The Eighties

New Leadership

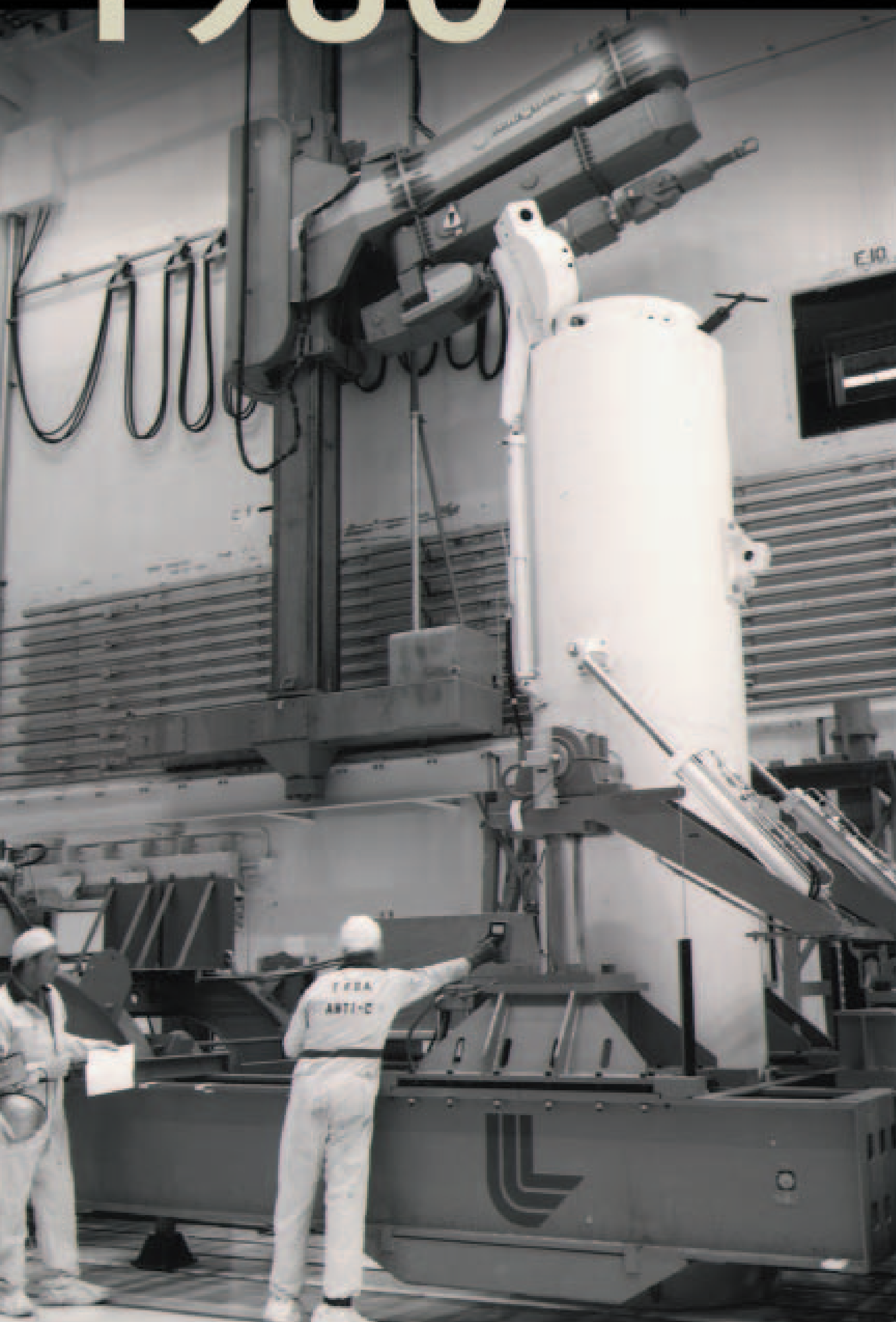
John H. Nuckolls
(1988•1994)

Simulations and experiments

All major programs at the Laboratory have relied on the interplay between computer simulations and experiments to increase scientific understanding and make dramatic engineering improvements. In the 1980s, the combination of testing and simulations greatly contributed to the development of new strategic weapons, such as a nuclear bomb that could be delivered at low altitude, to help win the Cold War. The combination was also critically important to scientific exploration of x-ray lasers and the complexities of intense laser light interacting with matter. Major new experimental facilities were constructed such as the Bunker 801 complex at Site 300 for hydrodynamic testing, the Nova laser, and the High Explosives Applications Facility; and the first three-dimensional simulation codes were developed.

In the late 1980s, Laboratory researchers began to explore the feasibility of using multiple parallel processors for scientific computing—now a key component of efforts to maintain the nation's nuclear weapons stockpile. Since Livermore opened, the need for ever more powerful simulations for nuclear weapons design has guided industry's development of supercomputers, and the Laboratory has helped industry make prototype machines ready for a wider range of users.

1980 Spent Fuel Test—Climax



Meeting Challenges of Nuclear Waste

Each spent-fuel canister was moved over paved Nevada Test Site roads from the hot-cell facility to the mined test facility in a specially designed surface cask mounted on a low-boy trailer. The cask was upright for loading and almost horizontal for travel.

Canisters of spent nuclear fuel were entombed 1,400 feet below the Nevada Test Site as part of the DOE National Waste Terminal Storage Program. They were placed in holes drilled in the Climax granite formation and retrieved three years later.

In 1980, the Laboratory placed spent nuclear fuel 420 meters underground at the Nevada Test Site beneath the floor of a tunnel in Climax granite. In this experiment, Spent Fuel Test–Climax (SFT–C), researchers measured thermal loads from 11 canisters of spent fuel, 6 electrical heaters designed to mimic fuel canisters, and 20 electrical heaters in adjacent tunnels. The combined measurements of the three-year-long test simulated the thermal behavior of part of a large geologic repository for nuclear fuel.

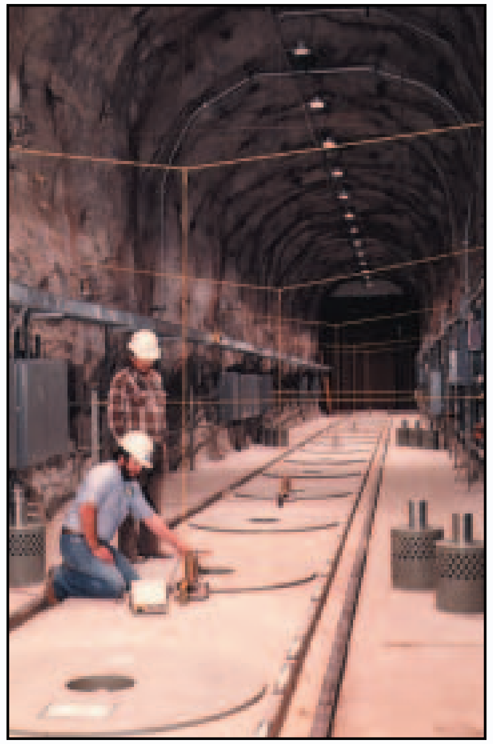
The Climax test was a significant large-scale field test for demonstrating essential technologies and revealing unexpected effects of high-level nuclear waste disposal in geologic repositories. Nuclear waste issues were looming on the horizon long before 1980, but Congress did not pass the Nuclear Waste Policy Act to deal with the problem until 1982.

Opportunities for testing at full scale were very limited this early in the U.S. nuclear waste management program. Livermore undertook SFT–C to demonstrate the feasibility of spent-fuel handling and retrieval from an underground repository and to address technical concerns about geologic repository operations and performance. The test was part of the Nevada Nuclear Waste Storage Investigations (NNWSI) project for the Department of Energy.

Operational objectives included packaging, transporting, storing, and retrieving highly radioactive fuel assemblies in a safe and reliable manner. In addition to emplacement and retrieval operations, three exchanges of spent-fuel assemblies between the SFT–C tunnel and a surface storage facility were part of this demonstration.

SFT–C technical objectives required a measurements program with nearly 1,000 field instruments and a computer-based data acquisition system. The system had to be robust enough to withstand the vagaries of the Nevada Test Site's power grid, shaking from nuclear weapons tests, and high temperatures caused by the thermal load. This was a major challenge for 1980s technology. When the Laboratory requested bids for a computer for logging the test data, only one company (Hewlett-Packard) answered the call. Undaunted, Livermore scientists and engineers designed most of the instruments, installed the system, and recorded geotechnical, seismological, and test status data on a continuing basis for the three-year storage phase and six months of monitored cool-down.

The SFT–C demonstrated the feasibility of deep geologic storage of spent nuclear fuel from commercial nuclear power reactors. The SFT–C showed the Laboratory's strong capabilities in materials science, nuclear science, earth sciences, advanced simulations, and engineered systems. The test's success provided a foundation for subsequent collaborations with nuclear waste disposal programs in other countries. More directly, as NNWSI evolved into the Yucca Mountain Project (YMP), the SFT–C helped prepare Livermore researchers for their role as experts in addressing YMP waste form, waste package, near-field environment, and repository performance issues.



Scientists perform an instrumentation checkout in the tunnel at the Nevada Test Site. The purpose of Spent Fuel Test–Climax was to determine the issues involved with storing and retrieving nuclear wastes underground.

1981 LODTM GROUNDBREAKING

The Large Optics Diamond Turning Machine and an aspherical mirror that the machine was first able to produce.

The Art of Precision Machining

It has been called the world's most accurate lathe, the world's most precise large machine tool. With the groundbreaking for the Large Optical Diamond Turning Machine (LODTM) in 1981, the Laboratory solidified its place at the top of state-of-the-art precision machining.

More than 20 years later, the machine's precision is such that LODTM (pronounced "load-em") still outperforms the measurers—the National Institute of Standards and Technology cannot corroborate the accuracy of its work. LODTM can machine metal to a mirror-smooth accuracy within one-millionth of an inch—1,000 times more accurate than conventional machine tools. It can handle a workpiece with a diameter up to 1.65 meters, a height up to 0.5 meters, and a weight up to as much as 1,360 kilograms.

Like a lathe, LODTM spins a workpiece as a tool cuts the revolving surface. But the similarity ends there, because LODTM leaves behind a gleaming reflective surface that often needs no further polishing. Since its construction, LODTM has been the tool of choice for contractors making lenses for heat-seeking missiles and other weaponry, exotically shaped optics for lasers, and mirrors for powerful telescopes such as Keck in Hawaii and NASA's space-based lidar-system, SPARCLE. When the Shoemaker–Levy comet collided into Jupiter in 1994, it was witnessed in real time, thanks to mirrors turned on LODTM and then installed at Keck.

Almost since its inception, the Laboratory has been among the leaders in the development of advanced techniques for precision measurement and manufacture to meet the demands of programmatic work. Livermore's first diamond turning machine was built in the late 1960s, and by the early 1970s, one-millionth of an inch precision was achieved. The idea of the LODTM arose later in the decade when researchers began considering the development of powerful lasers as an element of missile defense. The laser system's optics had to be extremely large, exotically shaped, and fabricated with a precision that corresponded to a small fraction of the wavelength of light. No machine had the needed capabilities.

Livermore's Precision Engineering Program, under the leadership of Dennis Atkinson, Bob Donaldson, Ray McClure, Steve Patterson, and others, designed and built the LODTM. The culmination of previous Laboratory research in machine tool accuracy, LODTM incorporated exhaustive analysis and elimination of factors that caused errors in machine tools—from the heat of the human body to the vibration from a heavy truck passing by.

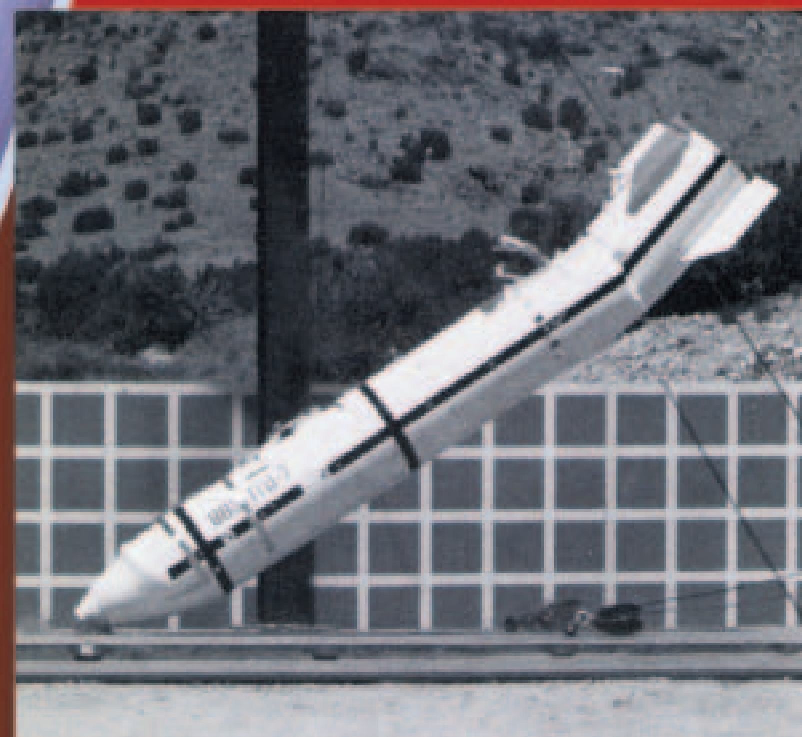
LODTM opened in 1983, two years after its groundbreaking. It continues to produce one-of-a-kind prototype optical devices. LODTM's next big project may be producing optics for NASA's next generation of telescopes.

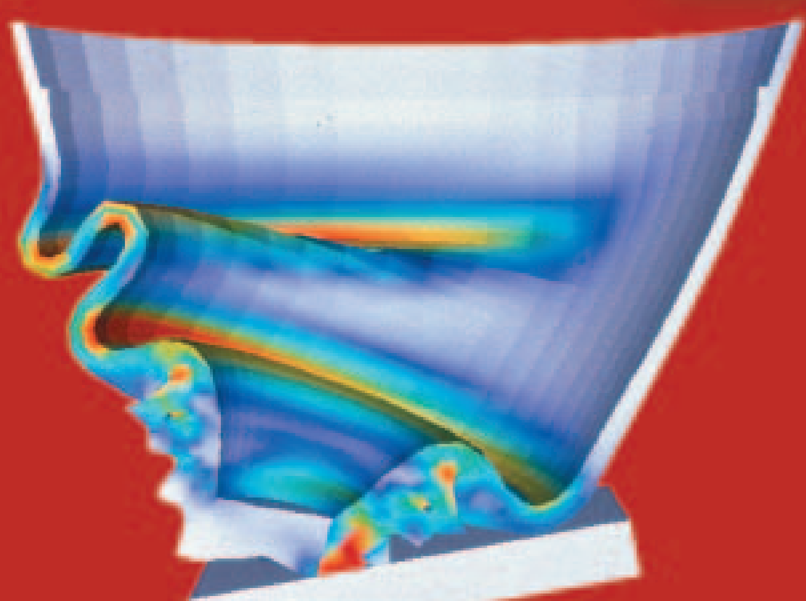
A Hero of U.S. Manufacturing

Literally billions of dollars worth of machine tools have been tested with a small measuring device invented by Jim Bryan, who made wide-ranging contributions to metrology and precision machining in 32 years of service at the Laboratory. In the 1980s, Bryan reworked an old British invention called a fixed ball bar by adding a telescoping arm to the instrument. Today, versions of Bryan's ball bar are used around the world to test machine tool performance quickly. For this invention and other achievements, which include leading the design and construction of record-breaking diamond turning machines in the 1970s, Bryan was recognized in 2000 by *Fortune* magazine as one of six "Heroes of U.S. Manufacturing."

Machining metal up to 1.65 meters in diameter and at a precision of 2 micrometers is possible with LODTM.

1982 DYNA3D





DYNA3D calculation of the crush-up upon impact of the nose cone of the B83 strategic bomb (above). Simulations were in excellent agreement with the results of experiments, such as this drop test with a B83 test unit landing on a rigid steel plate (left). Use of DYNA3D accelerated the B83 development program and lowered costs by reducing the number of actual crash-test experiments needed.

From Swords to Plowshares with DYNA3D

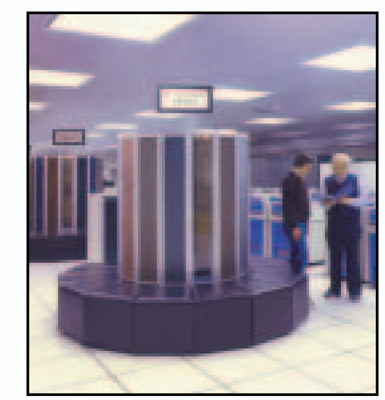
In 1982, a growing list of users benefited from the publication of the first *User's Manual for DYNA3D.* This three-dimensional computer code was developed by Laboratory mechanical engineers to meet the needs of the nuclear weapons program, and it grew to become a remarkable "swords to plowshares" story. Interest in DYNA3D rapidly expanded from a manual to an international conference on the code's applicability to a wide range of structural analysis problems. The computer code has been used by industry for making everything from safer planes, trains, and automobiles to better beer cans.

Much of the early incentive to develop DYNA3D, short for dynamics in three dimensions, arose from challenges presented by the B83 program. The B83 nuclear bomb was to be released from a low-flying aircraft, and even though it was to be retarded by a parachute, the bomb would have to survive an impact with the ground or whatever irregular structure it hit at up to 75 miles per hour. Lawrence Livermore and Sandia national laboratories needed an affordable program of tests and simulations to design the B83 and certify its crashworthiness. DYNA3D was used to model the structural performance of the B83, a complex design using a wide variety of materials, and it saved millions of dollars and years of time.

The code DYNA3D soon began spreading to private industry in one of the Laboratory's best examples of technology transfer of software. An unclassified code, DYNA3D's list of current or one-time industrial users reads like a "Who's Who" of major firms—General Motors, Daimler-Chrysler, Alcoa, General Electric, Lockheed Missiles and Space, General Dynamics, Boeing Commercial Airplane Group, Adolph Coors Co., Rockwell International, and FMC Corp. For example, General Motors and Daimler-Chrysler have run DYNA3D to help design safer cars; GE Aircraft Engines has operated the code to design jet engine fan blades; and, in 1991, a British engineering firm used the code to study a London train mishap that killed two people and injured 512 others.

At times, upwards of 300 companies have used the code to model their systems before they were built. A 1993 study found that DYNA3D and DYNA-like programs conservatively save U.S. industry $350 million annually. As one aerospace engineer stated, "DYNA is what Hershey is to chocolate bars and Kleenex is to tissue. People don't ask for a (dynamic) finite element code; they ask for a DYNA-like code."

Since work started on it in 1976, DYNA3D has blossomed from a small 5,000-line computer code into a 150,000-line package. Another version of DYNA3D for parallel computers, called ParaDyn, went into production use in 2000.

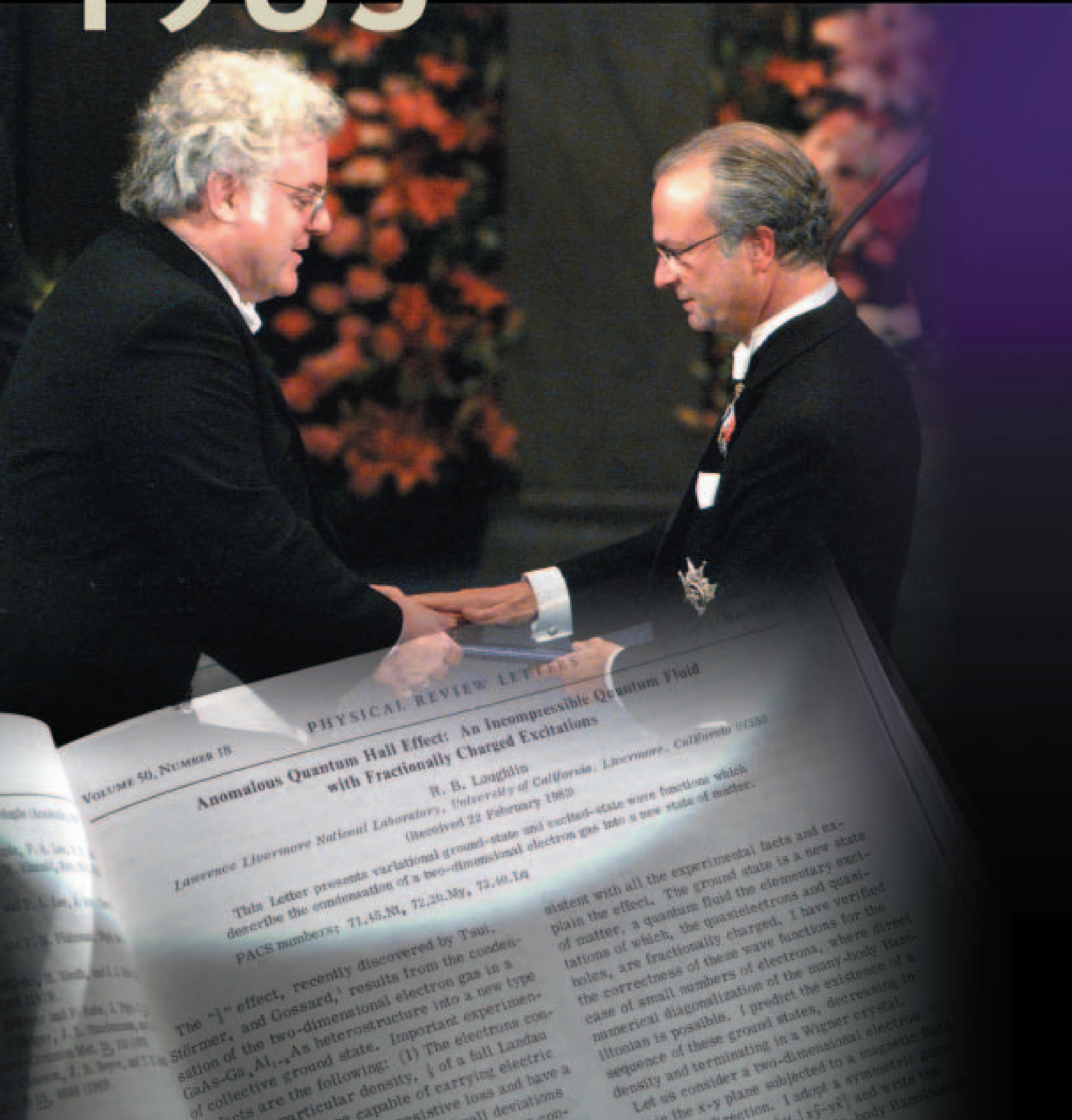


With the first Cray 1 arriving in 1979, Cray Research was the principal provider of mainframe machines to the Laboratory until the transformation to massively parallel computing in the 1990s.

Getting to the Heart of the Matter

In the early 1990s, as bioengineers looked to computer modeling to better understand complex human health problems, some turned to DYNA3D for help. One researcher, in a study associated with Duke University Medical Center, used the Livermore computer code to simulate the experimental response of arteries to balloon angioplasty. Other researchers employed DYNA3D to undertake studies showing the effect of impacts on the human chest and helmets. In addition, DYNA3D was even used in the design of some medical equipment.

1983 Laughlin Nobel Work



Award-Winning Science and Technology

The road to the Laboratory's Nobel Prize in physics was a 15-year journey, one that winner Robert B. Laughlin credits to Livermore's strength in team science.

Laughlin earned his Nobel in 1998, but it was in 1983 that *Physical Review Letters* published his elegant theoretical work explaining the so-called fractional quantum Hall effect. The effect had been experimentally discovered in 1982 by Horst Stormer of Columbia University and Daniel Tsui of Princeton University, who shared the Nobel with Laughlin. Its key surprise is that collective motions of electrons can behave like a fraction of the electrical charge for one electron. Previously, the only example of fractional charges in nature had been quarks.

By the time Laughlin's research was lauded in ceremonies held in Stockholm, Sweden, on December 10, 1998, Laughlin had become a professor of physics at Stanford University. But the work that led to that Nobel Prize was born in the Laboratory's condensed matter physics division. It was there that Laughlin, a solid-state postdoctoral physicist, benefited from Livermore's multidisciplinary approach to science—first championed by Laboratory co-founder and Nobel winner Ernest O. Lawrence.

Laughlin learned the ins and outs of plasma physics, and the mathematics of classical hot liquids, from physicists such as Hugh DeWitt, David Young, Marvin Ross, and Forrest Rogers. While waiting for his security clearance, he passed time by learning Monte Carlo simulation methods, studying the experimental literature of fluids, and making computer models of fluids. While thinking of the possibilities for the quantum Hall wave function, Laughlin realized "it was a fluid problem." He believes that he would not have seen that if he had not been interacting with fellow H Division physicists, who understood fluids. Although some experts think the fractional quantum Hall effect research could lead to advances in computers or power generation, Laughlin sees the main value of his work as revealing fundamental insights into quantum mechanics.

Laughlin has the distinction of being the first national laboratory employee ever to win the Nobel Prize. He is the seventy-first winner who worked or conducted research at a Department of Energy institution or whose work was funded by DOE, and he is the eleventh University of California employee to receive a Nobel Prize in physics.

Though Laughlin spends most of his time at Stanford, he continues his association with the Laboratory. His work stands as the hallmark of the world-renown science conducted at Livermore, work that has earned hundreds of other scientists, like Laughlin, E. O. Lawrence Awards, Teller medals, distinctions from every world-wide scientific society, and even the Nobel Prize.

Robert Laughlin (left) received the Nobel Prize for physics from Swedish King Carl XVI Gustaf at the ceremonies in Stockholm, Sweden, on December 10, 1998.
(AP photo/Jonas Ekstromer)

Breakthrough Laser Science and Technology

In the early 1980s, researchers were exploring how to produce x-ray laser beams initiated by nuclear explosives at the Nevada Test Site. At the same time, success was achieved creating a soft-x-ray (about 200 angstroms) laser in a laboratory setting using the Novette laser, which was a test bed for the design of Nova. Nova became operational in December 1984, enabling further groundbreaking research in x-ray lasers and many other areas of laser science and technology.

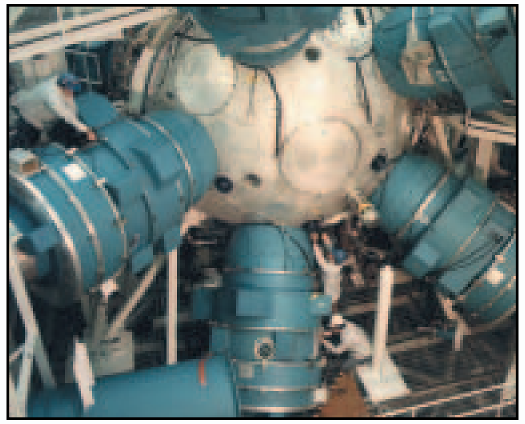
Ten times more powerful than Shiva, its predecessor, Nova was the world's most powerful laser. Its 10 beams produced laser pulses that delivered up to 100 trillion watts of infrared laser power for a billionth of a second. For that brief instant, its power was over 25 times greater than the combined power produced by all the electrical generating plants in the United States.

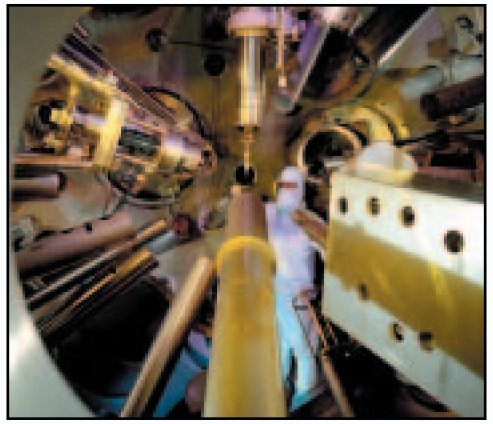
In 1986, in inertial confinement fusion experiments, Nova produced the largest laser fusion yield to date—a record 11 trillion fusion neutrons. The following year, Nova compressed a fusion fuel pellet to about 1/30th its original diameter, very close to that needed for high gain (fusion energy exceeding energy input). The laser exceeded its maximum performance specifications in 1989 when Nova generated more than 120 kilojoules of laser energy at its fundamental infrared wavelength in a 2.5-nanosecond pulse. In addition, in 1996, one arm of Nova was reconfigured as a petawatt laser. Record-setting laser shots produced pulses with more than 1300 trillion watts, or 1.3 petawatts, of peak power. The laser pulse lasted less than one-half trillionth of a second—more than a thousand times shorter than shots typically produced by Nova's 10 beams.

About 30 percent of Nova's shots were used by the nuclear weapons program. When the United States ceased nuclear testing, laser facilities became even more important for defense research, and the portion of Nova shots dedicated to the weapons program increased considerably. Researchers using Nova continued obtaining high-temperature data necessary to validate the computer codes used to model nuclear weapons physics.

Livermore also developed increasingly sophisticated diagnostic instruments to measure and observe what was happening with the laser beam, in the target, in the interaction between the laser light and the plasma, and in the fusion process. Some of the technologies provided spin-off advances, such as improved medical technologies, femtosecond laser machining, and techniques for using extreme ultraviolet light for lithography to produce faster computer chips (see Year 1999).

Nova served as the proving ground for the 192-beam National Ignition Facility (NIF). Achievements on Nova helped scientists to convince the Department of Energy of the viability and probable ultimate success of achieving thermonuclear ignition on NIF (see Year 1997).





In 1984, when it began operation, Nova was the world's most powerful laser. Laser pulses were produced with 10 beams (top), which were directed to a 5-meter-diameter target chamber (far left). Inside the chamber (left), the laser light was focused on BB-size targets.

Nova Shutdown

An era ended at the Laboratory in May 1999 when Nova fired its last shot. After 14 years and more than 14,000 experiments, Nova sent its last 10 beams of light down its 280-meter tubes in an experiment for the Stockpile Stewardship Program.

"It was very much a bittersweet moment," said Kim Budil, Laser Programs physicist and lead experimenter on the final shot. "The excitement of the shot was dampened by the realization that this was absolutely the last experiment we would ever perform with Nova."

"Nova has been an extremely successful facility," said John Emmett, associate director for Laser Programs when Nova was designed and built. "It's been a lot more productive than anyone thought it would be."

Nova was dismantled and some parts were shipped to other research facilities for their laser fusion and science programs.

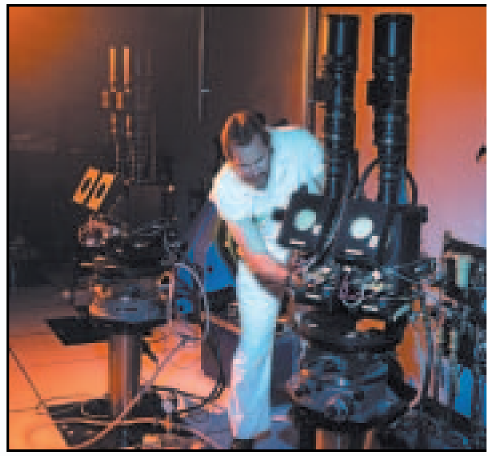
Improving Implosion Images

In 1985, Livermore completed the Bunker 801 project to upgrade what was in fact the very first facility (then called Bunker 301) at Site 300, the Laboratory's remote experimental test site. The newly refurbished bunker—actually a complex of protected enclosures, largely underground—became a fully modernized hydrodynamic test facility to gather data crucial for assessing the operation of a nuclear weapon's primary stage. Until project completion, weapon designers relied largely on technologies from the 1960s for much of their hydrodynamics experimentation.

After the upgrade, Bunker 801 contained the most modern diagnostics available. They included a Fabry–Perot interferometer to measure the velocity of explosion-driven surfaces, 10 high-speed cameras to capture the progressive movement of a pit's outer surface, and an electrical-probe diagnostics system for recording data from hundreds of shorting pins that time the arrival of the interior surface. Additionally, an important diagnostic tool was the Flash X Ray (FXR), a 16-megaelectronvolt linear-induction accelerator (see Year 1960 on the development of linacs). Electrons from the FXR strike a target to produce an intense burst of x rays, which are used to image a mock nuclear weapon primary as it implodes. Built between 1978 and 1982, the FXR produced five times the x-ray dose of previous machines in one-third the pulse length. Much denser objects could be radiographed and with less blur because of the shorter pulse.

Continual upgrades to Bunker 801 since 1985 have kept the facility equipped with the most modern capabilities. For example, in the 1990s, Laboratory scientists and engineers improved the beam quality of the FXR so that a higher overall x-ray dose is produced. More recently, a double-pulse feature was added to take two radiographs in one experiment. In addition, the Laboratory developed a gamma-ray camera to record the radiographic images produced. The system is 70 times more sensitive than the radiographic film it replaced. With these upgrades, scientists in 1998 were able to carry out the first "core punch" experiments on mock pits for two stockpiled weapons—the W76 submarine-launched ballistic missile warhead and the B83 strategic bomb. In core punches, images are obtained of the detailed shape of the gas cavity inside a highly compressed pit.

In 2001, Bunker 801 became the Contained Firing Facility after another major upgrade, the addition of a firing chamber to the complex. The debris from test explosions is contained in a more environmentally benign manner than ever—dramatically reducing particle emissions and minimizing the generation of hazardous waste, noise, and blast pressures. With walls up to 2 meters thick and protected by steel plating, the firing chamber is designed to withstand repetitive tests that use up to 60 kilograms of high explosives.



Before completion of the Contained Firing Facility in 2001, tests at the Bunker 801 complex were conducted outdoors (top left). Now the complex (far left) includes an indoor firing chamber (right), which will contain debris and minimize the environmental consequences of tests that use up to 60 kilograms of high explosives. The facility is equipped with the latest diagnostics, including electronic image-converter framing cameras (middle).

1986 W87

Strategic Warheads with Modern Safety Features

In March 1986, the first production unit of the W87 warhead for the Peacekeeper intercontinental ballistic missile (ICBM) was completed at the Pantex plant in Amarillo, Texas. This event culminated a four-year advanced development program executed by the Laboratory in close coordination with Sandia National Laboratories, the Air Force and its contractors, particularly AVCO, which was responsible for the Mk21 reentry vehicle. Peacekeeper carries 10 independently targetable Mk21 reentry vehicles with W87 warheads.

The W87 design is unique for strategic ballistic missile systems in its use of an insensitive high explosive (see Year 1976) and a fire-resistant pit design; both features help to minimize the possibility of plutonium dispersal in the event of an accident. First incorporated in Livermore's W84 warhead design for the ground-launched cruise missile, a fire-resistant pit includes in the weapon primary a metal shell that is able to keep molten plutonium contained. Both the W84 and W87 also include detonator strong links that provide additional safety assurance.

The enhanced safety design features of the W87 were incorporated at an early stage of the development program when Air Force plans called for Peacekeeper, at that time known as MX, to be based in the Multiple Protective Shelter mode. To improve missile survivability in an attack, a large number of moderately hardened shelters would be built, and the ICBMs would be clandestinely shuttled among them, forcing an attacker to target all shelters or to guess which held a missile. Although this plan was later abandoned in favor of basing the missile in Minuteman silos, the enhanced safety features were included in the W87 because they were accommodated within the weight allowance and they provided additional insurance against plutonium dispersal if an accident occurs during operations.

Engineering tests supported the development of the W87 warhead for the Peacekeeper missile, which carries 10 Mk21 reentry vehicles with W87s. Through an ongoing Stockpile Life Extension Program, W87 warheads are being refurbished to extend their long-term use on Minuteman III ICBMs.

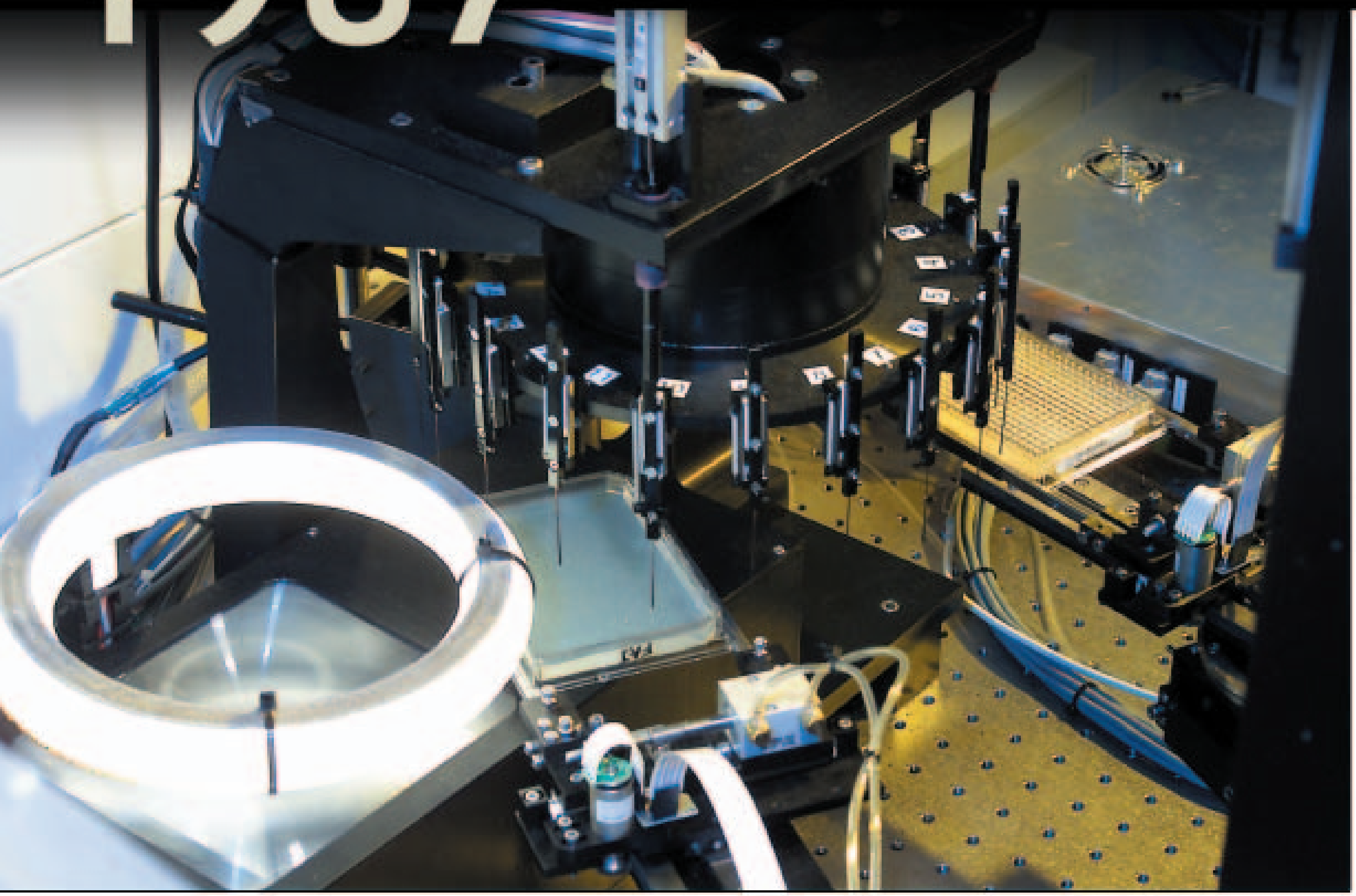
The U.S. has decided to retire Peacekeeper ICBMs and to deploy a large fraction of its W87 warheads on Minuteman III missiles. To prepare for long-term continuing deployment of the W87, a Life Extension Program for the W87 was initiated in 1995 to make some mechanical modifications. The first refurbished warhead under this program was produced in 1999, with all units to be completed in 2004. Extensive ground and flight testing together with detailed calculations using the newly available Blue Pacific supercomputer preceded formal certification of the refurbished W87s in April 2001. Certification without nuclear testing was an important early demonstration of new capabilities developed under the Stockpile Stewardship Program.

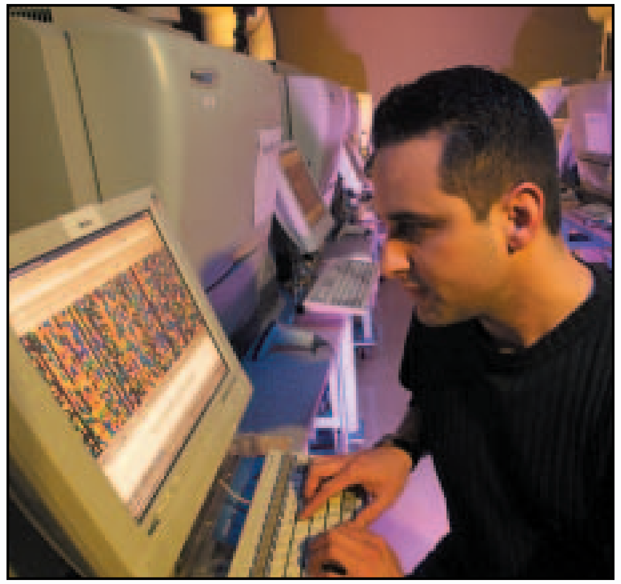
Studies of MX Basing

In 1982, President Reagan set up a commission led by Professor Charles M. Townes (University of California at Berkeley) to evaluate basing options for the MX missile. The commission sought input from a variety of sources, including weapon systems analysts from Livermore's D Division.

Upon conclusion of the study, Townes wrote to University President David Saxon: "It was clear that most of the industrial organizations were quite cautious about giving information or making conclusions which would be contrary to Pentagon policy. I was personally impressed that the many persons who helped us from Livermore seemed completely objective in examining the technical facts, in investigating what needed to be looked into, and in being willing to state plainly, though diplomatically, where they did not agree. . . . I make the above point because I think, contrary to some opinions, Laboratory personnel are often important in giving helpful perspective and ameliorating U.S. nuclear policy, and that this is partly because they are protected by the management structure from the obvious pressures to which commercial or governmental laboratories are subjected."

1987 Human Genome Project





The sequencing process at the Joint Genome Institute (JGI) has numerous steps, four of which are shown here: Colonies of cells containing human DNA are selected from a cell culture plate (above). The CRS robot system (upper right) places a DNA sample plate onto a plate washer for purification of the DNA. A JGI researcher (lower right) removes a plate of purified DNA from a plate washer. A JGI research technician (far right) reviews the sequencing data produced by one of JGI's 84 DNA capillary sequencers.

Deciphering the Human Genetic Code

In 1987, Livermore biomedical researchers began studying chromosome 19. At the same time, Los Alamos began work on chromosome 16 while Lawrence Berkeley was considering decoding chromosome 5. Work had begun in what grew to be an international effort to decode the human genome.

Livermore's involvement in genetic research stretches back almost to its first biological program, chartered in 1963 to study the radiation dose to humans from radiation in the environment (see Year 1963). A natural extension was to explore how radiation and chemicals interact with human genetic material to produce cancers, mutations, and other adverse effects. The Laboratory's work on chromosome 19 dates to a project that examined three genes on chromosome 19 involved in the repair of damaged DNA. By 1984, Livermore and Los Alamos were working together to build human chromosome-specific gene libraries. Advanced chromosome-sorting capabilities, essential to the genome initiative, had been developed at both laboratories.

In 1984, the Department of Energy's Office of Health and Environmental Research (OHER) cosponsored a meeting in Alta, Utah, that highlighted the value of acquiring a reference sequence of the human genome. Leading scientists were invited by DOE OHER to a subsequent international conference, held in March 1986 in Santa Fe, New Mexico, where participants concluded that mapping and then sequencing the human genome were desirable and feasible goals. DOE became the first federal agency to commit to the goal by launching its Human Genome Initiative. This decision was endorsed in an April 1987 report by a DOE Biological and Environmental Research Advisory Committee, which noted that DOE was particularly well-suited for the task because of its demonstrated expertise in managing complex, long-term multidisciplinary projects.

In 1990, DOE joined with the National Institutes of Health and other laboratories around the world to kick off the Human Genome Project, the largest biological research project ever undertaken. Thanks to the commercial development of automated, high-throughput sequencing machines, a rough draft of the sequence of the entire 3 billion base pairs of our DNA—all 23 chromosomes—was completed in 2001, several years ahead of schedule. DOE's Joint Genome Institute (JGI), a sequencing production facility in Walnut Creek, California, sequenced chromosomes 5, 16, and 19. The JGI combines the efforts of Lawrence Livermore, Lawrence Berkeley, and Los Alamos national laboratories.

Since the completion of the draft human genome, the JGI has gone on to sequence mouse DNA, many microbes, and other organisms. The mouse is especially interesting because about 99 percent of its genes are similar to our own. The similarities indicate which parts of the genome are particularly important. A focus of continuing genetic research at the Laboratory, comparative genomics is a useful tool for studying the functions of genes, inherited diseases, and evolution.

Collaboration on Genetic Kidney Disorder

Laboratory bioscientists collaborate in the discovery of sources of genetic diseases. As an example, in 1993, researchers from Sweden and Finland had narrowed their search to chromosome 19 for the gene for congenital nephrotic syndrome, a usually fatal inherited kidney disease that occurs primarily in families of Finnish origin. They contacted the Laboratory for assistance. Livermore bioscientists expedited completion of a physical map of the genetic region in question and sequenced an area that contained 150,000 base pairs. The collaboration paid off. In 1998, researchers announced the breakthrough discovery of one particular gene that was mutated in the families carrying the disease, and the protein associated with the gene was well expressed in the kidneys.

1988 Joint Verification Experiment

Heralding a new era of cooperation, U.S. and Soviet flags fly side by side atop the experiment tower at the Nevada Test Site during the first of two Joint Verification Experiments.

Reducing the Nuclear Threat

In 1988, a landmark event in U.S.–Soviet relations occurred when Soviet and U.S. teams for the first time conducted measurements of nuclear detonations at each other's nuclear testing sites. The event, called the Joint Verification Experiment (JVE), allowed Soviet and U.S. scientists to become more familiar with characteristics of the verification technologies that were proposed to monitor compliance with the Threshold Test Ban Treaty and the Peaceful Nuclear Explosions Treaty. The intent of both treaties was to limit the yield of nuclear explosions to no more than 150 kilotons.

Planning for the JVE took place in Geneva and at the two nation's nuclear test sites. A U.S. delegation made a familiarization visit to the Semipalatinsk Test Site early in January 1988, and a Soviet delegation visited the Department of Energy's Nevada Test Site a short while later.

Russian scientists were on hand to witness the Kearsarge event that was detonated August 17, 1988, on Pahute Mesa at the Nevada Test Site. As a symbol of international good faith and cooperation, the Soviet Union flag was raised to the top of the emplacement tower next to the U.S. flag.

Nearly 150 people from the U.S. traveled to the Semipalatinsk test site to participate in the preparation of the Shagan test on September 14, 1988. Forty-five U.S. personnel witnessed the event, standing just 4 kilometers from the test ground zero.

Both nuclear tests were in the yield range of 100 to 150 kilotons of explosive power. Livermore personnel were heavily involved in fielding the two explosions, with the Laboratory contributing equipment, instrumentation, and technical advice.

For each of the two tests, both sides made hydrodynamic yield measurements in the emplacement hole and in a satellite hole located about 11 meters from the emplacement hole. U.S. scientists carried out CORRTEX (continuous reflectometry radius versus time experiment) measurements. CORRTEX is a technology that measures nuclear yield based on close-in observations of the velocity of the shock wave generated by the nuclear explosion. The Soviets made CORRTEX-like measurements as well as a hydrodynamic measurement using switches. The satellite holes at the test sites were drilled by U.S. personnel with U.S. equipment because of a professed Soviet lack of such capability.

JVE was a turning point in Soviet relations with the West. Many American–Russian friendships were forged, and the more open atmosphere anticipated the post–Cold War era. Since the collapse of the Soviet Union, Laboratory scientists have traveled thousands of miles between Livermore and Russia and the newly independent states. They have monitored and assisted the progress of arms reductions; pursued cooperative efforts to better protect, control, and account for nuclear materials; and collaborated with scientists on nonweapons-related projects.

Associate director J. I. Davis leads a tour of the Nova laser for senior managers from Arzamas and Chelyabinsk (the Russian counterparts to Los Alamos and Livermore) as part of a groundbreaking series of U.S.–Russian lab visits in 1992.

Livermore leads the U.S. team that works with the Russian Navy and Icebreaker Fleet to improve the security of nuclear fuel for their nuclear-powered vessels.

1989 COMPUTING IN PARALLEL

First available from Bolt, Beranek and Newman Advanced Computers Inc. in 1989, the BBN-ACI TC-2000 had a multiprocessing architecture that allowed individual processors to be partitioned into clusters and dynamically reallocated. Because data could be shared within and between clusters, the computer was able to integrate distinct segments of a complex calculation.

Exploring the Future of Scientific Computing

In October 1989, the Laboratory Directed Research and Development office funded the ambitious Massively Parallel Computing Initiative (MPCI), which cut across directorates at the Laboratory and helped redefine high-performance computing as massively parallel computing. The exploratory work performed as part of the initiative—and comparable efforts at Los Alamos and Sandia national laboratories—paved the way for the Accelerated Strategic Computing Initiative (or ASCI, now the Accelerated Simulation and Computing program), which is a vitally important part of the Stockpile Stewardship Program.

Led by Eugene D. Brooks III, the three-year initiative explored the relevance to Laboratory computer applications of then-accelerating trends in commercial microprocessors. Advances in very large-scale integration had increased both computer chip speed and reliability so much that massive, coordinated clusters of microprocessors were sometimes rivaling the performance of custom-designed supercomputers. For example, early tests here with radiation transport codes (used in weapons simulations) suggested a factor of 20 advantage for the massively parallel approach.

In 1990, the MPCI project acquired Livermore's first substantial, onsite massively parallel resource, a 64-node BBN-ACI TC-2000 machine that was upgraded to a full 128-node configuration a year later. Scientists from across the Laboratory's technical directorates probed the software development challenges of effectively using this new architecture by running a variety of computer problems on the MPCI machine. By 1992, early results were already available in such diverse areas as particle-physics event simulation, multidimensional numerical analysis, parallel graphics rendering algorithms, and sedimentation modeling. Each MPCI annual report not only encouraged use of this new approach to scientific computing but also summarized the latest trial programming techniques and output evaluations for Laboratory researchers.

One rewarding long-term effect of the early MPCI work was a heightened desire to widely share centrally managed massively parallel computing resources among many unclassified projects at the Laboratory. In 1996, a formal Multiprogrammatic and Institutional Computing (M&IC) initiative began providing fast, high-capacity parallel computers to program collaborators on and off site, managed by the Livermore Computing program. A Cooperative Research and Development Agreement between the Laboratory and Compaq Computer Corporation led to further design improvements and to the delivery of serial number 1 of the M&IC Tera Cluster 2000 parallel computer in 2000.

The Laboratory's continued investment in such massively parallel computers, in addition to the supercomputers acquired through ASCI, has repeatedly enabled unclassified simulations on groundbreaking projects that complement the classified ASCI work. High-resolution modeling of the response of materials to extreme temperature and pressure, of the consequences of global warming and climate change, and of the interaction of proteins and genes have all resulted from software innovations developed using these parallel computational resources at Livermore.

CIAC: Keeping Cyberspace Safe

On February 1, 1989, the Department of Energy formed the Computer Incident Advisory Capability (CIAC) at Livermore. A continuous stream of security incidents had begun the previous year, affecting computer systems and networks throughout the world. Crackers and intruders made bold headlines with their stealthful entry into government computers, commercial equipment, and telephone systems. The world of computers was proving to be a dangerous one, and clearly something needed to be done. CIAC's primary mission has been to help and protect the DOE computer community. The list of federal clients has grown to encompass other agencies, and in several instances, CIAC has worked with the Federal Bureau of Investigation to respond to incidents.