The Seventies

New Leadership

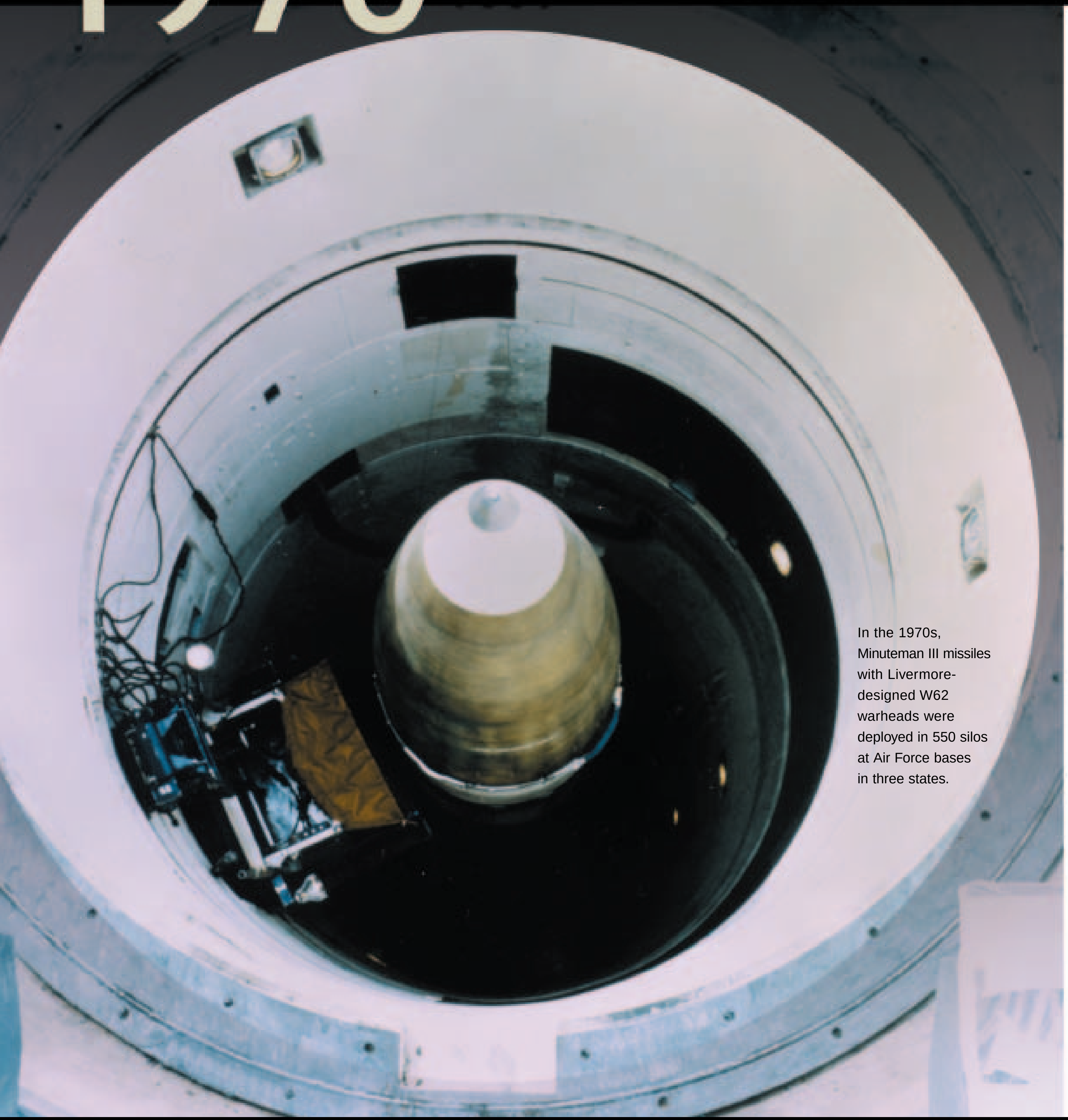
Roger E. Batzel
(1971•1988)

In the early 1970s, the Laboratory completed development of new warheads for the nation's strategic missile forces and for the Spartan antiballistic missile interceptor. Livermore pushed the frontiers of what was possible in nuclear weapon design and engineering. Designers then turned their attention to modernizing NATO's nuclear forces with novel weapon designs and to exploring the use of insensitive high explosives for improved nuclear weapons safety.

On the frontiers of science and technology

Capitalizing on an emerging technology, Livermore also began a laser program and has been at the forefront of laser science and technology ever since. In 1974, Janus was built, the first of a sequence of ever-larger lasers to explore inertial confinement fusion (ICF) for national security and civilian applications. Design, engineering development, and use of the Laboratory's ICF lasers have contributed to thermonuclear weapons science, enabled new scientific discoveries, and stimulated the development of new products and processes in U.S. industry. The 1970s energy crisis helped to invigorate long-term research efforts in both ICF and magnetic fusion as well as other energy research programs at the Laboratory.

1970 FIRST MIRV WARHEADS



In the 1970s, Minuteman III missiles with Livermore-designed W62 warheads were deployed in 550 silos at Air Force bases in three states.

Multiple Warheads Increase Missile Effectiveness

In 1970, the United States introduced a new capability that dramatically increased the effectiveness of its land- and sea-based strategic missile forces. Both the Minuteman III intercontinental ballistic missile and the Poseidon C-3 submarine-launched ballistic missile were deployed with multiple independently targeted reentry vehicles (MIRVs), a technology that allowed each missile to attack multiple targets within a large "footprint." This provided considerable flexibility in targeting. MIRVs also were more cost-effective because they leveraged the large costs of missile silos and submarines. The warheads for each of these missile systems were designed by Livermore. The W62 warhead for Minuteman III (deployed in April 1970) and the W68 warhead for C-3 (deployed in June 1970) pushed the envelope of yield-to-weight ratio, a key to the MIRV concept. They were also the first designs to include a comprehensive set of hardening features for protection against antiballistic missile (ABM) defenses. The warheads were the product of an extremely fruitful period in weapon development at the Laboratory during the 1960s.

The MIRV concept resulted from the convergence of missile technology improvements, concerns about Soviet work on ABM systems, and the desire for improved accuracy. Early in the development of Minuteman III, it became clear that a liquid-fueled fourth stage was needed for higher delivery accuracy. Further consideration led to the concept of using additional fuel in the fourth stage to independently target multiple RVs and penetration aids. Meanwhile, the ability of missile systems to deploy individual satellites through use of a post-boost control system had been demonstrated in the U.S. space program in October 1963. In December 1964, Secretary of Defense Robert McNamara approved development of a MIRV system for Minuteman III. By early 1965, the Navy's Strategic Systems Project Office had developed baseline design requirements for the C-3 missile that would include MIRV capability.

Livermore received the assignment for both systems, and each program faced significant design challenges. The requirement to put 14 vehicles on the relatively small C-3 platform was very stressing. The W68 (in the Mk3 reentry body) was the smallest strategic warhead ever deployed by the U.S. The accuracy requirement for the Mk12, which carried the W62, led to a vehicle design that placed stringent volume limitations on the warhead, and the yield had to be sufficient for attacking hardened missile silos. In addition, both warheads included special hardening features intended to improve survivability when penetrating a threat antiballistic missile system. These features were developed with the aid of an extensive series of "exposure" nuclear tests conducted in conjunction with the Defense Nuclear Agency.

When the first MIRV systems were deployed more than 30 years ago, they marked the end to a chapter in which Livermore and the military redefined the strategic missile posture of the United States. The W62 and W68 represented such a dramatic advance in the state of nuclear design that all subsequent missile system warheads have incorporated many of their key elements. Their extensive development programs, conducted in close coordination with the Air Force and Navy and their contractors, were a model for all subsequent generations of delivery-system design teams.

The Poseidon C-3 missile launched from a submerged submarine.

1971 CANNIKIN

A Spartan missile body with the nuclear device is lowered downhole for the Cannikin event. The test was successfully conducted on November 6, 1971, on Amchitka Island, Alaska.

At the Frontier of Missile Defense Technology

The morning before the Cannikin event at Amchitka Island, Alaska, the test site was subjected to rain and wind gusts up to 124 miles per hour. The test crew and visiting dignitaries, including Atomic Energy Commission Chairman James Schlesinger and his family, anxiously waited. Meanwhile, the Supreme Court ruled by a 4–3 margin that the test could take place. On November 6, 1971, at 6:30 a.m. in Amchitka, the go-ahead came from the White House on a telephone hotline. Cannikin was successfully detonated at 11 a.m., and the nearly 5-megaton blast generated the ground motion of a 7.0 Richter-scale-magnitude earthquake.

Cannikin was a massive undertaking involving hundreds of Laboratory employees and nearly five years of effort. Test operations overcame a myriad logistics hurdles, and experimenters achieved many technical firsts. Two years of drilling produced a record-breaking emplacement hole that was 6,150 feet deep and 90 inches in diameter with a 52-foot-wide cavity mined at its bottom. The diagnostics canister was 264 feet long, and altogether 400 tons of cables and equipment were lowered downhole. Cannikin was the first test in which a laser successfully aligned diagnostics downhole and a computer system assisted field operations. A record-setting number of recording trailers, 2,000 feet from ground zero and shock mounted to withstand a ground upheaval of 15 feet at shot time, were instrumented with 250 oscilloscopes. One hundred percent of the test data was successfully retrieved.

The experiment tested the design of the warhead for Spartan, the interceptor used in the upper tier of the U.S. Safeguard Anti-Ballistic Missile (ABM) system. Spartan missiles were to engage clouds of reentry vehicles and decoys above the atmosphere and destroy incoming warheads with a burst of high-energy x rays. The Laboratory stepped up to the difficult challenge of designing the appropriate warhead. The Spartan warhead had high yield, produced copious amounts of x rays, and minimized fission output and debris to prevent blackout of ABM radar systems. Livermore also developed and first tested the warhead technology for the second-tier interceptor, the Sprint missile. Subsequently, Los Alamos was assigned responsibility to develop the nuclear warhead for Sprint.

The Safeguard ABM system was a scaled-down version of the Sentinel system for defense of U.S. cities. Rapid evolution of offensive missile technologies (see Year 1970) made national defense impractical, and in 1972, the United States and the Soviet Union signed the ABM Treaty. However, protection against ballistic missile attack remained a noble goal and technological challenge for Laboratory researchers and was pursued with renewed vigor after President Reagan launched the Strategic Defense Initiative. Nuclear directed-energy weapons were pursued at Livermore, including experimental demonstration of x-ray lasing at the Nevada Test Site. Laboratory researchers also devised the concept of Brilliant Pebbles for nonnuclear defense against missiles in boost phase, which led to the Clementine experiment to map the Moon (see Year 1994).

During preparation for the Cannikin event, workers—including Test Director Phil Coyle (right)—ate their meals near the rigging.

1972 OZONE DEPLETION CALCULATIONS

Photo credit: The Boeing Company

Depletion of stratospheric ozone was one of the concerns raised when development began of commercial supersonic transport aircraft. Later, use of chlorofluorocarbons was prohibited because of similar concerns about ozone depletion.

Less Bay Area Ozone

In the late 1960s, the Laboratory responded to a growing interest in the quality of our environment by applying its capabilities to help understand human-induced affects on the atmosphere. The rising number of excess ozone days in the Livermore Valley prompted Mike MacCracken and colleagues to adapt a new modeling technique developed at the University of Illinois for use as the core of a Bay Area air-quality model. Results from this model and later versions served as the basis for preparing the Bay Area's Air Quality Maintenance Plan, which, with later revisions, has lowered the number of days of excess ozone from about 50 per year to just 1 or 2 per year.

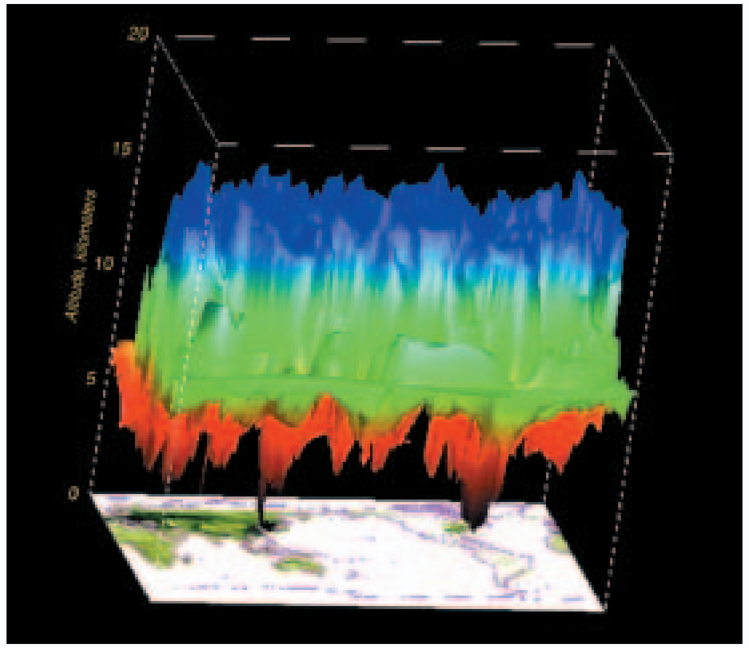
Preventing Planetary Sunburn

In 1972, the Laboratory applied newly developed modeling capabilities to investigate whether human activities might degrade the stratospheric ozone layer, which screens out most of the radiation that causes sunburns and skin cancer. U.S. decision-makers needed information on the potential effects of a proposed fleet of supersonic transports (SSTs)—faster-than-sound commercial jet aircraft—that would fly in the stratosphere. Concerns were raised that exhaust emissions might chemically react in ways that would thin the stratospheric ozone layer. Livermore's one-dimensional (altitude) model of stratospheric ozone, developed under Julius Chang, was one of the first simulation tools in the world used to examine ozone interactions with the SST's nitrogen oxide emissions.

An important early test of the model was its ability to explain the observed decrease in stratospheric ozone concentrations following atmospheric nuclear testing by the United States and the Soviet Union in the early 1960s (see Year 1962). These simulations clearly indicated that use of a large number of megaton-size nuclear weapons in a nuclear war would seriously deplete stratospheric ozone—in addition to the extensive destruction caused at the surface. This finding later played a central role in a 1974 National Academy of Sciences study on the potential long-term world-wide effects of multiple nuclear weapons detonations, adding impetus for the two superpowers to reduce weapon yield and the size of their nuclear arsenals.

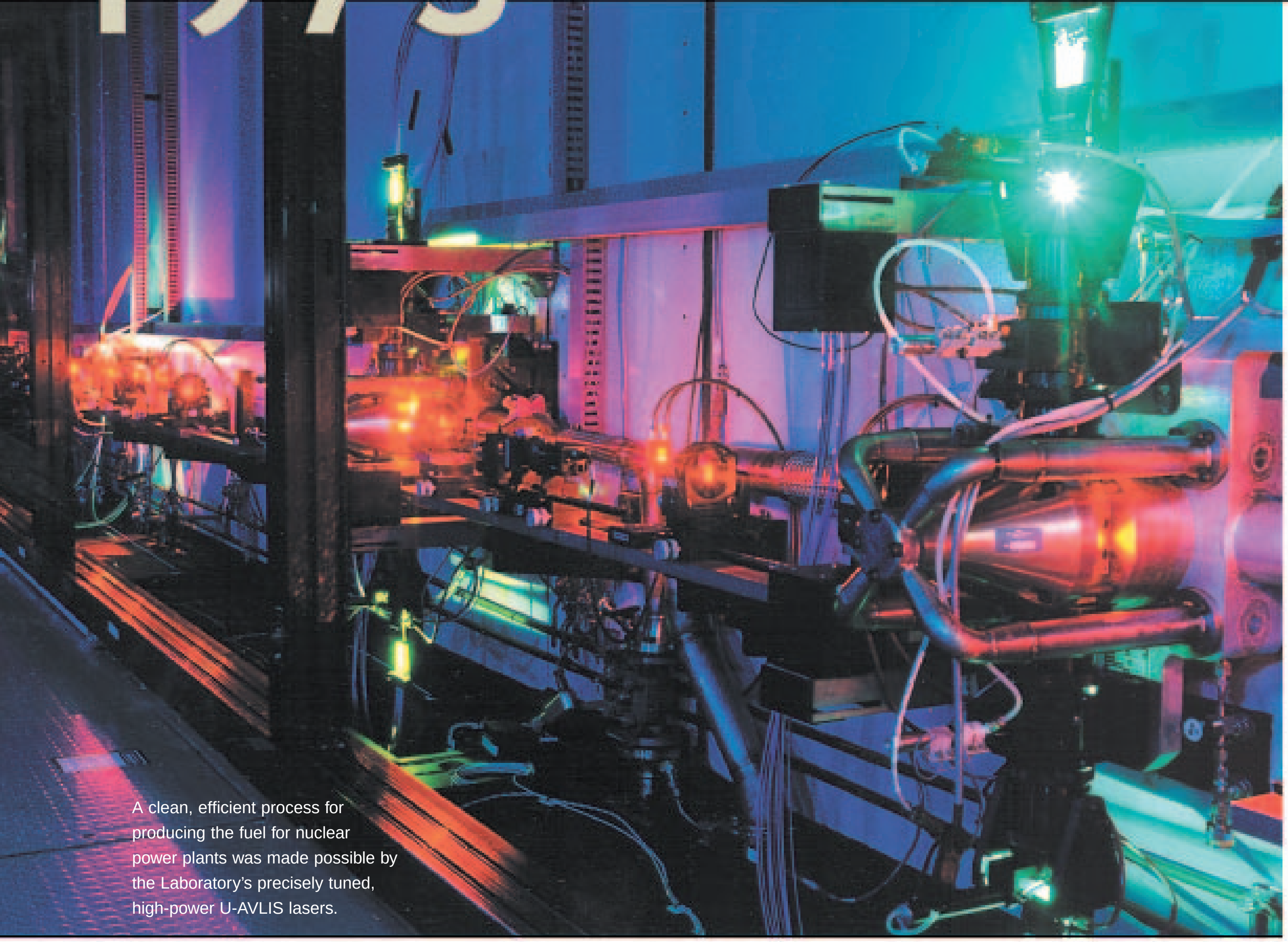
In 1974, the effect of chlorofluorocarbon (CFC) emissions on stratospheric ozone also became an issue. In response, Don Wuebbles and colleagues at the Laboratory developed a two-dimensional (latitude and altitude) model that predicted increasingly severe ozone depletion from continued use of CFCs in aerosol spray cans, refrigerators, and air conditioners. These results provided important input to the first international assessment of stratospheric ozone. International negotiations to limit CFCs ensued, and the U.S. prohibited their use as propellants in spray cans. Later, the research team developed a technique for calculating the Ozone Depletion Potential (ODP) of other compounds, a formulation that was included in the Montreal Protocol. Adopted in 1987, the protocol set goals for globally phasing out the use of halocarbons that have high ODP.

As computers became more powerful, Laboratory researchers developed three-dimensional global simulation capabilities and began analyzing the details of chemical reactions involving airborne aerosols (particles). Because of the Laboratory's scientific expertise and large-scale computing capabilities, Livermore now serves as the Core Modeling Team for the NASA Global Modeling Initiative.



Livermore researchers continue to improve the air chemistry models in simulations of atmospheric circulation. The transport of ozone from the lower stratosphere to near-surface altitudes is studied using models that require the Laboratory's supercomputers.

1973 U-AVLIS Program Begins



A clean, efficient process for producing the fuel for nuclear power plants was made possible by the Laboratory's precisely tuned, high-power U-AVLIS lasers.

Livermore's plant-scale uranium separator system was one of the largest technology transfer projects in the Laboratory's 50-year history.

Industrial-Scale Applications for Lasers

In the early 1970s, many analysts were projecting a shortage of electricity starting in the next decade. One option was expanded use of fission energy, for which an inexpensive source of enriched uranium fuel was needed. At the same time, the inherent properties of lasers were recognized as having the potential of leading to a low-cost method to produce such fuel by selectively ionizing uranium 235 and electrostatically separating it from uranium 238. The Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) program began at Livermore in 1973 to help maintain the U.S. market share of enriched uranium fuel for the host of nuclear power plants that would be constructed to meet the world's energy needs.

The U-AVLIS process for separating isotopes of uranium presents numerous advantages. It achieves separation in one or two passes through the laser beam, rather than the hundreds of passes required in other processes. It needs only 1/20th the electrical power required by diffusion plants, producing significant cost savings. Because U-AVLIS uses uranium metal as the source material rather than uranium hexafluoride, the process is less expensive and less hazardous and produces less low-level nuclear waste.

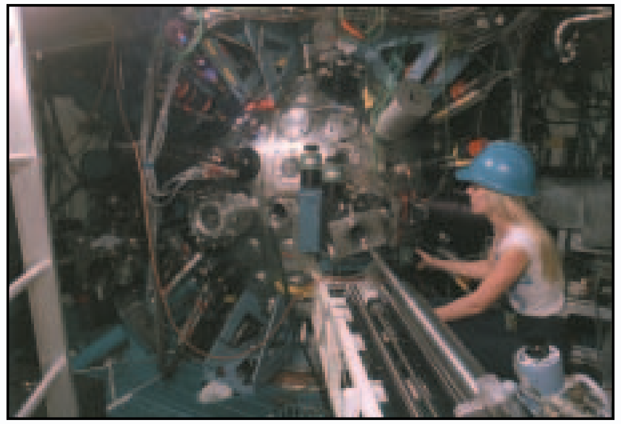
In the early years of the program, the U-AVLIS process used copper vapor lasers to pump liquid dye lasers to effect the separation process, while in later years, more efficient solid-state lasers were developed as the pump lasers. Dye lasers were used because they can produce a broad and almost continuous range of colors. An optical system in the laser is able to "tune," or select, the laser to the precise color needed to separate the desired isotope.

Through its 25-year history, the U-AVLIS Program progressed from the Morehouse experiment that produced the first milligram quantities of enriched uranium in 1974 through the REGULIS separator in 1980, the MARS Facility in 1984, and the Uranium Demonstration System and the Laser Demonstration Facility in the 1990s. In the process, tunable laser technology was dramatically advanced, and significant scientific progress was made in the physics of laser–atomic interactions. In addition, the Laboratory staff gained valuable experience in laser-based industrial production, which contributed not only to the U-AVLIS program but also to other projects such as the Laser Guide Star (see Year 1996), the Laser and Materials Processing program, and the National Ignition Facility (see Year 1997).

Congress created the United States Enrichment Corporation (USEC) in 1992, which was a government corporation until privatized in 1998, to move the U-AVLIS program into the private sector. By the late 1990s, however, the energy economies of the world and the supply versus demand for enriched uranium had changed. USEC suspended the U-AVLIS program in 1999, retaining the rights to U-AVLIS technology for commercial applications.

A technician works with the diode-pumped solid-state green laser developed for U-AVLIS. The technology is being used for precision machining and many other applications, such as pumping ultrashort-pulse lasers, creating laser displays, and treating disfiguring skin conditions.

The first Livermore laser for ICF research, Janus, had two beams and produced 10 joules of energy.



With the 20-beam Shiva laser in 1977, the Laboratory established its preeminence in laser science and technology.

Lasers Join the Quest for Fusion Energy

With the goal of achieving energy gain through inertial confinement fusion (ICF) as its mission, the Laser program constructed its first laser for ICF experiments in 1974. Named Janus, the two-beam laser was built with about 100 pounds of laser glass.

Under the leadership of John Emmett, who headed the Laser program from 1972 to 1988, researchers used Janus to gain a better understanding of laser plasma physics and thermonuclear physics and to demonstrate laser-induced compression and thermonuclear burn of deuterium–tritium. It was also used to improve the LASNEX computer code developed for laser fusion predictions. Janus was just the beginning of the development, in quick succession, of a series of lasers, each building on the knowledge gained from the last, moving toward the National Ignition Facility (NIF) under construction today. The pace of laser construction matched the growth in ICF diagnostics capabilities, computer simulation tools, and theoretic understanding.

In 1975, the one-beam Cyclops laser began operation, performing important target experiments and testing optical designs for future lasers. The next year, the two-beam Argus was built. Use of Argus increased knowledge about laser–target interactions and laser propagation limits, and it helped the ICF program develop technologies needed for the next generation of laser fusion systems.

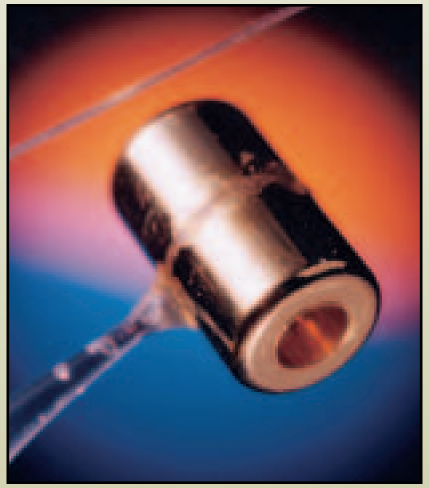
The $25-million 20-beam Shiva became the world’s most powerful laser in 1977. Almost the size of a football field, it delivered 10.2 kilojoules of energy in less than a billionth of a second in its first full-power firing. Two years later, Shiva compressed fusion fuel to a density 50 to 100 times greater than its liquid density. Shiva provided more power, better control over conditions, higher temperatures, and greater fuel compression than any previous laser.

The Novette laser came on line in 1983 as a test bed for the Nova laser design and an interim target experiment facility. It was used to demonstrate the efficient coupling of higher-harmonic laser light to fusion targets and to create the first soft-x-ray laser. The Nova laser (see Year 1984), 10 times more powerful than Shiva, was built the following year.

Altogether, six large fusion laser systems were engineered and built in 10 years. The next decade of ICF research was devoted to studying and demonstrating the physics required for fusion ignition and gain (fusion output greater than energy input). The work prepared the Laboratory to take the next major step, construction of the 192-beam National Ignition Facility (see Year 1997), where scientists expect to achieve fusion ignition and energy gain.

Inertial Confinement Fusion

In a fusion reaction, two nuclei—deuterium and tritium—collide and fuse together, forming a heavier atom and releasing about a million times more energy than in a chemical reaction such as fossil fuel burning. The nuclei must travel toward each other fast enough to overcome electrostatic forces. Thus, the fuel’s temperature must be over 10 million kelvins, and the fuel must be compressed to a density 20 times greater than that of lead. Laser beam light heats the surface of the fuel pellet and rapidly vaporizes its outer shell, which implodes the inner part of the fuel pellet and reduces it in size by a factor of 30 or more—equivalent to compressing a basketball to the size of a pea.



Side view of a typical hohlraum for the Nova laser shown next to a human hair. Hohlraums for the National Ignition Facility will have linear dimensions about five times greater than those for Nova.

1975 W79 DEVELOPMENT

Nuclear artillery shells for the Army's 8-inch howitzers included "enhanced radiation" capability developed at Livermore.

Special-Effect Weapons for the Tactical Battlefield

In January 1975, Livermore was assigned the task of developing a new nuclear artillery shell warhead, the W79, for the Army's 8-inch howitzers. Nuclear artillery shells were part of the U.S. arsenal from the mid-1950s until 1992. They were deployed for both Army and Navy systems and provided a highly accurate, short-range (typically about 10 miles), all-weather capability using delivery systems already deployed with conventional shells.

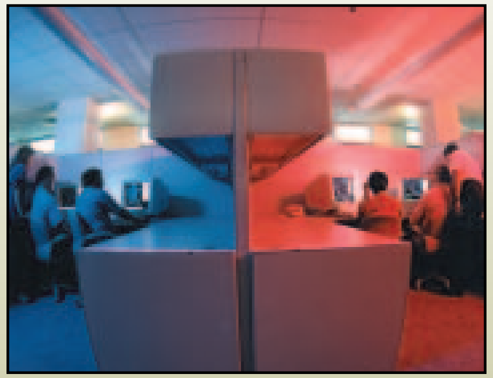
The W79 and the W70-3 were to be the first battlefield nuclear weapons to include an "enhanced radiation" (ER) capability. ER provided a relatively high fraction of the prompt weapon output in the form of neutrons (hence the nickname "neutron bomb"). ER technology began to be developed at Livermore in the early 1960s and entered the stockpile in 1974 with the deployment of the W66 warhead for the Sprint antiballistic missile interceptor (see Year 1971).

ER weapons were also developed for NATO forces. They were far more effective than previously deployed battlefield nuclear weapons for blunting a Soviet armored invasion of Western Europe and hence strengthened deterrence. A lethal radiation dose to enemy troops—likely protected in armored vehicles—could be achieved with the much smaller yield of an ER weapon than with a standard nuclear weapon. ER weapons could be employed to strike enemy units much closer to urban areas while avoiding collateral damage to towns and civilians.

The W79 development program led to deployment in 1981. In 1976, the Laboratory received a second related assignment—to provide an enhanced radiation modification to the Livermore-designed W70 warhead for the Army's short-range Lance missile system. This warhead, the W70-3, was also deployed in 1981. The W82, a weapon program for the 155-millimeter howitzer, was also assigned to Livermore, but that program was canceled in the mid-1980s prior to deployment.

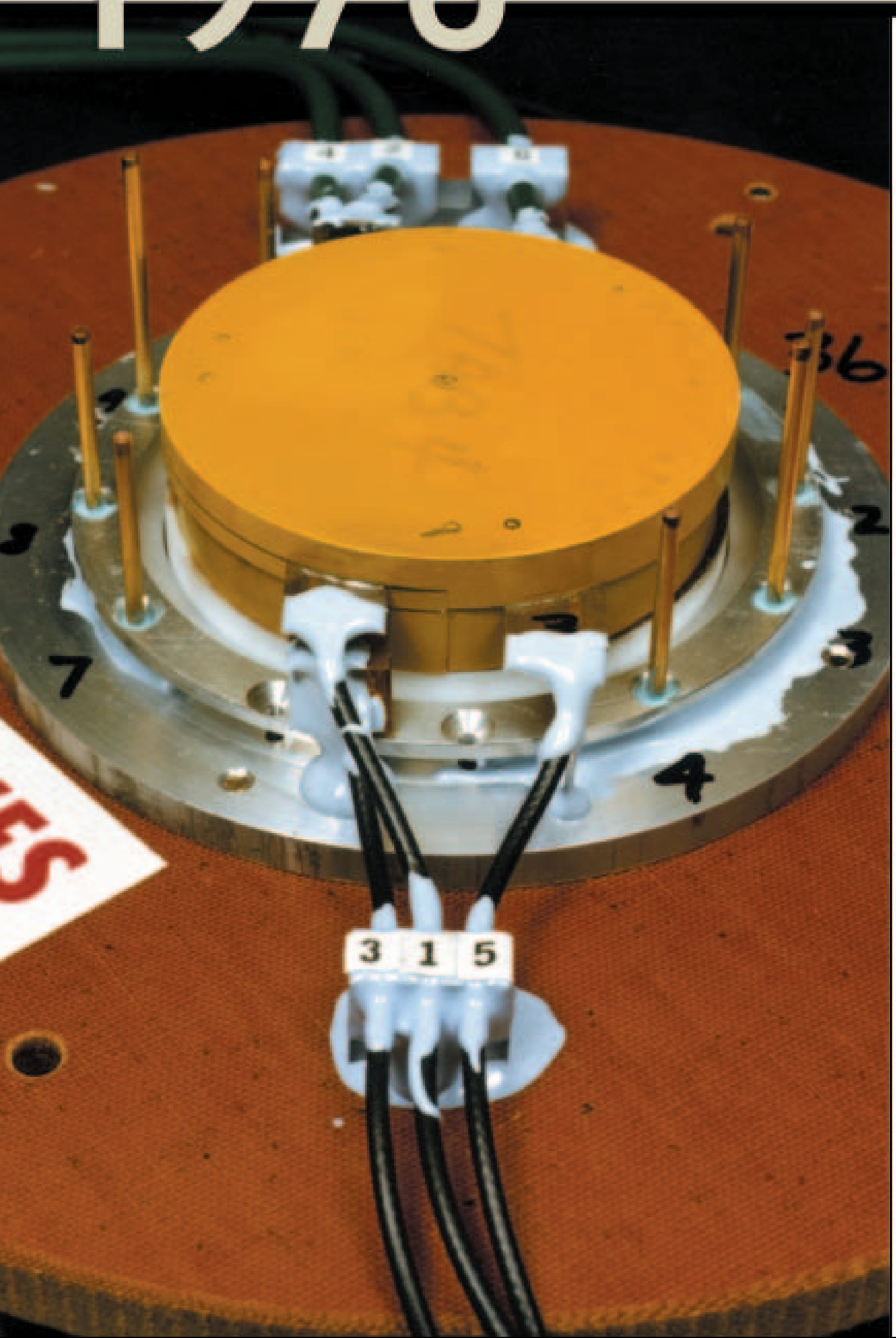
By the time the W70-3 and the W79 were part of NATO forces, they had become the center of an international controversy. A principal concern expressed by opponents was that by virtue of the lower yield and greater utility of ER weapons, their deployment would serve to lower the threshold for nuclear war. This controversy led to a 1985 Congressional order that future W79s be built without the ER capability, and existing units were modified to remove this capability. Eventually, all U.S. battlefield nuclear weapons were retired in accordance with President Bush's September 1991 address to the nation.

Conflict Simulation Laboratory



To understand the role of tactical nuclear weapons, analysts have had to take into account many factors that are not amenable to analytical models—the so-called "fog of war." In the mid-1970s, under the leadership of Don Blumenthal, the Laboratory began building high-resolution combat simulation models. A major advance occurred in 1978, when George Smith developed Mini-J, the first two-sided, player-interactive combat simulation model. The players observed their own units in real time, interactively acquired enemy units on a computer screen, and gave orders. Mini-J evolved into Janus, and successively improved models developed by Livermore's Conflict Simulation Laboratory followed. The culmination of this work is the Joint Conflict and Tactical Simulation (JCATS) model, which is widely used by the Department of Defense, Secret Service, and other agencies for training and planning.

Models that could accommodate an increasingly larger number of units and were applicable to a wider range of scenarios, such as urban combat, were developed at the Conflict Simulation Laboratory (left) in the 1980s. Player-interactive simulations are used by the U.S. military for training, analysis of tactics, and mission planning.



Research on energetic materials at the Laboratory has led to the formulation, detailed characterization, and development for weapons use (left) of extremely safe high-explosive materials for weapons.

TATB Makes Nuclear Weapons Safer

In 1975, Laboratory researchers published their first report on investigations of an insensitive high explosive, TATB (triamino-trinitrobenzene). Further work to characterize the material and find improved ways of producing it has led to widespread use of insensitive high explosives (IHE) in nuclear weapons. Use of IHE is one of the many important advances made over the past five decades to improve the safety and security of nuclear weapons. Its development is a demonstration of the expertise in energetic materials that resides at the nation's nuclear weapons laboratories.

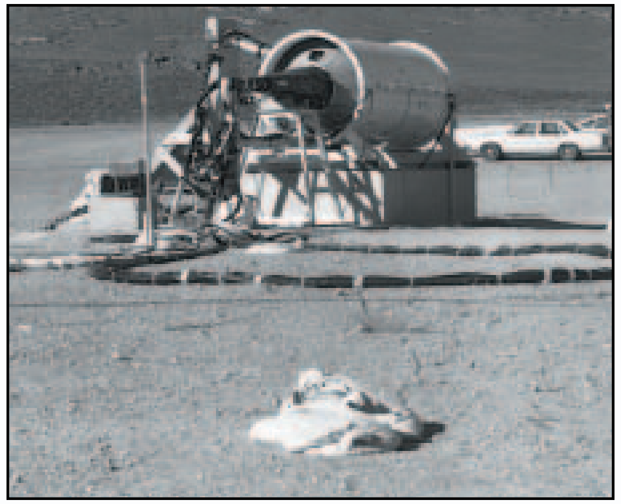
First synthesized in the 19th century, TATB is referred to as an insensitive high explosive because of its inherent insensitivity to shock. The material is virtually invulnerable to significant energy release in plane crashes, fires, or explosions or from deliberate attack with small arms fire. In fact, TATB is so stable that researchers had to discover how to reliably initiate an explosion of the material. They also had to find a ready and affordable way to produce the material. Building on advances made at both nuclear design laboratories, Los Alamos researchers made a key improvement in 1967 by finding a way to prepare TATB as a molded, plastic-bonded explosive at close to theoretically maximum density.

Subsequent experiments at Livermore by Richard Weingart and his colleagues included shock-initiation, heat, and fracture tests to define the safety characteristics of plastic-bonded TATB. Other experiments helped researchers to understand how to initiate TATB reliably even in the extreme conditions that a nuclear weapon might face. A team led by physicist Seymour Sack made design advances that enabled TATB's reliable use in nuclear weapons. The first nuclear weapon systems to include TATB were a variant of the B61 bomb and B83 strategic bomb. The W87 ICBM warhead was the first design to use TATB for the explosive detonators as well as for the main explosive charge, further enhancing safety.

Despite its broad potential for military as well as civilian applications, use of TATB is largely limited to nuclear weapons because it is costly to manufacture. Even for nuclear weapon applications, a more environmentally benign method for producing TATB was needed. In response, Livermore developed in the 1990s a new manufacturing process called vicarious nucleophilic substitution (VNS). The process uses industrial materials that are environmentally less hazardous and avoids the need for chlorinated starters. VNS also saves 60 percent in manufacturing time and cost. The Laboratory's goal is to transfer the new process to private industry.

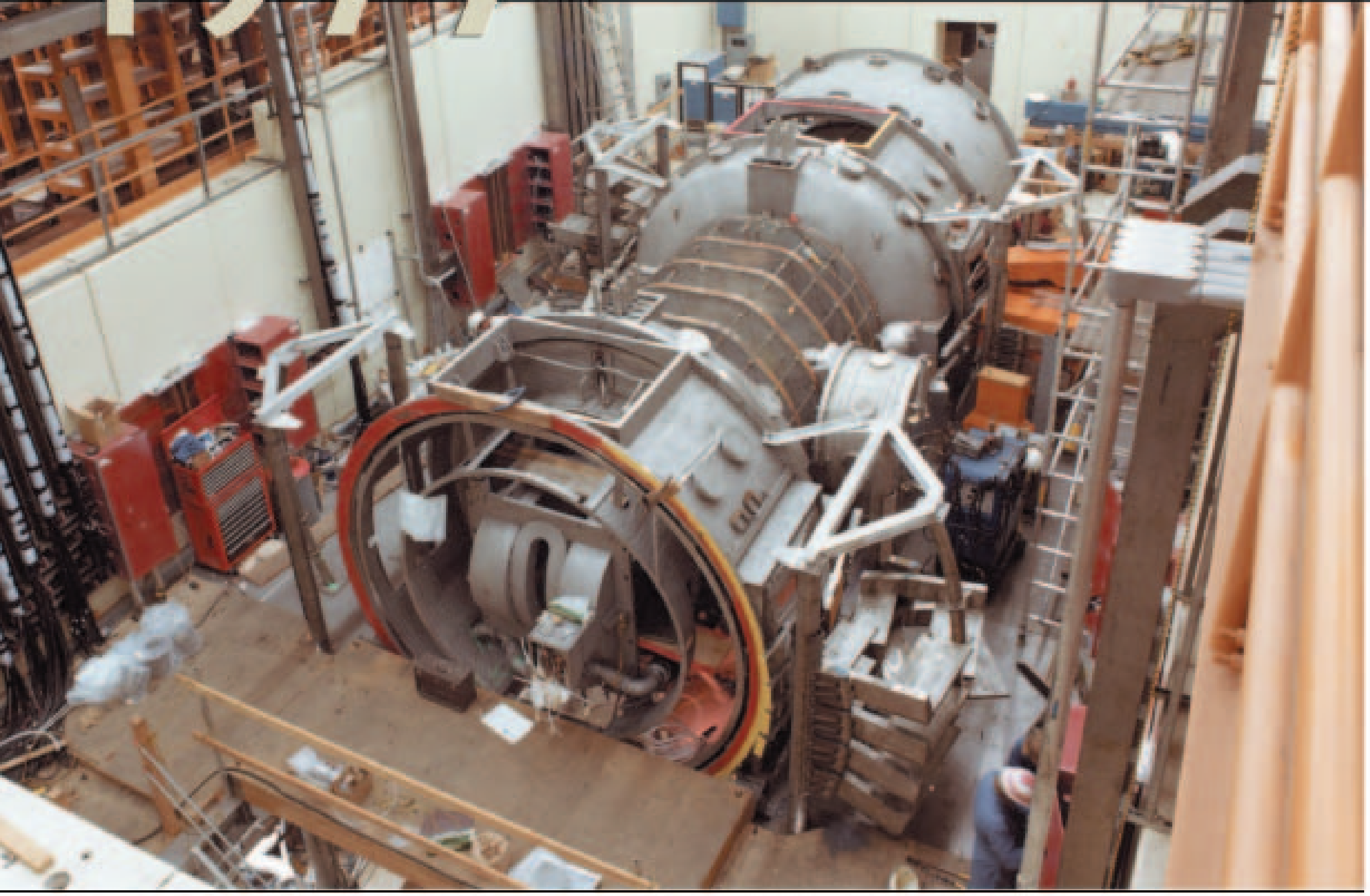
Energetic materials research at Livermore includes experimental activities at the High Explosives Applications Facility (HEAF) and Site 300, theoretical studies, and modeling efforts. One major challenge is to improve the models of the chemistry of detonation that are used in simulations of weapon performance. The detonation process involves many rapid chemical changes, with materials reaching extremely high pressure (up to 500,000 atmospheres) and high temperature (many thousands of kelvins).

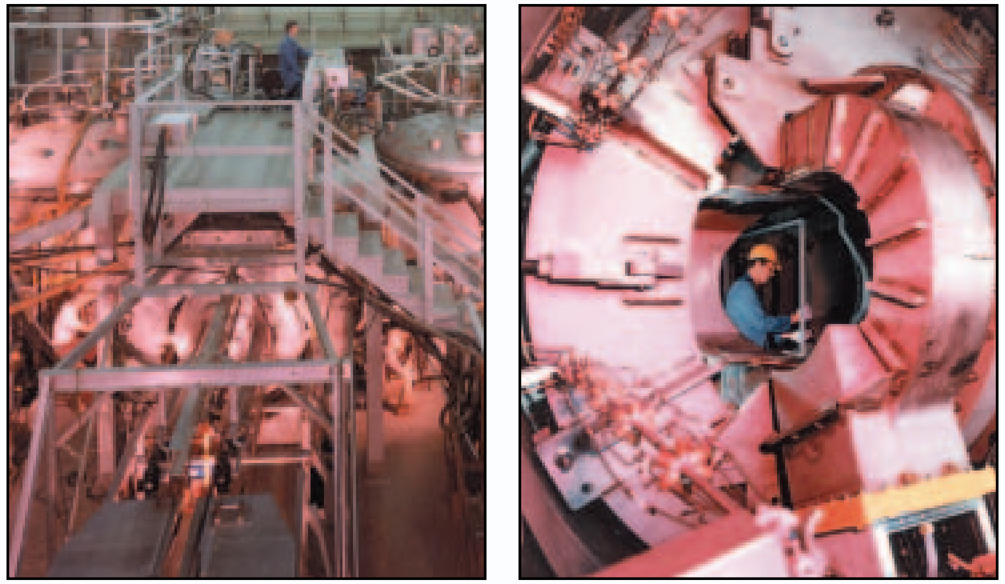
Crystals of TATB (triamino-trinitrobenzene), which are shown magnified in the background, are examined under a microscope.



A mock W87 warhead with IHE in a Mk21 reentry vehicle is mounted on simulated upper stages of the Peacekeeper missile (in the canister) in preparation for an explosive test to determine accident environments and warhead response.

1977 TANDEM MIRROR EXPERIMENT





Great success in the Tandem Mirror Experiment (above) led to TMX-Upgrade (far left and left). The vacuum vessel was enlarged, and new end coils were installed in an attempt to demonstrate the thermal barrier concept and improve performance over TMX.

Enormous Strides in Magnetic Fusion

In 1977, Laboratory researchers were making enormous strides both in the quality of their insights into plasma physics and in the size of their experimental equipment. In the spring, the Energy Research and Development Administration approved $11 million for the Tandem Mirror Experiment (TMX), which promised major performance improvements. That summer, researchers used an intense beam of energetic neutral atoms to generate and sustain a high-density (10^{14} particles/cm^3), high-temperature (160 million kelvins) plasma in the 2XIIB machine, which was the single-cell mirror experiment that set the stage for TMX. And in autumn, construction began on the Mirror Fusion Test Facility (MFTF), an advanced experimental fusion device designed to be an intermediate step between the existing mirror machines and an experimental fusion reactor. The goal was to increase plasma confinement to nearly 100 times that of 2XIIB and to increase plasma temperature to more than 500 million kelvins.

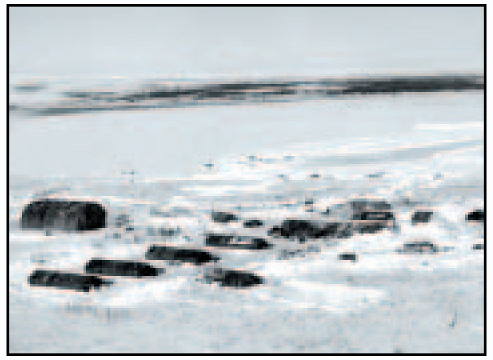
Success with TMX experiments over the next several years led the Laboratory to attempt to improve plasma confinement by heating the electrons at the ends of the machine to create a thermal barrier—a change that turned out to add to instabilities. At the same time, the MFTF design was substantially modified into a large tandem mirror configuration called MFTF-B. With a 58-meter-long vacuum vessel and the largest set of superconducting magnets in the world, MFTF-B was the Laboratory's largest construction project ($372 million) when completed in 1986. However, what could have been learned with MFTF-B will never be known because it was officially mothballed later that year. A scientific tool that had pushed the limits of engineering was turned off before it was ever turned on.

The decision was a major setback for fusion energy research at Livermore, but scientists continued work on other approaches to magnetic fusion. Laboratory researchers are collaborating in experimental studies of tokamak performance using the DIII-D tokamak at General Atomics, and they are providing leadership in the development and use of large-scale simulation of plasmas to carry out fusion research. In addition, Livermore is focusing its attention on advanced and alternative plasma confinement concepts. The Sustained Spheromak Physics Experiment (SSPX) was dedicated in January 1999. Its attractive features are simplicity of design and economy of size and cost when compared to the warehouse-size, technologically complex tokamak.

As one of its significant legacies, the large magnetic mirror fusion effort at the Laboratory led to the establishment of the nation's first unclassified national supercomputing center to provide magnetic fusion researchers nationwide with the computing horsepower that was then available only to nuclear weapons designers. When it opened at Livermore in 1974, the computer center pioneered many practices: remote access by thousands of users; high-performance data storage and retrieval; online documentation; and, around-the-clock support for users. In the 1980s, the center became the National Energy Research Scientific Computing Center (NERSC). It is now located at Lawrence Berkeley National Laboratory.

One of the yin-yang magnets for MFTF-B being moved into Building 431. The magnet system for MFTF-B was the largest superconducting system ever built.

1978 OPERATION MORNING LIGHT



NEST members from Livermore join the search for Cosmos 954, a fallen Soviet satellite. They found small pieces of the satellite and its nuclear reactor on frozen Baker Lake in the Northwest Territories of Canada.

When Satellites Go Bad

Cosmos 954 started losing orbital altitude in December 1977. The North American Aerospace Defense Command (NORAD) thought it would burn up in the Earth's atmosphere on reentry, but not much was known about the Soviet satellite—its size, its weight, and most important, the amount of nuclear material in its reactor. A month later, the Laboratory was quietly notified to get ready. NEST—the Nuclear Emergency Search Team—was prepared to find the satellite, wherever it landed.

After the first meeting at the Laboratory on January 18, 1978, two Livermore computer scientists were provided the exclusive use of a CDC-7600 computer, and they spent the next few sleepless days refining calculations of the trajectory and figuring out how wide an area—called the footprint—would result from the impact of variously sized pieces of Cosmos, including perhaps 100 pounds of nuclear fuel. The exact time and place of reentry would not be known until the final orbit.

Meanwhile, the Laboratory's NEST contingent—a group of health physicists, chemists, nuclear physicists, and engineers—left for the Las Vegas NEST office to wait. They had packed every type of clothing because they had no idea where they would ultimately end up. Radiation detectors, liquid nitrogen, sample containers, power generators, what passed for portable computers then, and even a helicopter were loaded into a C-141 aircraft—all to look for anything that survived reentry.

The final orbit happened on January 24. Cosmos fragments scattered across a 30-mile-wide, 500-mile-long swath of the Northwest Territories of Canada, a desolate area populated by caribou and a few Inuit hunters. Within 6 hours, the official request for help came from Canada, and Operation Morning Light began. The Canadians were depending on the Laboratory team to help find Cosmos pieces, identify the reactor fuel, and estimate the fission product inventory.

Soon, planes with radiation detectors were surveying the frozen landscape. The first radioactive pieces were found on January 26. Radioactivity ranged from a few milliroentgen to 100 roentgens per hour. No single piece was much larger than a small trash can, and tiny bits of radioactive fuel dotted the landscape. Hotspots were concentrated in a few places in the snow-packed forest and in the middle of frozen lakes. Because of the intense cold, team members could work only for short periods.

Operation Morning Light officially ended on April 18. At the peak of its operation—the first two weeks—120 U.S. personnel worked alongside the Canadians. Of that number, 39 were Laboratory people, with an additional 80 people back at Livermore supporting the team. Today, Laboratory personnel are still part of the Department of Energy's NEST team, ready to deploy at a moment's notice anywhere in the world.

Not Exactly California Weather

During Operation Morning Light, Livermore's Tom Crites was at the Baker Lake site, where the temperature hovered around –40˚F, or around –120˚F with the wind-chill factor. The Canadians had outfitted every team member with the latest survival gear. Tom needed it all. The hydraulically powered helicopter failed one day, requiring the team to build snow igloos and keep fires going. They endured a subzero night before a plane rescued them. A few people lost fingers and toes to frostbite. Tom has put his experience to good use leading Boy Scout camping trips in the Sierras. "Besides," he says, "where else can you look south to see the Northern Lights?"

ARAC scientist Marv Dickerson keeps members of the media informed about the status of radioactive releases from the Chernobyl nuclear power plant meltdown in 1986.

Responding to Nuclear Emergencies Worldwide

On March 29, 1979, Marv Dickerson and Tom Sullivan were at a meeting to secure an agreement with the Air Force Global Weather Center to supply information to the Atmospheric Release Advisory Capability (ARAC) at Livermore. ARAC had recently begun pilot operations under the sponsorship of the Department of Energy. They received a call: “There’s been an accident at the Three Mile Island nuclear power plant. Could ARAC help, and how soon?”

Over the course of the next 10 days, ARAC scientists worked 24 hours a day, 7 days a week to predict possible levels and areas of radioactive fallout. Working with a private contractor that was taking aerial radioactivity measurements during flyovers of the area, Livermore scientists were able to use meteorological and topographical information to determine where the plume of radioactive materials was located and where it would travel.

From 1973 to the Three Mile Island incident in 1979, ARAC was a research and development project with a goal to track any radioactive accident that happened at a Department of Energy facility and assess its effect on the surrounding community. With the meltdown at Three Mile Island, ARAC became a household name within the group of federal agencies responsible for responding to nuclear accidents. The group included the Environmental Protection Agency, DOE, the Department of Defense, the Nuclear Regulatory Commission, and even the Federal Emergency Management Agency.

ARAC has since changed its name to the National Atmospheric Release Advisory Center (NARAC) partly because it has expanded its role to respond to nuclear, chemical, biological, or natural hazardous material releases. The center has responded to more than 160 alerts and incidents in over two decades of operations. Key events include the 1980 Titan II missile explosion in Damascus, Arkansas; the Chernobyl nuclear power plant meltdown in 1986; the Kuwaiti oil fires during and after the Persian Gulf War in 1991; the 1991 Mount Pinatubo eruption; an industrial cesium-137 release in Algeciras, Spain, in 1998; and local toxic incidents such as a large tire fire in Tracy, California, in 1999.

NARAC’s Emergency Response Modeling System has been continually improved and now uses third-generation codes. The system realistically models actual terrain, uses observed and forecasted weather data, and simulates the release, transport, diffusion, and deposition of particles. Recently, NARAC scientists improved capabilities to simulate how a biological or chemical release would spread in and around complex urban environments, studying in detail Salt Lake City, Utah, the site of the 2002 Winter Olympics. In support of homeland defense, NARAC is an important tool in analyzing how a dangerous airborne substance could travel in a heavily populated area.

ARAC scientists track various airborne releases (left). They helped California state agencies and emergency workers during the June 1999 tire fire in Tracy, California, providing three-dimensional forecasts of the smoke dispersion of particulate concentrations (below).