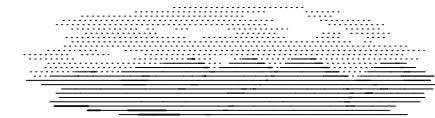


DATELINE LOS ALAMOS

ACCELERATOR TECHNOLOGY IN LINE WITH NATIONAL INTERESTS

PROBING THE STRUCTURE OF MATTER
FOR DEFENSE, INDUSTRY, AND BASIC SCIENCE

Los Alamos is refocusing the mission of its accelerator complex to respond to the increased national need for a steady and reliable source of neutrons for defense and civilian applications. Along with its new mission, the accelerator complex has acquired a new name: the Los Alamos Neutron Science Center, or LANSCE. The new facility will take full advantage of existing infrastructure and accelerator technology developed at Los Alamos over the last 50 years, while incorporating new design features to make LANSCE the most advanced neutron-scattering facility in the world. Neutron scattering — a reaction in which neutrons are scattered by target nuclei rather than absorbed by them — is one of the most effective tools for elucidating the structure and dynamics of physical and biological materials.



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↑
Protons at the Los Alamos accelerator begin their journey here, in the domes at the top of three of these Cockcroft-Walton accelerators. By the time the particles leave this section, they have been accelerated to 7,440 miles per second (4 percent of the speed of light). From here, the beams pass through low-energy transport systems where they are steered, focused, and bunched for injection into the second stage of the accelerator. This photo also appears on the cover of this issue.

The Los Alamos Neutron Science Center accelerator has produced particle beams for hundreds of experiments and thousands of scientists worldwide for nearly a quarter of a century.

Commissioned in 1972 as "LAMPF" or the Los Alamos Meson Physics Facility, it is still the most powerful linear proton accelerator in the world, with an output power of about one megawatt. To create neutrons for the neutron-scattering facility, part of this powerful accelerator beam is channeled through a proton storage ring to create more intense and shorter "bunches" of protons.

One application of neutrons produced via accelerator technology is currently under review by the U.S.

Department of Energy as a safe, cost-effective way of meeting the nation's long-term tritium supply for nuclear weapons. Tritium — a radioactive form of hydrogen — boosts the explosive power of nuclear warheads. The United States needs a reliable, continuous supply of tritium to maintain its smaller, post-Cold War stockpile of nuclear weapons.

Until 1988, tritium came from dedicated DOE production reactors that have since been rendered inactive. With no new nuclear weapons in production and the U.S. moratorium on nuclear testing, current requirements are being met by recovering tritium from dismantled



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weapons. But tritium is radioactive and decays at about 5.5 percent a year, so a new tritium production facility must be operating within the next 10 years to sustain the remaining weapons and maintain the U.S. nuclear deterrent.

Only two practical systems exist that can make enough neutrons to produce tritium: reactors and accelerators. In a reactor, nuclear fission supplies the neutrons. Accelerators avoid the use of fissile material, an advantage that eliminates any chance of a criticality accident and avoids the generation of high-level nuclear waste.

Los Alamos is leading a multi-laboratory effort to design and develop a low-energy demonstration accelerator at LANSCE, which will serve as a prototype for the tritium-production system proposed for the DOE's Savannah River Site in South Carolina.

The need for the U.S. to maintain a safe and reliable nuclear weapons stockpile for the indefinite future in the absence of nuclear testing presents a significant new challenge to the DOE weapons complex.

Careful attention to the underlying science and the production process is required for scientists to provide dependable certification of the enduring stockpile as it ages substantially beyond its originally envisioned lifetime or undergoes gradual replacement with units produced by different plants and processes than the original ones.

Retaining confidence in the safety and reliability of weapons in the aging stockpile can only be derived from a thorough understanding of the physical processes that bring about a nuclear explosion.

The DOE's Stockpile Stewardship and Management Program has been developed to address these challenges. A broad range of capabilities such as plutonium chemistry and metallurgy, high-performance computing, and dynamic experimentation are required to carry out this program. LANSCE is a critical component of this program, providing intense neutron and proton beams for a broad range of weapons applications associated with stockpile assessment and refurbishment.

In addition to defense research activities, neutrons are an indispensable tool to civilian researchers. LANSCE will contribute to many scientific fields, including condensed matter physics, materials science, chemistry, fundamental nuclear and particle physics, structural biology, engineering, and geology.



A view of the interior of the second stage of the Los Alamos accelerator, the drift-tube linac, where particles are accelerated to 80,000 miles per second (43 percent of the speed of light).



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The third and longest stage of the accelerator is the side-coupled-cavity linac, where protons are accelerated to their final energy of 800,000,000 electron volts, moving about 157,000 miles per second (84 percent of the speed of light).

Neutrons, which reside in the nucleus of an atom, are equal in mass to their proton neighbors, but unlike protons, or electrons that orbit the nucleus, they carry no charge. This neutrality means neutrons are a very penetrating, thus useful, form of radiation. Neutron-scattering technology is complementary to X-ray diffraction, electron microscopy, magnetic resonance, and other technologies used to probe structures on a microscopic level.

Neutron scattering is important for the study of high-temperature superconductors, polymers, new-generation catalysts, and magnetic materials. Neutrons also have a key role to play in clarifying the relationship between biomolecular structure and function. This knowledge is crucial to advancements in modern molecular medicine and biotechnology.

The LANSCE facility will allow industrial scientists to incorporate neutron scattering into manufacturing processes for commercial products such as automotive parts, steel bearings, tire rubber, polymer solutions for oil recovery, and magnetic films for next-generation magnetic storage devices. LANSCE will allow comprehensive and detailed studies of residual and induced strains in engineered components and permit the history of fabrication to be followed.

A unique capability that has been developed at LANSCE is the measurement of transmission diffraction spectra using a single beam pulse. This method has already been used to study the phase evolution that is part of the preparation of a special tough steel used for ball bearings and to suggest changes to the manufacturing process that would reduce the time and energy needed.

A team of IBM and Los Alamos scientists working at LANSCE has discovered that irradiating high-temperature superconductors with energetic protons significantly improves their critical current-carrying capability, making their use in practical applications more realistic.

A great advantage of a research facility based at a proton accelerator is that the multiple research and development activities can be carried out simultaneously. This allows the synergism between different disciplines to be exploited, and permits ideas to flow between academic, industrial, and defense sectors. ♦



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A HISTORY OF ACCELERATORS AT LOS ALAMOS

IT'S A PARTICLE WORLD AFTER ALL

In spite of many advances in accelerator technology over the last 50 years, the basic principle of particle acceleration remains simple: An electric field surrounds a beam of charged particles — typically protons or electrons — and accelerates them to higher and higher energies.

Although the basic principle of particle acceleration is simple, execution is not. Designing an accelerator requires creativity and ingenuity, and operating an accelerator is sometimes more an art than a science. Accelerators fall into two categories: linear or circular. The linear accelerators, or linacs, move particles in a straight line. This

design was first developed by Ralph Wideröe in 1928 and later refined by Luis Alvarez. The circular machine moves particles in a doughnut-shaped path. Ernest Lawrence conceived this design in 1929 and dubbed his invention the "cyclotron."

Accelerators have been work horses at

Los Alamos since the Laboratory's inception. As early sources of neutrons, accelerators were used to direct low-energy beams on light elements such as lithium to study the nuclear reactions relevant to weapons physics. Four accelerators arrived at Los Alamos in



Three of the five accelerators used at Los Alamos during World War II. Clockwise from the top: the Harvard Cyclotron, the Illinois Cockcroft-Walton, and the Wisconsin Short Tank.

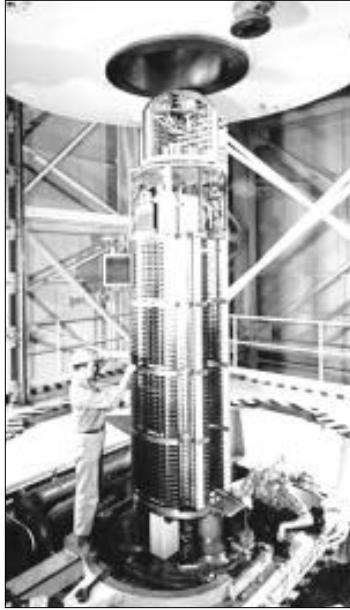




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The vertical Van de Graaff accelerator. Recently shut down, the accelerator was in use at Los Alamos for 40 years.



the spring of 1943: a Cockcroft-Walton from the University of Illinois, which produced neutrons of 2.5 million electron volts; two Van de Graaffs from the University of Wisconsin, which produced neutrons with energies between a few hundredths of an MeV and several MeV; and a cyclotron from Harvard University, which produced neutrons with even lower energies.

These accelerators made it possible for the Manhattan Project scientists to determine the critical masses of plutonium and uranium. Both fuels were so scarce that direct measurements were impossible. Another challenge was to find a way of preventing a "fizzle," or

predetonation, in the plutonium bomb — a problem that could arise from the spontaneous fission of fuel impurities. The accelerators made it possible for the scientists to study neutron-induced fission at all the relevant neutron energies.

In December 1944, Los Alamos acquired a circular electron accelerator known as a betatron. The betatron provided X-ray-like images of a mock sphere of fuel during implosion. This diagnostic technique helped solve the problem of uneven collapse in the implosion weapon design that ultimately became "Fat Man."

After World War II, Los Alamos retained three of the wartime accelerators and built a high-energy Van de Graaff accelerator to replace one of the Wisconsin models, which went home after the war. As relations between the United States and the former Soviet Union went into a deep freeze, the Laboratory built two electron linacs to provide radiographs of the implosion process in thermonuclear bombs.

That work eventually led to construction in 1963 of PHERMEX — pulsed high-energy radiographic

A Cockcroft-Walton accelerator.





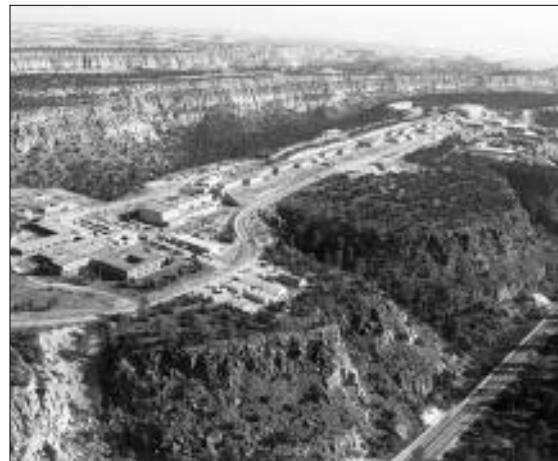
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machine emitting X-rays — a huge electron accelerator that generates X-rays by accelerating an electron beam into a tungsten target. Still in operation at Los Alamos, PHERMEX was used recently to study the strength of ceramic tank armor.



The LAMPF beam channel is excavated in 1969.

In 1946 the first proton linac, designed by Alvarez, was built at the University of California. A linac accelerates charged particles with a series of electrical pushes, each of which increase the particles' energy by an amount that is small compared to the total energy gain desired.



→
An aerial view of the LAMPF complex and the surrounding mesas.

The Alvarez design would later form the drift tube linac, or the guts of the low-energy portion of "LAMPF," the Clinton P. Anderson Meson Physics Facility, built on a mesa top at Los Alamos National Laboratory in the late 1960s.

↓
Louis Rosen (standing center right) and others celebrate as the LAMPF linac produces its first 800 MeV beam on June 9, 1972.

If the World War II accelerators were scientific work horses, then LAMPF has been the nuclear physics community's work elephant for more than two decades.

Los Alamos physicist Louis Rosen, the chief architect of LAMPF, proposed the idea of a new high-intensity proton accelerator in 1962. Since most accelerators at that time were being designed to achieve higher energies per particle rather than more particles per unit time, Rosen predicted such a facility would supply an abundance of particles known as pi mesons to study in new ways nuclear interactions and the





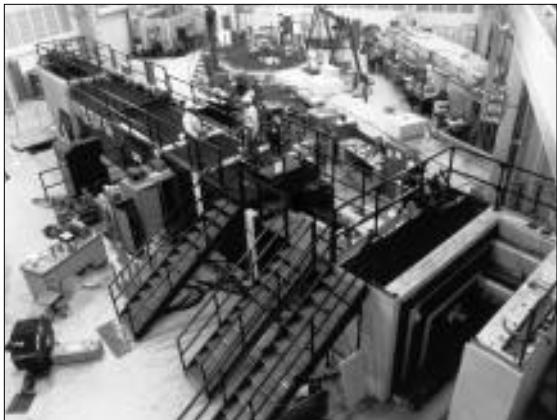
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structure of nuclei. The idea quickly gained support among his colleagues.

A small Los Alamos team led by Darragh Nagle and Ed Knapp rejected a number of different designs before perfecting a design in 1965 known as the side-coupled cavity linac that could accelerate high-intensity beams of protons to 800 MeV. In 1967 a working prototype proved the viability of their concept and construction began on LAMPF, a half-mile-long linear accelerator that generates a medium-energy proton beam more intense than any other beam in the world.

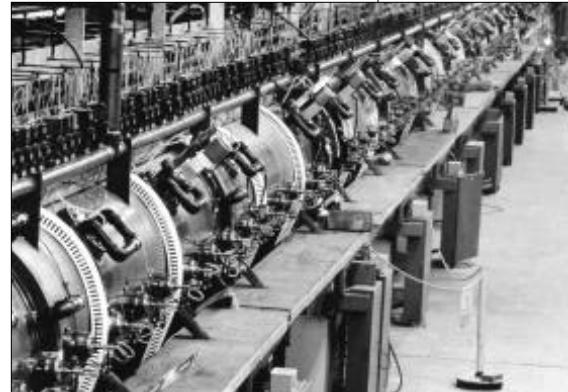
The ground-breaking for LAMPF was held on Feb. 15, 1968. The facility was completed four years later and officially named the Clinton P. Anderson Meson Physics Facility because of the late New Mexico senator's long-time interest in and support of Los Alamos National Laboratory.

→
An experiment hall at the
Manuel Lujan
Jr. Neutron
Scattering
Center.



proton-induced spallation of heavy-metal nuclei to produce an intense supply of neutrons over a range of energies.

LAMPF was built nearly 25 years ago to study nuclear reactions involving energetic protons or pions. Now one of those reactions — proton-induced spallation — is the basis of a new neutron-scattering facility to be built at Los Alamos. That facility is "LANSCE," the Los Alamos Neutron Science Center. ♦



The side-coupled cavities, where highly intense pulses of protons are accelerated to 800 MeV.

Los Alamos recently refocused the accelerator's mission to serve the nation's need for a steady and reliable source of neutrons for defense and civilian applications. By upgrading LAMPF's existing facilities, scientists can use



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LANSCE LAUNCHES RESEARCH CRITICAL TO STOCKPILE STEWARDSHIP

ACCELERATOR FACILITY PROVIDES INTENSE
NEUTRON AND PROTON BEAMS
FOR A BROAD RANGE
OF WEAPONS APPLICATIONS

The one-year-old stockpile stewardship program at the Los Alamos Neutron Science Center has already made significant contributions to the Department of Energy's Stockpile Stewardship and Management Program. By providing intense neutron and proton beams for a broad range of weapons applications associated with stockpile assessment and refurbishment, LANSCE is a key national resource for maintaining confidence in the nuclear weapons stockpile in the absence of nuclear testing.

The Stockpile Stewardship and Management Program focuses on five critical issues:

- ♦ Annual certification of performance and reliability — Ensuring that the weapons in the stockpile are capable of fulfilling their deterrence missions.
- ♦ Safety — Characterizing how weapons would perform in unusual and adverse conditions, such as an accident.
- ♦ Stockpile aging — Predicting the effects of aging on a weapon's performance and reliability, and knowing how to respond with appropriate life-extension measures.
- ♦ Weapon rebuilding and small-scale production — Maintaining the capacity to rebuild stockpiled weapons and replace any weapons that have been destroyed in the surveillance process.
- ♦ Ensuring a tritium supply — Producing a sufficient inventory of tritium, which is critical to the long-term availability and performance of nuclear weapons.

This article discusses seven research areas at LANSCE and their importance to these critical issues.



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DYNAMIC RADIOGRAPHY

Without nuclear testing, the only means available for studying the integral performance of a weapon during implosion is hydrodynamic testing. For many years, X-ray radiography has been a key diagnostic tool for these tests. However, the current need for more detailed information pushes X-ray technology into a very challenging realm. Using high-energy proton beams instead of X-rays as radiographic tools is now being explored by LANSCE researchers as a more powerful means of taking dynamic "snapshots" of implosion experiments at a future facility. This research will have an important bearing on annual certification, safety, and stockpile aging issues.

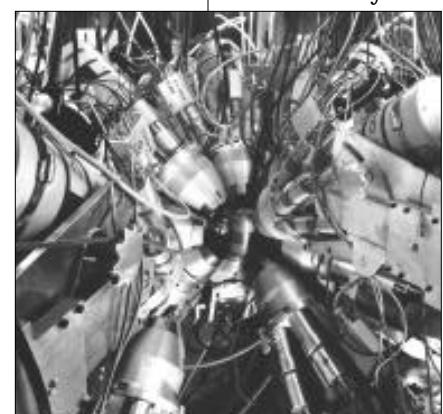
STATIC RADIOGRAPHY FOR NONDESTRUCTIVE SURVEILLANCE

Certifying weapon components in an aging stockpile requires information on the condition of light weapons materials, such as hydrogen, that lie inaccessible under dense materials, such as uranium. Radiographic techniques that use neutrons in a manner analogous to CAT scan technology probe nondestructively the mechanical structure of the lighter materials and eliminate the need to disassemble the part. LANSCE scientists are exploring the use of fast, thermal, and cold neutrons for a number of surveillance applications.

WEAPONS NUCLEAR DATA

Nuclear physicists at LANSCE are using an advanced gamma-ray detector array in conjunction with high-energy neutron beams for the first time anywhere. With this array, they will explore nuclear processes relevant to nuclear weapons and help interpret the impressive archive of diagnostic measurements left behind by a long history of nuclear weapons testing.

By measuring nuclear cross sections not easily accessible by other means, they will provide precise benchmarks for the sophisticated weapons simulation codes needed to certify the safety and reliability of the aging stockpile. The Accelerator Production of Tritium program will benefit from similar benchmarking studies carried out with other detector instruments at LANSCE.



The GERmanium Array for Neutron-Induced Excitations (GEANIE) is a multi-million dollar, high-efficiency, high-resolution, gamma-ray detector array used in weapons nuclear data studies at LANSCE.





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WEAPONS MANUFACTURING PROCESS STUDIES

Neutron scattering techniques at LANSCE can assess the quality, uniformity, performance, and expected lifetime of weapons components. These capabilities will be increasingly important for stockpile certification, aging, and rebuilding, since many replacement parts will be manufactured by new production processes in a different production complex.

Many components are fabricated using casting, forging, welding, and brazing processes. These processes produce residual internal stresses that may affect a part's response to shock, thermal cycling, radiation, and other environmental conditions. A LANSCE technique called neutron diffractometry provides the only means of obtaining this information throughout the volume of thick parts.



Researcher Rob Robinson stands atop the PHAROS inelastic scattering instrument, which will be used to study the character of plutonium's interatomic bonds.

WEAPONS MATERIALS CHARACTERIZATION

LANSCE studies of the fundamental properties of plutonium and other weapons materials provide a better understanding of how materials behave under the extreme conditions of high-pressure shocks induced by high-explosives.

For example, studies that investigate the nature of the interatomic bonds that hold plutonium atoms in their lattice will provide information that will be important in developing more sophisticated models of weapons materials behavior. When incorporated into advanced simulation codes, these models will provide the chief means by which safety, performance, and reliability of the aging stockpile is assessed.

HIGH-EXPLOSIVES CHARACTERIZATION

Information guiding the computational modeling of the sensitivity and performance of pristine, aged, damaged, or remanufactured high explosives is crucial for understanding nuclear weapons safety.

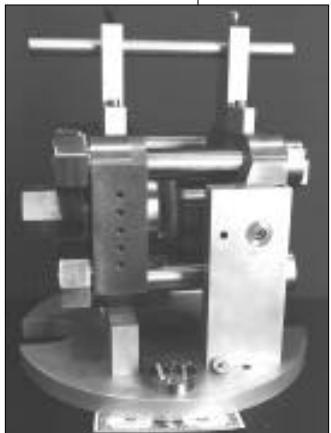
LANSCE efforts in this area include two types of experiments: characterizing the microstructure and other materials properties of high explosives using well-established neutron scattering methods (but never before applied to high explosives), and employing a new experimental technique called neutron resonance radiography to study temperatures and



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velocities in the interior of reacting high explosives. This new technique promises to be the only feasible way to make accurate measurements in an explosive environment that may exist for only millionths of a second. The very intense, short bursts of low-energy neutrons available at LANSCE are the key to the feasibility of these measurements.

DYNAMIC MATERIALS RESPONSE



Another application of the neutron resonance radiography technique mentioned above is direct investigation of the behavior of weapons materials under transient high-pressure (for example, shock wave) conditions. This technique provides more information on the behavior of shocked materials on a macroscopic scale that is fundamentally more complete than has ever before been available.

Studies of this kind complement studies of microscopic properties discussed in "weapons materials characterization," but they address the same need for more sophisticated modeling of materials behavior. Work that demonstrates the practicality of these measurements is now in progress at LANSCE.



A high-pressure cell for neutron-scattering studies. This cell, which was developed by materials scientists in France, holds weapons materials samples at high static pressures while detector instruments record neutron-scattering data.

IN CONCLUSION ...

The LANSCE program for stockpile stewardship has made significant advances toward its research objectives in the year since its inception. Each of the key issues in DOE's Stockpile Stewardship and Management Program is addressed by one or more of the LANSCE research areas discussed above. These advances would not have been possible without the collaborative efforts and broad interdisciplinary mix of talent contributed by LANSCE researchers and their colleagues throughout the weapons research community.

The synergism among many elements of the defense, basic, and applied research communities at Los Alamos and elsewhere, particularly Lawrence Livermore National Laboratory in California, has turned the stockpile stewardship effort at LANSCE from a vision into a growing reality.

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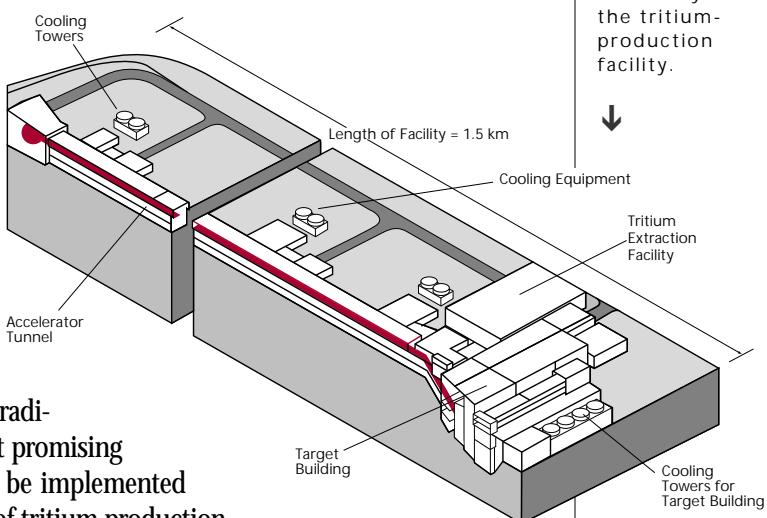
TRITIUM PRODUCTION VITAL TO LONG-TERM SAFETY AND RELIABILITY OF NUCLEAR WEAPONS STOCKPILE

LOS ALAMOS COLLABORATES
WITH OTHER NATIONAL LABORATORIES
TO DESIGN A SAFE, SIMPLE METHOD
OF TRITIUM PRODUCTION

By 2007, the United States will need a steady and reliable source of tritium to maintain the viability of its nuclear weapons stockpile. Present tritium requirements are being met through the reuse of tritium recovered from dismantled nuclear weapons, but this will not be sufficient for future needs. So, the Department of Energy is evaluating two methods of producing tritium: a reactor-based system and an accelerator-based system.

In December 1995, Secretary of Energy Hazel O'Leary announced the decision to pursue a "dual-track" strategy, funding development of both reactor- and accelerator-based systems for tritium production.

The Accelerator Production of Tritium Project, or APT, led by Los Alamos, will build and test critical components of the accelerator system and will participate in the design of the plant. The DOE will support other laboratories in the development of reactor-based tritium targets and examine the policy and regulatory issues associated with the purchase of a commercial reactor or irradiation services. The most promising method of the two will be implemented as the primary method of tritium production.





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Tritium, an isotope of hydrogen, is used to increase the explosive power of nuclear warheads. Tritium occurs naturally, but rarely, and has a radioactive half-life of 12.3 years. A radioactive half-life is the average time required for one-half of any quantity of radioactive atoms to undergo radioactive decay. Although no new weapons are being produced, tritium in stockpiled weapons must be replaced periodically to ensure their reliability and performance.

Production of tritium at a quantity sufficient to maintain the nuclear weapons stockpile requires an abundant source of neutrons. The most efficient way to make neutrons with an accelerator is through a nuclear reaction process called spallation. In spallation, high-energy particles bombard atoms in a target material, producing neutrons and other secondary particles.

The source of the high-energy particles in the APT system is the proton-beam injector, located at the front of the accelerator, which ionizes



Researcher Joe Sherman demonstrates how the proton injector accelerates ionized hydrogen atoms to form a low-energy proton beam.



hydrogen atoms to form a low-energy proton beam. Subsequent sections of the accelerator gradually increase the speed of the protons. The design of the APT accelerator calls for a linac that is approximately one mile in length and accelerates a proton beam to 92 percent the speed of light — about 171,000 miles per second.

At the accelerator exit, the beam is expanded to distribute protons evenly across the face of the target. The expanded proton beam strikes a tungsten-and-lead target initiating a spallation process that produces about 43 neutrons per proton. To form tritium, helium gas captures the neutrons once they have been slowed by heavy water. Tritium produced in the target is extracted continuously and purified at the tritium-extraction facility.

Los Alamos has been studying the advantages of an accelerator-based tritium production system since the late 1980s. Recently, a team of Los Alamos-led scientists and engineers from several U.S. national laboratories and industry have designed an accelerator-based



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More than 50 industry leaders recently toured the proton accelerator at LANSCE after they were briefed on using an accelerator to produce tritium for the nation's nuclear weapons stockpile. From left to right are Dwayne Wilson, Fluor Daniel Inc.; Robert Taussig, Bechtel National Inc.; and Jim Stovall of Los Alamos.



tritium production system based on well-established, existing technology in operational accelerators, tritium extraction, and neutron targets.

The design, completed in late

1994, used expertise from Los Alamos, Brookhaven, Lawrence Livermore, and Sandia national laboratories as well as the industrial companies Bechtel, Babcock & Wilcox, Northrop-Grumman, General Atomics, Maxwell Balboa, and Merrick.

The design of an accelerator-based tritium production system is based on 23 years of operating experience at LANSCE (formerly LAMPF), the Los Alamos high-power linear accelerator, or linac, and its associated spallation neutron sources.

Accelerators such as LANSCE have demonstrated exceptional performance under long-term, factory-like conditions, operating 24 hours a day, seven days a week with periodic shutdowns for maintenance. Virtually all APT components have been sufficiently demonstrated to provide confidence that the plant will operate as designed and produce all the tritium required to supply the stockpile.

Accelerator Production of Tritium has several advantages, the greatest of which is that neutrons are produced in a spallation process (without fissile materials) and, therefore, has no chance of a criticality accident. Furthermore, no spent nuclear fuel is generated.

The system can be shut off almost instantaneously, and once shut down, does not generate neutrons. Tritium is extracted constantly from the production area in the APT system, preventing buildup of tritium as in reactors, and thus greatly reducing the possibility of a release of radioactivity into the environment.

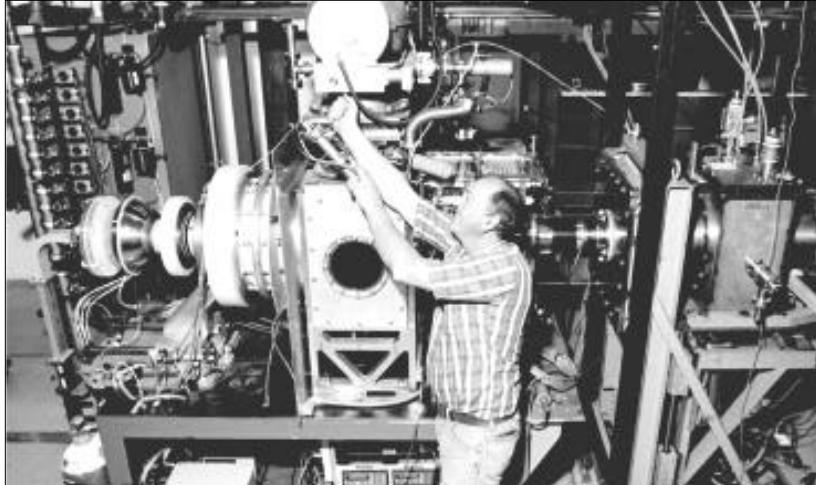
Although nuclear reactors can also be used to produce tritium, accelerator-based technology does not jeopardize the long-standing United States practice of separating the use of commercial nuclear power equipment from military material production.



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Researcher Dave Hodgkins makes a minor adjustment to the proton injector. This is a prototype of the injector to be built for the Low-Energy Demonstration Accelerator at Los Alamos.



To ensure that APT can be built on schedule and on budget, Los Alamos is assembling a low-energy demonstration accelerator to verify long-term performance. Scientists will demonstrate the production efficiency of APT with prototype targets using a low-power beam at LANSCE.

Participation in the technology demonstration as well as plant design and construction will be done by a prime contractor who will be selected by the DOE late this summer. If the DOE selects APT, the Savannah River Site in South Carolina will be the preferred location for a tritium production plant because of its long-standing expertise and capability in handling tritium.

Total cost for the project — estimated in 1995 — is approximately \$2.9 billion. Annual operating costs are estimated at \$120 million to \$200 million, depending on the cost of electricity.

Accelerator Production of Tritium is a safe, environmentally benign method of producing tritium to ensure the viability of our nuclear weapons stockpile.

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WHAT IS TRITIUM?

Tritium is a radioactive form of hydrogen that is made naturally in small amounts in the atmosphere. It also can be made artificially in any quantity for purposes ranging from medical to military.

Tritium generates a weak type of radiation known as beta emission. Beta particles cannot penetrate clothing or skin; however, by breathing in water-vapor containing traces of tritium, or by eating or drinking tritium-contaminated food or water, tritium can be a serious health hazard — even lethal in extremely large doses.

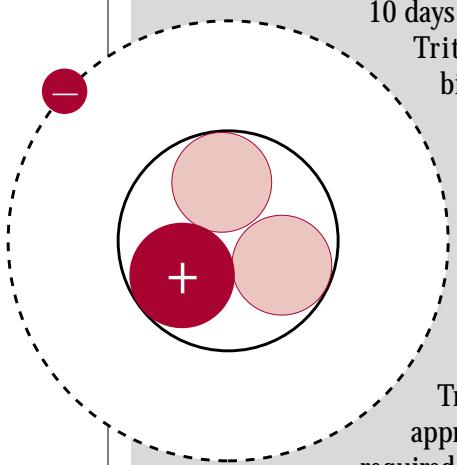
Tritium has a biological half-life of approximately 10 days, which means if a person ingests tritium, it takes the body approximately 10 days to rid itself of half the amount ingested.

Tritium's weak radiation and 10-day biological half-life make it an important tracer for studying biological processes or testing the effectiveness of new pharmaceutical drugs.

Cosmic rays produce some tritium in the upper levels of the atmosphere, and rainwater is usually found to contain minute amounts of tritium.

Tritium has a radiological half-life of approximately 12.3 years — the average time required for one-half of any quantity of radioactive atoms to undergo radioactive decay into a stable or less-radioactive daughter product.

Tritium production for defense applications requires either a nuclear reactor or an accelerator. Both systems produce neutrons, which are then captured by lithium or helium atoms, converting them to tritium. The Department of Energy is currently evaluating both systems as a potential future source of tritium.



A tritium atom is composed of a nucleus containing one proton and two neutrons and one orbiting electron.



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LOS ALAMOS APPROACH ELIMINATES NUCLEAR WASTE

TRANSMUTATION PROCESS TRANSFORMS
LONG-LIVED RADIOACTIVE MATERIALS
INTO SHORT-LIVED MATERIALS

A Los Alamos approach to reduce the long-term hazards and storage requirements of radioactive nuclear waste could solve one of the world's most pressing environmental problems.

More than 1,000 tons of plutonium exist today in the spent fuel of the world's nuclear reactors. An additional 80 tons are added each year from the same reactors. The inventory of plutonium already separated from reprocessed spent fuel is more than 130 tons and steadily growing, and plutonium from dismantled nuclear warheads is now contributing to this large excess.

Los Alamos researchers are developing an accelerator-driven transmutation technology that bombards nuclear wastes with neutrons and transmutes them into stable or short-lived products. This procedure transforms radioactive materials into a form that allows cheaper and safer disposal.

Current plans for high-level waste generated by nuclear reactors and nuclear weapons research and development are to store it in isolation for tens of thousands of years until its radioactivity decays to safe levels. In 1987, Congress selected Yucca Mountain, Nev., as the nation's first site for the geological storage of high-level nuclear waste. The Los Alamos Accelerator-Driven Transmutation of Waste concept offers a potential alternative to the geological storage of nuclear waste.

The Los Alamos transmutation concept begins with an accelerator that directs medium-energy protons (1,000 million electron volts) onto a target of liquid lead. Each proton creates an energetic spray of about 30 neutrons. The target is surrounded with molten salts, such as lithium and beryllium fluoride, which contain less than .1 percent of actinides such as plutonium. When long-lived radionuclides, including plutonium,

Spent fuel rods from nuclear reactors, such as those pictured below, must sit in storage for thousands of years. The Los Alamos waste transmutation system would eliminate the need for managed storage of fuel rods and other high-level nuclear waste.





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americium, neptunium, technetium, and iodine absorb a neutron they transmute into nuclides that are not radioactive or into nuclides whose radioactivity decays much faster, thus eliminating the need for protected storage beyond a few hundred years. Transmuting to short-lived nuclides is an important advantage because it is much easier to engineer and guarantee a containing structure for this shorter time frame.

The intense fluxes of slow neutrons allow high transmutation rates with modest waste inventories. As the system converts the waste into stable or short-lived radioactive elements, chemical-separation processes continuously remove undesirable neutron-absorbing products. The heat produced in the transmutation process can be converted efficiently into electrical energy — about five times the electrical energy required to power the accelerator. (See related article in this issue of *Dateline*.)

The power of a typical linear accelerator designed for large-scale waste transmutation would be roughly 50 times greater than the existing Los Alamos accelerator. Producing the required accelerator is considered a relatively straightforward extension of today's technology.

The U.S. nuclear power industry currently practices a "once-through" fuel cycle. Once the spent fuel is removed from a reactor it must be stored virtually forever. Other nations reprocess the fuel by removing the plutonium and recycling it into new reactor fuel rods. President Jimmy Carter rejected the reprocessing method in 1977 because it concentrates plutonium into a form that can be extracted and used for nuclear weapons. There is still no large-scale reprocessing done in the United States and more than 28,000 metric tons of spent fuel reside in holding pools at U.S. nuclear reactor sites.

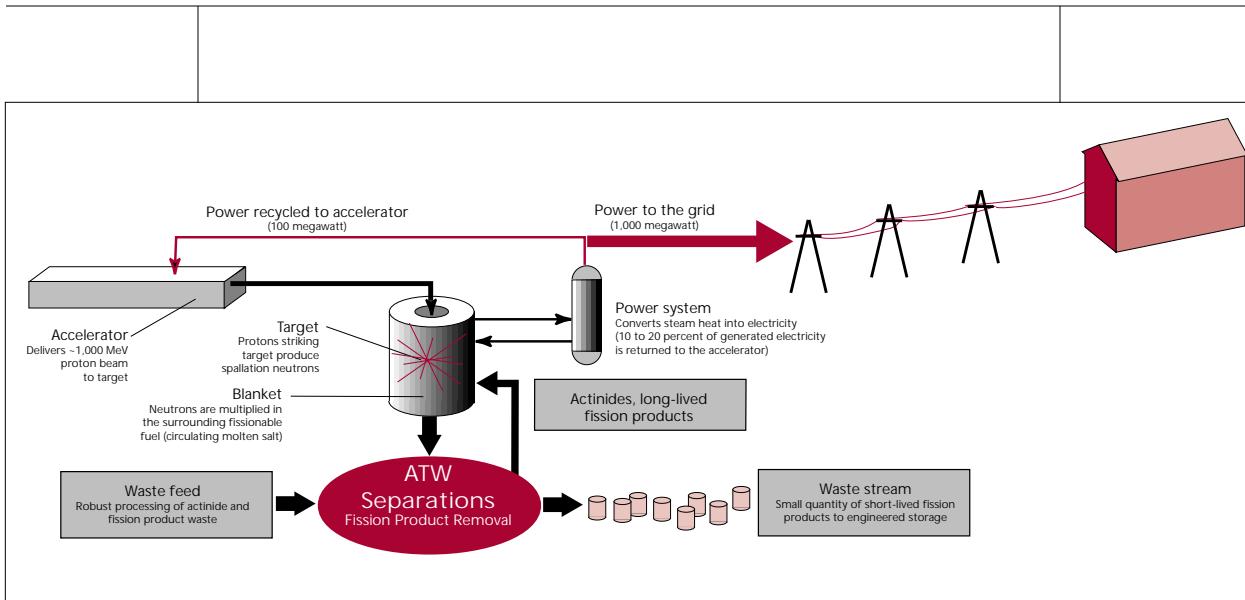
In the short term, unprocessed spent fuel is relatively inaccessible to terrorists because it is mixed with highly radioactive fission products. But over the long term, large and growing quantities of this spent fuel, the spread of plutonium separation technology, and the gradual reduction in radioactivity from the fission products will make the plutonium contained in spent fuel increasingly accessible.

Reducing the inventory of plutonium and other fissile materials makes them easier to safeguard and diminishes the likelihood the materials will be diverted for weapons use.

The accelerator-driven transmutation technology is a robust, efficient, and complete waste-treatment system. The robustness of the subcritical accelerator-transmutation system allows it to accept a wide range of



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The Accelerator
Transmutation
of Waste, or
ATW, process.

nuclear waste, from defense spent fuel and scrap plutonium to commercial spent fuel. No plutonium-breeding material, such as uranium, is exposed to the neutron flux.

The system will transmute plutonium and most other components of nuclear waste efficiently because the transmuter needs only a small inventory of radioactive materials to operate. The system will operate to a high degree of completeness, leaving little untreated waste for long-term storage and reducing the potential hazard of any waste that is stored by eliminating its long-lived radioisotopes and chemically mobile fission products.

After a successful development and demonstration period, accelerator-driven transmutation technology will be available to transmute, over a few decades, the hundreds of tons of plutonium accumulated in worldwide inventories. An aggressive effort to develop and demonstrate the transmutation technology could see the first full-scale plant in operation by 2010.

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RUSSIANS COLLABORATE

WITH LOS ALAMOS ON

ACCELERATOR TRANSMUTATION OF WASTE

More than 300 weapons scientists from the former Soviet Union are cooperating with Los Alamos researchers on the development of Accelerator Transmutation of Waste.



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Los Alamos scientists Charles Bowman, Harry Dewey, and Ed Arthur join Dr. Kiselev, deputy director of ITEP, in toasting the future of Project 17 during the seminal November 1993 Transmutation Conference in Moscow.

Los Alamos researchers anticipate that their Russian counterparts will contribute a great deal to the success of the ATW program because of the Russians' highly specialized skills and their desire to redirect their efforts from weapons design to the challenging problems related to the handling and elimination of nuclear waste. The collaborative effort, known as Project 17, is sponsored by the Industrial Science and Technology Center.

Russian participation in the Laboratory's ATW effort began in October 1993. Guidelines for Project 17 were laid out in Moscow at the Institute of Theoretical and Experimental Physics during a conference on transmutation technology. The Russian laboratories of Chelyabinsk, Arzamas-16, Obninsk, Kurchatov, and the Institute of Theoretical and Experimental Physics have been prominent in the Project 17 collaboration. Project activities have ranged from theory and system studies to experimental nuclear physics and engineering.



The ISTC will fund some new ATW-related projects beginning this October. These projects include the study of liquid lead targets at the Institute of Power Physics and Engineering in Obninsk, the study of volatile extraction from molten salt systems at Kurchatov, presently not available nuclear cross-section measurements of fission products at Arzamas-16, innovative blanket design and large-scale molten salt loops at Chelyabinsk, and accelerator design at Yerevan, Armenia.



The Russian design group from Chelyabinsk at work on the ATW project shortly after Project 17 was initiated.



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ACCELERATOR-DRIVEN ENERGY PRODUCTION

ELECTRICITY FOR THE FUTURE

CAN BE PRODUCED WITHOUT SIGNIFICANT GENERATION OF WASTE

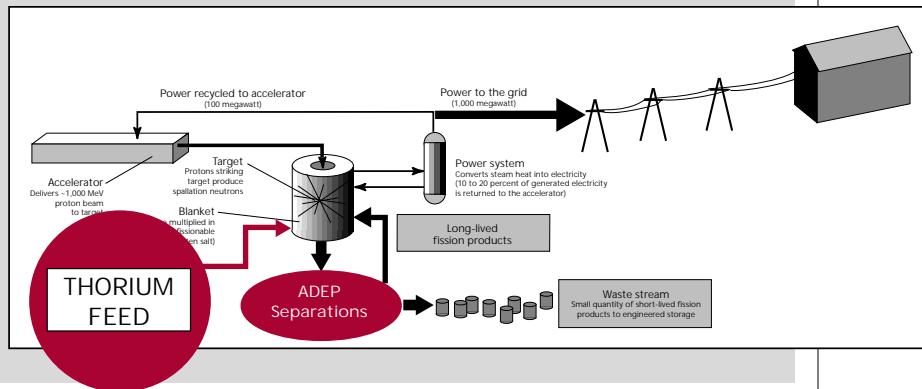
Scientists envision that the Los Alamos Accelerator Transmutation of Waste concept will not only destroy materials that pose hazards to both world peace and the environment, it will produce a safe, clean, and economic source of electricity.

Because of its versatility, the accelerator transmutation technology described in the previous article will be able to produce electricity as efficiently as today's nuclear reactors by using thorium once the supply of nuclear waste and spent fuel is exhausted. Thorium is a readily available natural element that exists in nearly limitless supply.

The thorium-based transmutation system generates virtually no plutonium and a negligible amount of waste that will not require management for thousands of years. The system will destroy its own long-lived fission products.

The system is safe because the thorium-based Accelerator-Driven Energy Producing system, or ADEP, unlike a nuclear reactor, contains too little fissile material to sustain a chain reaction and a supply of enriched fuel is not needed because the system itself generates the extra neutrons necessary for the thorium cycle to perform efficiently.

By adding thorium, ATW becomes ADEP, a safe, efficient, minimally polluting energy production system.





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As in the waste-burning Accelerator Transmutation of Waste system, the process begins with an accelerator-generated source of neutrons surrounded by an assembly consisting of a graphite moderator and a fuel that produces energy through fission. The fuel is embodied in the coolant — a lithium-beryllium-fluoride molten salt — to ensure a high-temperature, high-efficiency operation. The net power produced is five times that needed to drive the accelerator.

The system will constitute a major advance in technology from today's reactors. First, the assembly is subcritical and cannot sustain a chain reaction without the accelerator beam on. (Switch the beam "off" and the power drops instantly.) Second, the system generates no significant amounts of plutonium and the heat energy comes from the transmutation processes. The heat is then used to produce steam, which powers a turbine to produce electricity.

Thorium exists in sufficient quantities to support future worldwide electrical needs many times greater than today's for thousands of years. Thorium-producing mines are located in the United States, Brazil, the former Soviet Union, China, India, and Australia. Thorium also is used to manufacture sun lamps, incandescent lighting, medicines, ceramics, and electrodes.

A single truckload of thorium would be enough to power an accelerator-driven energy system for its projected lifetime of 30 to 40 years. A single accelerator-driven system could provide power to a city of more than half a million people.

The worldwide consumption of electricity is expected to increase 50 to 75 percent by 2020, according to the World Energy Council. Accelerator-Driven Energy Production from plutonium, spent fuel waste, and ultimately thorium could be a reality within the next 15 years.

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DATELINE: LOS ALAMOS

NEUTRON SCATTERING GIVES RESEARCHERS A PEEK INSIDE ADVANCED MATERIALS

TECHNOLOGY MAKES POSSIBLE
NONDESTRUCTIVE TESTING ON A WIDE VARIETY
OF INDUSTRIAL PRODUCTS

To design improved materials for industrial applications, scientists build on their understanding of existing materials, a large part of which comes from information about their structures. Neutron scattering can provide that information, often in situations where other techniques fail.



Successful neutron-scattering experiments require an intense source of neutrons to be directed at a sample because only a small fraction of the neutrons are scattered; the rest pass through the sample without being scattered or absorbed. At certain energies neutrons can penetrate solids and liquids up to 10,000 times more effectively than X-rays. Their neutrality and the weakness of their interactions with matter allow neutrons to provide information about a material's bulk, as opposed to its surface structure, and they do so nondestructively.



John Thomas (left) and Joyce Roberts (center) work with Hans-Rudi Wenk, a user from the University of California at Berkeley, to prepare ice samples for textural studies.

Neutron scattering is a proven tool for uncovering residual stresses that can be induced in materials during fabrication or in components after service. The consequences of residual stresses can be devastating, ranging from the unexpected failure of critical engineering components to the cracking of railroad tracks leading to train wrecks. Other techniques exist for identifying residual stress, but in many cases neutron scattering is the only nondestructive way of spotting and measuring the stress deep in the interior of engineering materials.

Since the 1950s, the origins of residual stress have been investigated and measured extensively to understand how they cause failures and how they can be prevented or controlled. It is easy to see gross changes in metal or plastic when a heavy load causes them to buckle or stretch. But residual stresses cannot be seen with the naked eye or measured directly. Neutron scattering gives researchers a way to understand the changes at the atomic level that result from applied stress. At the Manuel Lujan Jr.



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Neutron Scattering Center, Los Alamos researchers are working in a variety of programs with industry and academia to develop the relatively new tool of pulsed neutron scattering — a tool that provides a unique, nondestructive method of measurement for a range of advanced materials.

For example, there is currently considerable interest in the automobile and aerospace industries in using composite or heterogeneous materials for stronger, lighter engine parts because they offer increased fuel efficiency and reliability. However, because composites consist of two or more materials mixed intimately, they are difficult to study using conventional methods.

Because of their penetrative strength and ability to distinguish between different materials, neutrons have proved an invaluable aid in understanding the performance of new materials. Recently, Los Alamos scientists collaborated with researchers from General Electric to measure residual stresses in one such composite. The material, titanium reinforced with continuous fibers of silicon carbide, is intended for use in high-temperature regions of jet engines. Its performance in this demanding environment depends strongly on the residual strains that crop up wherever the two materials interface.

In a similar study, Los Alamos scientists recently worked with a researcher from the Massachusetts Institute of Technology to study microstructural changes in a pellet-sized sample of nickel-titanium when the sample was loaded with 11,000 pounds. The researchers studied the reversible atomic re-orientation between two crystalline structures — austenite and martensite. The reversible action is an effect called "shape memory" and is desirable in products such as eyeglass frames: In the event the frames are bent, they pop back to their original shape.

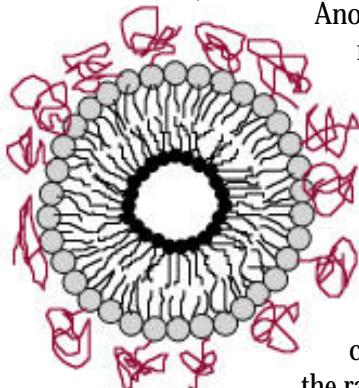
Although the scientists knew that nickel-titanium possessed the property of shape memory, neutron-scattering technology revealed the actual atomic transformations that occurred when a load was applied to a sample. The knowledge will help scientists find a way to stiffen nickel-titanium by reinforcing it with another material without sacrificing any shape memory in the process. This type of reinforced composite would be desirable in products that would benefit from shape memory but require more stiffness than that exhibited by the relatively low strength of the pure nickel-titanium material.

Mark Bourke prepares a high-temperature stress test. At LANSCE scientists use the stress rig to measure strain — an effect of stress — in each constituent of a composite material simultaneously. Measurements are made under both applied stress and high temperature.





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Medicine encapsulated in the center of this polymer stays in the body longer, increasing the probability of it being absorbed, rather than shed. Neutron-scattering measurements allow researchers to determine the exact structure of polymers.

Another aspect of residual strain research allows the measurement of strains at different positions inside deformed objects. For example, these strains are prevalent in steam pipes or pressure vessels which typically contain residual stresses from bending and welding during fabrication. In many cases these components are subjected to steady loading at elevated temperatures.

To predict the lifetime of this type of equipment in high-temperature environments such as electric power or chemical processing plants, manufacturers need to predict the rate of growth of any defects: a rate that depends on the presence of residual stress.

Los Alamos researchers in collaboration with scientists from the Imperial College in London used neutron scattering to examine how residual stresses evolve in a steel alloy used to make steam pipes. Their measurements will help manufacturers determine to what extent these stresses influence component lifetimes.

In polymer research, neutron-scattering techniques help scientists understand a polymer's behavior by providing the data needed to construct structural models of different materials and their interactions with each other.

Polymers are chains of repeating molecules that have a variety of material and biochemical applications. Although polymers are common in everyday products such as plastic containers and the nonstick coating on metal cookware, some fundamental questions remain as to how they interact with solvents and other materials and how they actually modify surface properties.

In a collaboration between Los Alamos and Sandia National Laboratories of Albuquerque, researchers investigated ways of enhancing the adhesion between copper and epoxy, a type of bonding common to circuit boards found in television sets, computers, even nuclear weapons. Any breakdown in the mechanical bonding between materials can have devastating effects on a component's reliability.

The researchers examined the feasibility of using special co-polymers to strengthen the chemical bridges between the two materials. A co-polymer is composed of two different types of polymers. In this example, one of the co-polymer's free ends formed a chemical bond with copper, while the other preferred to mix with epoxy.



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The researchers determined that by dipping a copper-coated silicon wafer in a polymer solution containing a weak solvent, they could orient the co-polymer molecules to ensure that the copper-binding end came in contact with the copper film. This orientation strengthened the bonding between the the copper film and the polymer. These results are the first step in developing circuit boards with better material-to-material adhesion.

The pharmaceutical industry is interested in using polymers as vehicles to transport drugs through the body. By encapsulating medicine in a structure that resembles a human cell decorated with hairy polymer arms, the medicine remains in the body for days rather than hours, thus increasing the probability it will be absorbed, not shed. By adding a sugar or a protein to the polymer's outer surface, it can be broken down by one type of cell and remain impenetrable to all others. This built-in specificity allows researchers to design drugs that treat disease sites such as tumors, without affecting the body's normal tissue.

Neutron scattering measurements make it possible for researchers to model the molecular structure of co-polymers. The models then help them design more effective drug therapies and predict a drug's consequences on the human body.

During the past decade, neutron-scattering techniques also have revealed the structure of the first high-temperature superconductors; the structure of buckminsterfullerenes, or bucky balls; the conformation of molecules in a polymer melt; the interfacial structure of artificially produced polymeric and magnetic layers; the spin dynamics of highly correlated electron systems; and the condensate fraction in super fluid helium, among others.

The Lujan Center provides neutron beams with a higher peak intensity than any other facility in the world, allowing scientists to perform experiments more quickly and on smaller samples. As more neutron spectrometers are added and the annual operating time is increased over the next few years, the Lujan Center has the potential to become the world's most productive pulsed-spallation source.

Greg Smith places a copper-epoxy sample in a polymer bath. The polymer strengthens the chemical and mechanical bonds between copper and epoxy — a finding that will help scientists improve the reliability of circuit boards.



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NEUTRON STUDIES REVEAL THE STRUCTURE OF A NEW TYPE OF CHEMICAL COMPOUND

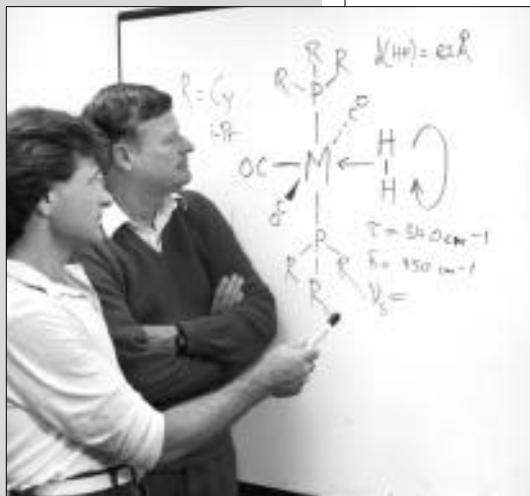
DISCOVERY COULD LEAD TO NEW, CHEAPER,
MORE-EFFECTIVE CHEMICAL CATALYSTS

Neutron scattering is effective in determining the structure and dynamics of new chemical compounds and catalysts. In a particular example, Los Alamos chemist Gregory Kubas and physicist Juergen Eckert used the technique to discover a new kind of chemical bonding — the stable hydrogen-metal complex — that has revolutionized the way chemists perceive how catalytic hydrogenation works.

Kubas was studying the effectiveness of various transition metals, such as molybdenum and tungsten, in catalyzing the conversion of sulfur dioxide, an atmospheric pollutant, into benign elemental sulfur. In the process, he realized that the product of one of these reactions contained a molecule of hydrogen bound to an atom of the transition metal.

Prior to Kubas' study, scientists generally believed that a hydrogen molecule could not bind to another atom, but would always split into two separate hydrogen atoms before undergoing a chemical reaction. Kubas proved that a stable hydrogen-metal molecule can exist under normal laboratory conditions. The structure of one of the new compounds was definitively demonstrated by the use of neutron-diffraction technology in collaboration with Los Alamos chemist Phil Vergamini.

Neutron scattering technology allowed Greg Kubas (right) and Juergen Eckert to determine the structure of a stable hydrogen-metal molecule involved in catalytic hydrogenation.





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This discovery was recognized as one of the most important findings in chemistry in the 1980s and has spawned related work in more than 50 research groups worldwide.

Eckert later probed the propeller-like rotation of the hydrogen molecule bound to the side of the metal atom with inelastic neutron scattering. His work proved a crucial chemical bonding force that both stabilizes the hydrogen molecule's bond to the metal and promotes the chemical reactivity of hydrogen. This so-called "activation," or weakening, of the strong hydrogen-to-hydrogen bond also applies to other chemical bonds such as the carbon-to-hydrogen bond in hydrocarbons.

One of the "holy grails" in chemistry is selectively transforming the methane in abundant natural gas to liquid fuels such as gasoline or methanol. Kubas' hydrogen-metal complex recently has been found to bind and activate the silicon-hydrogen bond in silane (SiH_4), a close relative of methane. Neutron studies of these compounds are in progress.

Because some evidence exists that metal-bound hydrogen and related molecules are directly involved in chemical catalysis, the discovery could lead scientists to new, cheaper, and more-effective chemical catalysts than those presently used in research and industry. Hydrogen is used in the largest volume commercial chemical reactions in the world, such as in crude-oil refining to remove sulfur and also to produce 10 billion tons of ammonia per year for fertilizers.

Although present catalysts are effective, the enormous volume of such reactions means any small improvement could translate into large savings in cost. Ammonia production is particularly energy intensive, and scientists have for decades looked to find a more efficient way of making it. The studies of how small molecules such as hydrogen are activated on metals could lead to a solution for this problem.

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FUNDAMENTAL LIFE PROCESSES INVESTIGATED WITH NEUTRON SCATTERING

EXPERIMENTS YIELD PRECISE
THREE-DIMENSIONAL MOLECULAR MODELS

Many of the techniques and areas of expertise applicable to research on nuclear weapons are also applicable to research on structural biology. Neutron scattering is one such technique. When combined with other advanced laboratory techniques such as stable-isotope labeling, neutron scattering gives scientists a way of obtaining precise three-dimensional pictures of important chemical structures. Because in nature form usually follows function, understanding the architecture of a biological molecule is the key to understanding how the molecule functions.

Some of the most significant experiments to date have focused on molecules involved in biochemical regulation. People rarely give much thought to the complex biochemical processes behind simple actions such as blinking an eyelid or lifting a glass. But one of the key issues in biochemistry is the question of how reactions are switched on and off or accelerated and decelerated in different types of cells, at different stages of development, and in response to external and internal signals.



Jill Trewella aligns the X-ray beam on the small-angle X-ray scattering instrument. Researchers use the instrument to obtain information on the overall shape of a molecule and to identify the solution conditions that will give the best small-angle neutron-scattering measurements.





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Los Alamos researchers Brian MacDonald (left) and Roy Nielsen prepare for X-ray scattering experiments at the computer data station.



Scientists already know that a breakdown in the regulation of these chemical processes can lead to disease or death; but to develop treatments and cures to fix the problems, they must first understand how the processes work.

The key to understanding biochemical processes lies in a complex network of chemical messengers, transmitters, and receivers that orchestrate the time and rates of reactions in response to physiological stimuli.

One of the simplest messengers involved in biochemical regulation is the doubly charged calcium ion, Ca^{2+} . Calcium typically binds to a number of different receptor proteins, the most ubiquitous of which is calmodulin. The resulting calcium-calmodulin complex then binds to and activates one of a number of different enzymes. These target enzymes are involved in a variety of biological functions, including muscle contraction, neurotransmitter release, and generation of metabolic energy from glycogen.

Neutron-scattering experiments at Los Alamos helped researchers understand how one macromolecule, the calcium-calmodulin complex, manages to regulate such a number of diverse enzymes. The sites on the target enzymes to which the calcium-calmodulin binds are as chemically diverse as the enzymes are functionally diverse. So, while calcium-calmodulin is the key that unlocks the actions of a variety of enzymes, the locks vary on each enzyme.

The Los Alamos researchers knew from previous studies by other scientists that the calmodulin protein had an unusual dumbbell-shaped structure with two football-shaped ends interconnected by a helical region. Two calcium binding sites exist on each of the dumbbell's ends.

Neutron scattering experiments allowed the researchers to observe calcium-calmodulin acting on a number of target enzymes and identify two general types of interaction.



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In the most common interaction, the helical region flexes so that the dumbbell collapses around a target enzyme. Imagine a person bending over and wrapping his arms around a bulky load. Just as a person can lift many types of loads, the flexibility of the helical region allows the molecule to collapse around different types of enzymes with different chemical surfaces.

In the other type of interaction, the calmodulin retains its dumbbell shape with the helical region of the macromolecule still extended when it binds to a target enzyme. The flexibility of the helical region allows this single molecule to accommodate diverse enzyme targets, while the constant chemical surface of the protein, which is independent of the overall conformation, programs specificity into the structure by requiring certain complementary features in the target.

Another protein, troponin C, resembles calmodulin in structure, but has the highly specialized function of triggering muscle contraction. Los Alamos researchers recently were able to elucidate the structure of the complex of troponin C with its regulatory target troponin I, which together serve as a switch for coordinated muscle action.

Each muscle cell contains bundles of thick and thin filaments. As the muscle contracts or relaxes, these filaments slide past each other. Researchers already knew that the movement of these filaments is regulated by a pair of protein molecules, troponin C and troponin I, that respond to the presence or absence of calcium. But until the Los Alamos researchers studied the problem, no one had a good model of how this protein pair did its job.

To discover how the protein molecules are linked and see how they interact, the researchers used neutron scattering and a stable-isotope labeling technique that substitutes deuterium for hydrogen. Deuterium is a heavier form of hydrogen whose atoms have an additional proton and neutron. The number of neutrons in an atom makes a fundamental difference as to how the neutrons scatter, so a molecule labeled with deuterium casts a distinct neutron shadow.

The researchers found that when calcium binds to troponin C, which is at all times locked into the muscle fibers, the troponin I molecule (which inhibits muscle action in the absence of calcium) is wrapped around and anchored to troponin C. In this form, the troponin complex triggers the formation of a protein bridge between the thick and thin filaments of the muscle cell.



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The bridge works like a lever to slide the thick and thin filaments past each other, causing the muscle to contract. When calcium is removed, troponin C releases its hold on troponin I, which then is free to bind to its alternate thin filament site, thus restoring its inhibitory function, and the muscle relaxes.



This reversible action happens at multiple sites on every filament in a cell simultaneously and there are hundreds of filaments in each muscle cell. When the muscle cells respond to the calcium switch in harmony, your eyelid blinks or your fingers grasp the paper. A paper summarizing this research appeared in the December 1994 issue of the journal *Biochemistry*.

The Los Alamos research on biochemical regulators may not lead to new treatments or cures in the short term, but it helps researchers understand the molecular basis for diseases, specifically those that are the direct result of a breakdown in biochemical regulation.

Neutron-scattering experiments have been carried out at the Laboratory's accelerator complex on a number of macromolecules in solution, including the complexes formed by antibodies and the foreign substances they target for elimination; chromatin, the structural fabric of DNA, and certain proteins that modulate the accessibility of genetic material to replication and transcription; complexes of DNA with other proteins; and viruses. All of the studies enabled researchers to obtain structural information about individual components of the macromolecules.



Griselda Hernandez prepares a biological sample for a neutron scattering experiment.

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DATELINE: LOS ALAMOS

A FUTURE OF NEUTRONS

POWERFUL NEUTRON SOURCE

SUPPORTS BASIC AND APPLIED RESEARCH

Every successful shopping center has as its anchor a large department store to draw in crowds of shoppers. Without a Neiman Marcus or a Saks Fifth Avenue, centers or malls are reduced to a smorgasbord of specialty stores that serves only a small, select group of customers. While a retail center is a far cry from a scientific research laboratory, Los Alamos' most important "anchor store" may soon be the Los Alamos Neutron Science Center, or LANSCE.



With LANSCE, Los Alamos can become the U.S. center for the development and use of spallation neutron sources for defense, research, and commercial applications. As

other articles in this issue describe, the laboratory already has powerful sources that produce short pulses of neutrons. In addition, the Laboratory is in the enviable position of having a powerful enough accelerator to be able to build a new neutron source — referred to as a long-pulse spallation source — that will complement the existing short-pulse capabilities and position the United States as a leader in neutron research. The new source can be built relatively quickly and with little technical risk.

Neutron science has contributed to many advanced technologies and provides basic knowledge that underpins U.S. economic competitiveness in vitally important industrial sectors such as automotive, aerospace, electronics, biotechnology, pharmaceuticals, materials, chemicals, and petrochemicals.

Since its beginning in 1987, the Manuel Lujan Jr. Neutron Scattering Center at Los Alamos has been open to scientists from industry, academia, and other national laboratories. The Lujan Center has made its share of scientific contributions, some of which are covered in this issue of *Dateline*. However, despite the successes and importance of neutron-scattering technology to basic and applied research, the United States has not kept pace with Europe in nurturing neutron-scattering programs. At present, the most productive program exists at the Institut Laue-Langevin reactor in Grenoble, France.



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The establishment of a long-pulse spallation neutron source at LANSCE together with the short-pulse spallation source already there will provide neutrons over a uniquely large range of energies for probing all kinds of materials. The proposed long-pulsed source will have 1 megawatt of power — more than 16 times the 60-kilowatt power of the Laboratory's current short-pulse spallation source. However, the most important aspect of the source will be its long pulses of neutrons, which are ideally suited for research using low energy, or "cold," neutrons. In contrast, the short neutron pulses already generated at the Lujan Center are best for materials research with more energetic, or "hot," neutrons. The two sources are complementary because each excels for a different type of scientific research.

Hot neutrons have short wavelengths and are used to probe the distances between neighboring atoms in materials. Changes that occur in these distances when, for example, a material is stretched or compressed can give engineers insights into the way the material may fail in use. Cold neutrons with their longer wavelengths probe the larger features in solid materials. In this context, large means many times the distance between neighboring atoms but still much smaller than can be seen with an optical microscope. Polymer molecules, which consist predominantly of chains of carbon and hydrogen atoms, and molecules of biological importance, such as proteins, can be examined using cold neutrons.

For material studies that use cold neutrons, the proposed long-pulse source will have the potential to perform neutron-scattering experiments as much as four times more quickly than the world's current best source for this purpose: the nuclear reactor at the Institut Laue Langevin. In some cases, the superior performance of the long-pulse source will make possible experiments that otherwise could not be done.

In addition to neutron scattering, the proposed long-pulse source will provide excellent capabilities for radiography, a technique used in the surveillance of nuclear weapons. For this reason, both the basic research and defense communities stand to benefit from the long-pulse spallation neutron source.

Los Alamos is working with the Department of Energy to devise a funding strategy for construction of a long-pulse source at LANSCE.

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BRIEFLY ...

The Los Alamos Neutron Science Center is a national facility for defense, basic, and industrial research available for use by members of the world's scientific community. At the heart of LANSCE is a half-mile-long linear accelerator that provides intense beams of protons with energies up to 800,000,000 electron volts. Scientists submit proposals to use LANSCE by completing a simple application form found on the world wide web. Approval is based on advice from program advisory committees that examine the scientific merit of proposed basic research and the relevance of defense research to stewardship of the nation's nuclear stockpile. In the past, the LANSCE accelerator produced beams for experimentation for about four months out of the year, but upgrades now under way will permit five months of operation in 1996, six months in 1997, and eight months per year from 1998. Fifty to 100 users a month conduct experiments at LANSCE on topics ranging from strain in engineered components to irradiation of electronic components of high-flying aircraft. For more information about the LANSCE users' program, call Amy Longshore at 505-665-5353, send e-mail to user_program@msmail.lansce.lanl.gov, or see the LANSCE home page on the world wide web (<http://www.lansce.lanl.gov>).

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LOS ALAMOS NATIONAL LABORATORY

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LINE WITH NATIONAL INTERESTS
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