore in 1972 and is now associate director for National Ignition Facility Programs, "Despite the reduction in the weapons budget, the 1970s were a remarkably active period."

In the last years of President Carter's administration our nation's leaders realized that DOE nuclear weapons capabilities had not been adequately maintained, that they needed to be revitalized if the U.S. was going to stay ahead in the arms race. Work started on several new warheads, including the W87 strategic warhead for the Peacekeeper intercontinental ballistic missile, the W84 tactical warhead for the ground-launched cruise missile, and the B83, a modern strategic bomb. These weapons incorporated innovative safety systems, including the new, less sensitive high explosive that is virtually impossible to detonate inadvertently; enhanced electrical nuclear detonation safety; and features to make the weapons safe in the event of fire.

In March 1983, President Reagan unveiled a new vision of national security based on protecting lives rather than threatening them. This announcement kicked off the Strategic Defense Initiative—popularly known as Star Wars—that invigorated weapons work at Livermore during the last years of Batzel's directorship. The Strategic Defense Initiative (SDI) included so-called third-generation, or nuclear directed-energy, weapons. While the long-term goal for SDI was an effective nonnuclear defense, research also continued on promising new nuclear explosive concepts. Design teams began studies of the nuclear-powered x-ray laser as a candidate defense technology and explored the physics of such weapons in underground nuclear tests. In addition, particle beams, the free-electron laser, and other nonnuclear directed-energy weapon concepts were studied on a laboratory scale.

"The crowning achievement of the Strategic Defense Initiative was Brilliant Pebbles," says John Nuckolls, who followed Batzel as Laboratory director. Brilliant Pebbles were to be small, lightweight spacecraft that could stop advanced ballistic missiles and their components in boost phase by colliding with them at high speeds. On command, a global constellation of these nonnuclear spacecraft could detect and destroy missiles without any external help.

Work at the Laboratory on SDI continued into the early 1990s before being discontinued after the end of the Cold War. Technologies developed for SDI were used in numerous later projects. As an example, sensors and cameras developed for Brilliant Pebbles became components of the Clementine moon-mapping project. SDI technologies may also have a role in 21st century missile defense.

Laser Fusion to Study Weapons

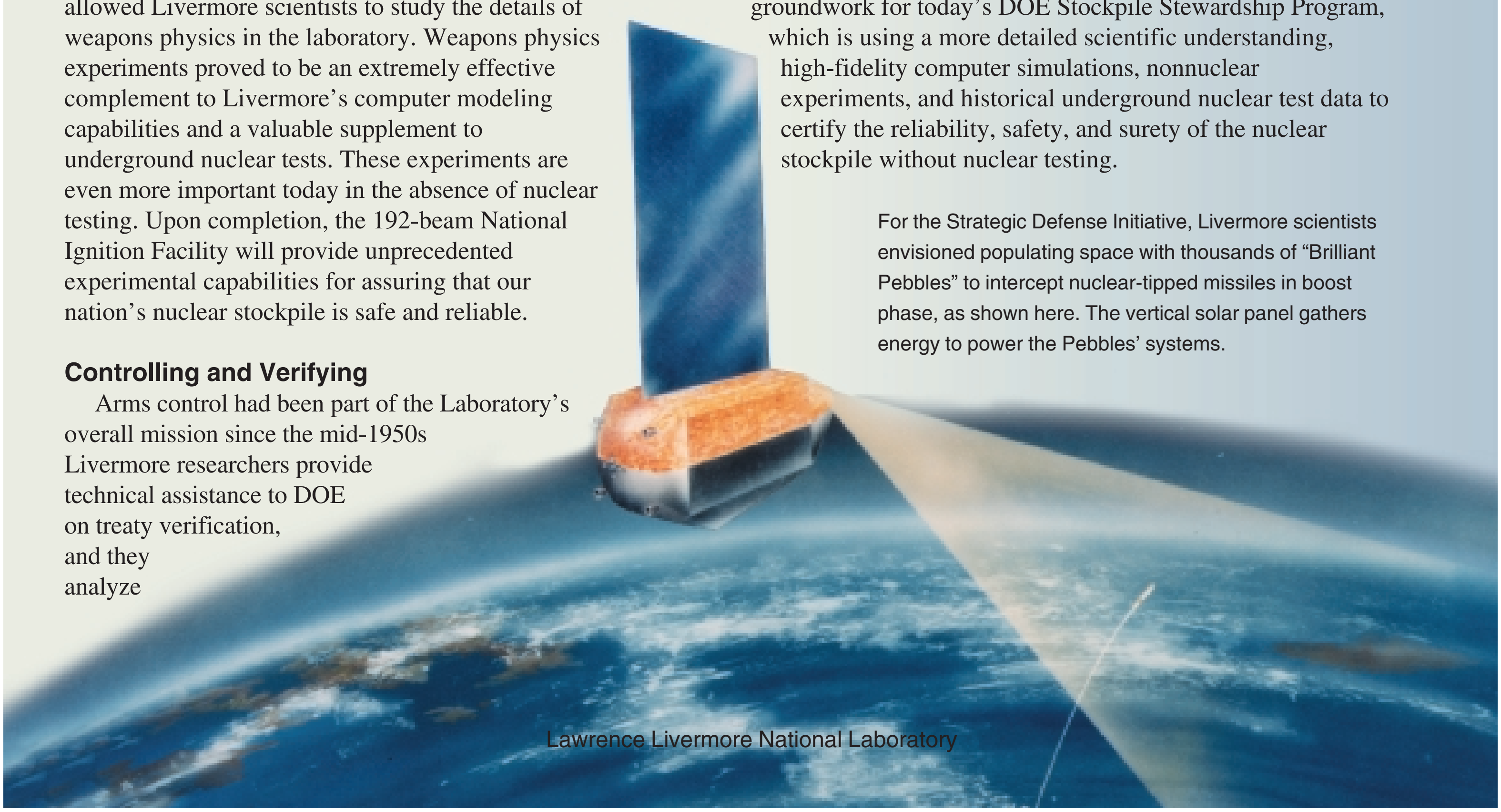
With Batzel's encouragement, the Inertial Confinement Fusion program was formed in 1972 to demonstrate laser fusion in the laboratory and to develop laser science and technology for both defense and civilian applications. First, the Shiva laser and, later, the more powerful Nova laser allowed Livermore scientists to study the details of weapons physics in the laboratory. Weapons physics experiments proved to be an extremely effective complement to Livermore's computer modeling capabilities and a valuable supplement to underground nuclear tests. These experiments are even more important today in the absence of nuclear testing. Upon completion, the 192-beam National Ignition Facility will provide unprecedented experimental capabilities for assuring that our nation's nuclear stockpile is safe and reliable.

Controlling and Verifying

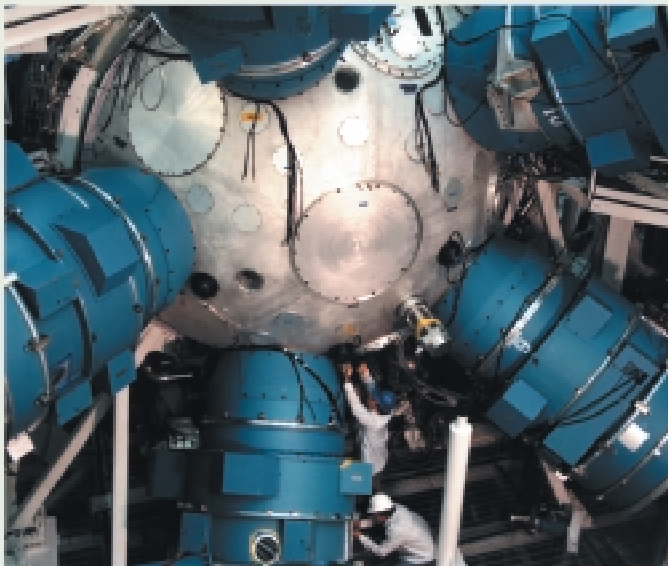
Arms control had been part of the Laboratory's overall mission since the mid-1950s Livermore researchers provide technical assistance to DOE on treaty verification, and they analyze the effects of test-ban and arms control measures on the weapons program and on the nation's nuclear deterrent. While Batzel was Laboratory director, Livermore assisted with continued negotiations between the U.S. and the Soviet Union on a test ban and on a number of arms limitation and reduction agreements.

By 1971, the weapons community knew that a threshold test ban was imminent. The Threshold Test Ban Treaty (TTBT) was signed in 1974 by President Nixon and Secretary Leonid Brezhnev, although it was not ratified by the U.S. Congress until 1990. It prohibited testing of any nuclear weapon whose yield exceeded 150 kilotons. (For comparison, the bomb dropped on Hiroshima had a yield of 15 kilotons.) Between 1971 and 1974, Livermore pursued an accelerated design and test program for weapons exceeding 150 kilotons to gain as much information as possible about those weapons before the treaty went into effect. The delay in ratification of the TTBT resulted in large part from evolving concerns that the treaty was not accurately verifiable.

In the fall of 1977, under President Carter, negotiations resumed after a hiatus of many years on a Comprehensive Test Ban Treaty (CTBT). With the possibility that all nuclear testing might end, Livermore weapon scientists began the research needed to more fully understand the physics of a weapon. Until then, weapon development was based largely on past experience and on improvements that were successful during testing. "In the 1970s, the technical approach to simulating nuclear weapons used many simplifying assumptions because of the limited capability of available computers," says Miller. Research started at this time laid the groundwork for today's DOE Stockpile Stewardship Program, which is using a more detailed scientific understanding, high-fidelity computer simulations, nonnuclear experiments, and historical underground nuclear test data to certify the reliability, safety, and surety of the nuclear stockpile without nuclear testing.



For the Strategic Defense Initiative, Livermore scientists envisioned populating space with thousands of "Brilliant Pebbles" to intercept nuclear-tipped missiles in boost phase, as shown here. The vertical solar panel gathers energy to power the Pebbles' systems.



The target chamber for the Nova laser, which came on line in December 1984. Until Nova was dismantled in May 1999 in preparation for the National Ignition Facility, it was the most powerful laser in the world.

During these CTBT negotiations, President Carter met with Harold Brown, Secretary of Defense; James Schlesinger, Secretary of Energy; Harold Agnew, Director of Los Alamos National Laboratory; and Lawrence Livermore Director Roger Batzel to discuss the ramifications of a ban on nuclear testing. Michael May, who preceded Batzel as director, says, "Lab directors have to tell unpopular truths. Roger always had the respect of people in Washington. His judgment could always be trusted." No doubt those traits stood him in good stead in this important meeting with President Carter.

Batzel and Agnew explained to the president the need for nuclear testing. Because the weapons laboratories did not yet have a detailed knowledge of the workings of a nuclear warhead, eliminating testing could threaten the U.S. nuclear deterrent. Also, the details of a test ban had not been worked out, particularly with respect to what yield-monitoring threshold the U.S. government could accept.

Since the beginnings of test-ban discussions in the 1950s, scientists had been developing ways to verify that other countries were complying with treaty requirements. Remote seismic monitoring methods were the primary verification tool for years for both a CTBT and the TTBT, but they had limitations. Local geology affects how monitoring systems determine the magnitude of a seismic event and thus the apparent yield of a weapon. While the Nevada Test Site was seismically well calibrated, U.S. scientists had little comparable data on the sites where the Soviets tested their weapons. For a CTBT, the challenge was one of detecting very low-level seismic signals that could be hidden and identifying them as nuclear explosions rather than earthquakes or other events. For a TTBT, the challenge was to deduce the explosive yields from the measured seismic magnitudes, a process generally acknowledged to have a factor of two uncertainty. For example, if the seismic measurements indicate a yield of 150 kilotons, the actual yield could be 300 or 75 kilotons.

Under Batzel, Lawrence Livermore scientists conducted analyses that showed, contrary to the judgment of some policy makers, that within the accuracy of the seismic yield estimates, the Soviets were not violating the terms of the TTBT. The Soviets were observing a yield limit, and that limit was consistent with the 150-kiloton limit of the TTBT. However, a factor of two uncertainty was not good enough for the Administration to press for Senate ratification of the TTBT.

During the latter years of Batzel's directorship, Livermore and Los Alamos scientists helped the U.S. government negotiate new protocols with the Russians based on the hydrodynamic method for measuring the yield of a weapon test. The TTBT was ratified with the improved protocols in 1990.

A Time of Change

Says Duane Sewell, who served as deputy Laboratory director for several years under Batzel, "Roger believed deeply in building up the strength of the United States." Most important to Batzel was bolstering national security.

By the end of Batzel's directorship (1988), Livermore and its sister laboratory at Los Alamos had been instrumental in developing a stockpile in which both the number of weapons and the total yield in the stockpile had been reduced dramatically from the numbers of the late 1960s. Improvements in the design and accuracy of weapons had had their effect. By 1988, the number of U.S. weapons was at its lowest point since the late 1960s, and the megatonnage had been reduced by approximately 75 percent since 1960.

Times change, the world changes, and certainly the Laboratory changed, growing and maturing, under Roger Batzel's capable leadership. And as it did during the era of Roger Batzel's remarkable leadership, the Laboratory must continue to evolve to help meet major new challenges, particularly in its primary national security mission.

—Katie Walter

Key Words: arms control, Brilliant Pebbles, inertial confinement fusion (ICF), Roger Batzel, Strategic Defense Initiative, tactical nuclear weapons, treaty verification.

For further information contact George Miller (925) 423-6806 (miller21@llnl.gov).

Each month in this space we report on the patents issued to and/or the awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory.

Patents

Patent issued to	Patent title, number, and date of issue	Summary of disclosure
Alexander R. Mitchell Phillip F. Pagoria Robert D. Schmidt	**Amination of Electrophilic Aromatic Compounds by Vicarious Nucleophilic Substitution** U.S. Patent 6,069,277 May 30, 2000	A process to aminate electrophilic aromatic compounds by vicarious nucleophilic substitution of hydrogen using quaternary hydrazinium salts. The use of trialkylhydrazinium halide, trimethylhydrazinium iodide, hydroxylamine, alkoxylamines, and 4-amino-1,2,4-triazole to produce aminated aromatic structures such as 1,3-diamino-2,4,5-trinitrobenzene (DATB), 1,3,5-triamino-2,4,6-trinitrobenzene (TATB), and 3,5-diamino-2,4,6-trinitrotoluene (DATNT) is described. DATB and TATB are useful insensitive high explosives. TATB is also used for the preparation of benzenehexamine, a starting material for the synthesis of novel materials (optical imaging devices, liquid crystals, ferromagnetic compounds).
Alexander R. Mitchell Phillip F. Pagoria Robert D. Schmidt	**Method for Isolating Chromosomal DNA in Preparation for Hybridization in Suspension** U.S. Patent 6,077,671 June 20, 2000	A method is provided for detecting nucleic acid sequence aberrations using two immobilization steps. A nucleic acid sequence aberration is present when one acid sequence has both a first nucleic acid sequence type (for example, from a first chromosome) and a second nucleic acid sequence type (for example, from a second chromosome). In the method, immobilization of a first hybridization probe is used to isolate a first set of nucleic acids from a sample of the first nucleic acid sequence type. Immobilization of a second hybridization probe is then used to detect and isolate a second set of nucleic acids from within the first set. The presence of the second set of nucleic acids indicates the presence of a nucleic acid sequence aberration. Chromosomal DNA in a sample containing cell debris is prepared for hybridization in suspension by treating the mixture with RNase. The treated DNA can also be fixed prior to hybridization.
Joe N. Lucas	**Immersion Echelle Spectrograph** U.S. Patent 6,078,048 June 20, 2000	A small spectrograph containing no moving components and capable of providing high-resolution spectra of the mid-infrared region from 2 to 4 micrometers in wavelength. The resolving power of the spectrograph exceeds 20,000 throughout this region and at an optical throughput of about 0.00005 square centimeters per steradian. The spectrograph incorporates a silicon immersion echelle grating operating in high spectral order combined with a first-order transmission grating in a cross-dispersing configuration to provide a two-dimensional spectral format that is focused onto a two-dimensional infrared detector array. The spectrometer incorporates a common collimating and condensing lens assembly in a nearly aberration-free axially symmetric design. The spectrometer has potential uses in general research as well as in areas such as monitoring atmospheric constituents for air quality, climate change and global warming research, and monitoring exhaust fumes for smog sources or exhaust plumes for evidence of illicit drug manufacture.
Charles G. Stevens Norman L. Thomas	**Vacuum-Compatible Miniature CCD Camera Head** U.S. Patent 6,078,359 June 20, 2000	A charge-coupled device (CCD) camera head that can replace film for digital imaging of visible light, ultraviolet radiation, and soft-to-penetrating x rays, such as within a target chamber where laser-produced plasmas are studied. The camera head is small, is capable of operating both in and out of a vacuum environment, and is versatile. The CCD camera head uses PC boards with an internal heat sink connected to the chassis for heat dissipation, allowing for close (0.22 centimeters, for example) stacking of the PC boards. Integration of this CCD camera head into existing instrumentation provides a substantial enhancement of diagnostic capabilities for studying high-energy-density plasmas in a variety of military, industrial, and medical imaging applications.

Patent issued to	Patent title, number, and date of issue	Summary of disclosure
Alan D. Conder	**Durable Silver Coating for Mirrors** U.S. Patent 6,079,425 June 20, 2000	A durable multilayer mirror that includes reflective layers of aluminum and silver and has high reflectance over a broad spectral range, from ultraviolet to visible to infrared. An adhesion layer of a nickel and/or chromium alloy or nitride is deposited on an aluminum surface, and a thin layer of silver is then deposited on the adhesion layer. The silver layer is protected by a passivation layer of a nickel and/or chromium alloy or nitride and by one or more durability layers made of metal oxides and typically a first layer of metal nitride. The durability layers may include a composite silicon aluminum nitride and an oxinitride transition layer to improve bonding between nitride and oxide layers.
Vincent Malba Anthony E. Bernhardt	**3-D Laser Patterning Process Utilizing Horizontal and Vertical Patterning** U.S. Patent 6,114,097 September 5, 2000	A process that vastly improves the three-dimensional patterning capability of laser pantography (computer-controlled laser direct-write patterning). The process uses commercially available electrodeposited photoresist (EDPR) to pattern three-dimensional surfaces. The EDPR covers the surface of a metal layer conformally, coating the vertical as well as horizontal surfaces. A laser pantograph then patterns the EDPR, which is subsequently developed in a standard, commercially available developer, leaving patterned trench areas in the EDPR. The metal layer ;under the EDPR is thereby exposed in the trench areas and masked in others; thereafter, it can be etched to form the desired pattern (subtractive process), or it can be plated with metal (additive process), followed by a resist stripping and removal of the remaining field metal (additive process). This improved laser pantograph process is simpler, faster, and more manufacturable, and it requires no micromachining.
David J. Erskine	**Single and Double Superimposing Interferometer Systems** U.S. Patent 6,115,121 September 5, 2000	Interferometers that can imprint a coherent delay on a broadband uncollimated beam are described. The delay value can be independent of incident ray angle, allowing interferometry using uncollimated beams from common extended sources such as lamps and fiber bundles and facilitating Fourier transform spectroscopy of wide-angle sources. Pairs of such interferometers matched in delay and dispersion can measure velocity and communicate using ordinary lamps, wide-diameter optical fibers, and arbitrary nonimaging paths, without requiring a laser.
Charles S. Vann	**Multidimensional Position Sensor Using Range Detectors** U.S. Patent 6,115,128 September 5, 2000	A small, noncontact optical sensor uses ranges and images to detect its relative position to an object in up to six degrees of freedom. The sensor has three light-emitting range detectors that illuminate a target and can be used to determine distance and two tilt angles. A camera located between the three range detectors senses the three remaining degrees of freedom, two translations, and one rotation. Various range detectors, with different light sources (for example, lasers and light-emitting diodes), different collection options, and different detection schemes (for example, diminishing return and time of flight) can be used. This sensor increases the capability and flexibility of computer-controlled machines. For example, it can instruct a robot how to adjust automatically to different positions and orientations of a part.

Patent issued to	Patent title, number, and date of issue	Summary of disclosure
Roscoe E. Marrs	**X-Radiography with Highly Charged Ions** U.S. Patent 6,115,452 September 5, 2000	An extremely small (1- to 200-micrometer full width at half-maximum) beam of slow, highly charged ions deexciting on an x-ray production target generates x-ray monochromatic radiation that is passed through a specimen and detected for imaging. The resolution of the x radiograms is improved, and such detection is achieved with relatively low dosages of radiation passing through the specimen. An apparatus containing an electron beam ion trap (and modifications thereof) equipped with a focusing column serves as a source of ions that generate radiation projected onto an image detector. Electronic and other detectors can detect more radiation per pixel than previous methods and apparatus could.
George E. Vogtlin David A. Goerz Mark Hsiao Bernard T. Merritt Bernie M. Penetrante John G. Reynolds Ray Brusasco	**Nitrogen Oxide Removal Using Diesel Fuel and a Catalyst** U.S. Patent 6,119,451 September 19, 2000	Hydrocarbons such as diesel fuel are added to internal combustion engine exhaust to reduce exhaust NO_x in the presence of an amphoteric catalyst support material. Exhaust NO_x reduction of at least 50 percent in the emissions is achieved with the addition of less than 5 percent fuel as a source of the hydrocarbons.
Kevin G. Knauss Sally C. Copenhaver Roger D. Aines	**Hydrous Pyrolysis–Oxidation Process for In Situ Destruction of Chlorinated Hydrocarbon and Fuel Hydrocarbon Contaminants in Water and Soil** U.S. Patent 6,127,592 October 3, 2000	The in situ hydrous pyrolysis–oxidation process is useful for degrading fuel hydrocarbons, chlorinated hydrocarbons, polycyclic aromatic hydrocarbons, petroleum distillates, and other organic contaminants present in the soil and water into nontoxic products. The process uses heat that is distributed through soils and water, optionally combined with oxygen and/or hydrocarbon degradation catalysts, and is particularly useful for remediation of solvent, fuel, or other industrially contaminated sites.
Anthony D. Lavietes Joseph Mauger Eric H. Anderson	**System and Method of Active Vibration Control for an Electromechanically Cooled Device** U.S. Patent 6,131,394 October 17, 2000	A system and method for controlling the active vibration of an electromechanically cooled device. The cooling device is characterized by its vibration transfer function, which depends on its mounting apparatus, proximity to vibration-generating devices, or temperature. Its vibrations—which may be triggered by powering up the system, having it reach an operating temperature, or resetting it—are received by a sensor in a vibration controller. The sensor generates a vibration signal that the controller uses, along with the vibration transfer coefficients, to generate a drive signal to a counterbalance that adjusts the vibrations to reduce them.
Steve P. Swierkowski James C. Davidson Joseph W. Balch	**Vacuum Fusion Bonding of Glass Plates** U.S. Patent 6,131,410 October 17, 2000	An improved apparatus and method for vacuum fusion bonding of large, patterned glass plates. One or both glass plates are patterned with etched features such as microstructure capillaries and a vacuum pump out moat, and one plate has at least one hole through it for communication with a vacuum pump out fixture. The plates are held in accurate alignment with a temporary clamping fixture until the start of the fusion bonding heat cycle. A complete, void-free fusion bond of seamless, full-strength quality is obtained throughout the plates because the glass is heated well into its softening point and because a large, distributed force presses the two plates together. The force is developed from the difference in pressure between the furnace ambient (high pressure) and the channeling and microstructures in the plates (low pressure) caused by the drawn vacuum. The apparatus and method may be used to fabricate microcapillary arrays for chemical electrophoresis, for example, or any apparatus using a network of microfluidic channels embedded between plates of glass or similar moderate melting point substrates with a gradual softening point curve. Or it may be used for assembling glass-based substrates onto larger substrates, such as in flat-panel display systems.

Awards

In early November 2000, President Clinton named Lawrence Livermore Director Emeritus **Herbert York** as one of the winners of the **Enrico Fermi Award**, given for lifetime achievement in the field of nuclear energy. Other winners were Sidney Drell, formerly of the Stanford Linear Accelerator Center, and Sheldon Datz, a physicist and senior fellow at Oak Ridge National Laboratory.

York, the Laboratory's first director (1952 to 1958), received the award for his efforts in nuclear deterrence and arms control agreements. A nuclear physicist and emeritus director of the University of California's Institute on Global Conflict and Cooperation, which he founded in 1983, York served as science adviser to President Eisenhower and was cofounder and first chief scientist of the Advanced Research Projects Agency. He was ambassador and chief negotiator for the Comprehensive Test Ban Treaty negotiations under President Carter.

York has been at the forefront of efforts to reduce international tensions through deterrence and negotiated arms control agreements.

York is the fifth Fermi award winner from Lawrence Livermore. Previous recipients include Edward Teller, Harold Brown, and John Foster, all previous directors. E. O. Lawrence, the Laboratory's founder, was also a Fermi recipient.

The Fermi Award, the U.S. government's oldest science and technology award, dates to 1956. It honors Enrico Fermi, leader of the group of scientists who, on December 2, 1942, achieved the first self-sustained, controlled nuclear reaction.

Livermore physicist **John Lindl** and retiree **Garth Cummings** have been named fellows of the **American Association for the Advancement of Science** (AAAS).

They are among 251 new fellows recognized by the AAAS this year for their efforts in advancing science or fostering applications that are deemed scientifically or socially distinguished.

Lindl was cited for his "distinguished contributions to the understanding of high-energy-density matter and to the development of inertial confinement fusion." He joined the Laboratory in 1972 as a physicist working on laser target design. He has served as associate program leader of theory and design in the Inertial Confinement Fusion (ICF) program and leader of the division responsible for ICF target design. He became scientific director of the ICF program in 1994 and was recently named head of the Laboratory's Fusion Energy program.

Cummings was cited for distinguished contributions to research on reactor design and operation and to the application of risk assessment techniques to improved reactor safety. He joined the Laboratory in 1956 and retired in 1996. He held numerous positions during his long career, including program leader for the Nuclear Systems Safety program, section leader for Engineering Mechanics, and Nuclear Systems group leader, and chief of operations for the Livermore Pool Type Reactor. He went to work in the Director's Office in 1990 as an assistant to the deputy director for Operations and has continued that work part time since his retirement.

Two Livermore plasma physicists, **Bruce Remington** and **Mordy Rosen**, have been selected by the executive committee of the American Physical Society's Division of Plasma Physics (DPP) to participate in DPP's **Distinguished Lecturer program**. They and four of their plasma physics colleagues were selected from several thousand to travel to various universities throughout the country to describe their research to undergraduate and graduate students and faculty.

According to Don Correll, director of Livermore's Science and Technology Education Program and chair of the DPP selection subcommittee, the Distinguished Lecturer program is designed to bring awareness of plasma physics to students throughout North America. "Being chosen from among the 2000 members of DPP to be a distinguished lecturer is an individual recognition of the scientist's contributions to plasma physics and his or her ability to share the information with a broad audience," Correll said.

Remington's talks will deal with "Scaling Astrophysics into the Laboratory." Rosen will address "High-Energy-Density Plasmas and the Quest for Fusion Ignition."

For more information on DPP and the Distinguished Lecturer's Program, see the DPP Web site at http://w3fusion.ph.utexas.edu/aps/.

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Also in March

- *At a recent Livermore-sponsored workshop on the "Barriers to Predictive Simulation in Science and Engineering," researchers discussed the progress and problems in using predictive computer modeling in their work.*

- *Measurements taken with a transmission electron microscope are helping Livermore scientists understand how plutonium ages—knowledge essential for assessing the condition of the U.S. nuclear stockpile.*

- *The Laboratory and a commercial partner have developed a new laser peening technology—blasting metals with laser beams to strengthen them—with a host of industrial applications.*

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