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DATELINE LOS ALAMOS

THE PLUTONIUM FUTURE

LOS ALAMOS DEVELOPS TECHNOLOGIES AND STRATEGIES TO MEET THE CHALLENGES POSED BY EXCESS PLUTONIUM

For 50 years the superpowers of the world sought to increase the number of weapons in their nuclear stockpiles — weapons fueled by plutonium. Luckily for mankind, the Cold War is over. Strategic arms reduction treaties and agreements have brought an end to weapons buildup, but the treaties have resulted in another dilemma: What should be done with the excess plutonium taken out of dismantled weapons?

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Together the United States and Russia have more than 200 tons of weapons-grade plutonium, much from dismantled nuclear weapons. Due to strategic arms reduction treaties and agreements made since the end of the Cold War, the two nations are expected to retire thousands more weapons from their nuclear stockpiles within the next decade. This voluntary downsizing of nuclear arsenals will remove many additional tons of plutonium and highly enriched uranium from military control.

According to a recent study on the "Management and Disposition of Excess Weapons Plutonium" by the National Academy of Sciences, the existence of this material constitutes a clear and present danger to national and international security.

The availability of plutonium and highly enriched uranium is key to the creation of nuclear weapons by proliferators or terrorists. Highly enriched uranium can be blended with natural uranium to make safe fuel for commercial reactors. Plutonium cannot be diluted effectively because theoretically all isotopes can be used to make a nuclear explosive. Preventing plutonium from being diverted into the hands of terrorists or nations desiring a nuclear capability is imperative to our national security.

A potentially bigger plutonium problem exists in the spent fuel of civilian nuclear reactors. The worldwide inventory of reactor-grade plutonium is close to 1,100 tons and swells by as much as 70 tons every

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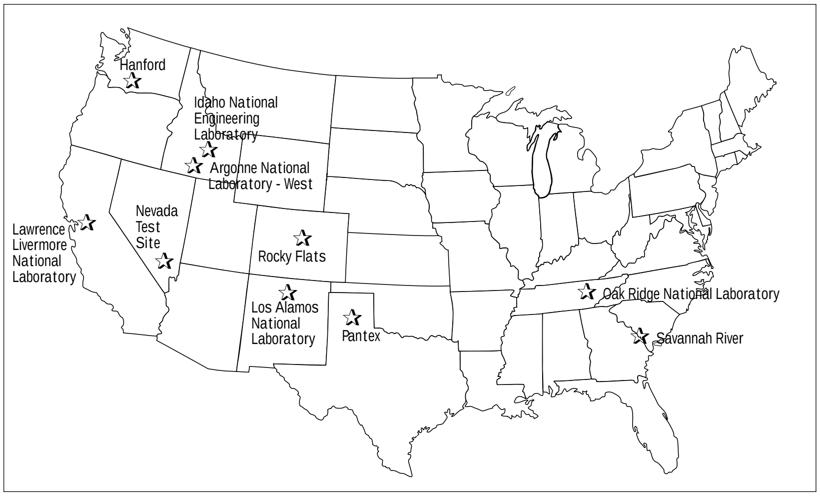

Who's got the weapons plutonium? The largest amounts are at Pantex and Rocky Flats.

year. Added to these inventories are the plutonium residues that remain in weapons facilities as a legacy of Cold War weapons buildup.

Los Alamos has more than half a century of experience in managing and handling plutonium and other nuclear materials. The same plutonium expertise required to maintain a nuclear deterrent will serve as a technical foundation for solving the many problems surrounding the management and disposal of excess plutonium and related materials. This issue of *Dateline: Los Alamos* summarizes researchers' efforts to secure the future against threats posed by excess plutonium.

Los Alamos is the technological leader in removing plutonium from retired nuclear weapons and converting it into forms appropriate for inspection by international auditors. The Laboratory also is taking the lead in converting weapons-grade plutonium into reactor fuel, which could significantly reduce the excess plutonium inventory and produce electric power for civilian applications.

Nuclear weapons will remain a cornerstone of U.S. national defense and a primary component of Los Alamos' compelling central mission to reduce the global nuclear danger. On Aug. 11, 1995, President Clinton announced the importance of maintaining a nuclear deterrent and the necessity of retaining high confidence in the safety and reliability of weapons remaining in the enduring stockpile.

Los Alamos — along with other national laboratories — is meeting the challenge of maintaining the nation's nuclear deterrent under current treaty conditions that disallow nuclear testing through a program known as science-based stockpile stewardship. The program provides the science and technology necessary to verify the quality of nuclear weapons that will remain in the stockpile long beyond their originally designed lifetimes.

Two critical components of the science-based stockpile stewardship program — surveillance and limited production of nuclear weapons pits, or fissile material — are unique to Los Alamos and essential to maintain the credibility of the nation's nuclear deterrent.

ON THE COVER:

A plutonium-238 heat source rests on a crucible. These heat sources powered space missions in the 1970s. The same technology will be used to help power the Cassini orbiter and Huygens probe that will be launched October 1997 toward Saturn. The spacecraft will explore the giant gaseous planet, its mysterious rings, and some of its frigid moons.

The work of Los Alamos scientists in the protection and management of nuclear materials includes lab-to-lab interactions with nuclear centers of the former Soviet Union to establish control over and accountability for nuclear material.

Reducing the nuclear danger requires Los Alamos to help clean up the legacy of 50 years of weapons buildup. Los Alamos and other defense laboratories are directing resources and technical talent to remediating environmental problems in the defense complexes of the United States, the former Soviet Union, and other countries as well.

Beyond the DOE complex, Los Alamos is a technology leader in defining advanced nuclear strategies and systems for future use in managing plutonium inventories from civilian reactors. Two examples of work in this area include development of nuclear fuels that do not generate additional plutonium as a byproduct of energy production, and accelerator-based systems that can use plutonium as fuel while converting the same material into a less long-lived radioactive product.

Finally, through its Nuclear Vision Project, Los Alamos is developing and assessing strategies and technologies that could be applied toward issues of rising global stocks of plutonium, which could lead to strengthened safeguards and nonproliferation measures for future nuclear power systems. ◆

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THE HAZARDS OF PLUTONIUM

RISK AND REALITY

Plutonium is a dense, brittle, silvery metal that feels warm to the touch because of energy released in the form of alpha particles. Plutonium delivers a negligible radiation dose to human skin because the heavy alpha particles do not have enough energy to penetrate clothing or skin.

If ingested, plutonium is mostly passed by the body. However, specks of plutonium oxide can become airborne and inhaled into the lungs. If the specks are small enough, they are hard for the body to dislodge, and eventually can lead to cancer. Inhaled plutonium is far more hazardous than ingested plutonium because it is more readily absorbed into the blood stream. However, plutonium can migrate from either the lungs or the gastrointestinal tract through the bloodstream to concentrate in the bones and liver.

➔ Plutonium has been called the “most toxic substance known to man.” ABC’s Joan Lunden holds a sphere of clad metal during a visit to the Lab’s Criticality Facility in 1993.

Plutonium has been called the “most toxic substance known to man.” Although this label has been refuted many times by scientists, the misconception persists that even a tiny amount of plutonium taken into the body will be fatal.

Plutonium’s reputation as the world’s pre-eminent poison was born in the aftermath of Nagasaki and Hiroshima, when the Nagasaki nuclear explosion delivered lethal doses of plutonium oxide into the lungs of

Japanese citizens. Scientists estimate that inhaling 20 milligrams of plutonium dust of optimal size would lead to death in about a month from pulmonary fibrosis or pulmonary edema. Ingestion of about 0.5 gram of plutonium would be necessary to deliver an acutely lethal dose of radiation. For comparison, ingestion of less than 0.1 gram of cyanide can cause sudden death.

No one disputes the lethal bursts of radiation unleashed from a bomb's fissioning of critical amounts of plutonium or uranium. However, the health risks of plutonium in its elemental, non-critical form have been grossly exaggerated in the popular press.

Plutonium is hazardous, but it is not as immediately hazardous to human health as many more common chemicals. To place plutonium's danger in a real-world context, physicist Bernard Cohen once made an offer to nuclear critics to ingest a pellet of plutonium if one of them would swallow an equal quantity of pure caffeine. To date, no one has taken him up on his offer.

This is not to downplay plutonium's potential toxicity, because chronic exposure to even small amounts should be prevented. Inhalation of less than acutely lethal quantities of plutonium will still result in an increased chance of getting cancer. For statistical comparison, an inhaled mass of 0.0001 milligram of plutonium decreases life expectancy about 15 days, while smoking a pack of cigarettes a day reduces life expectancy by more than six years. ◆

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THE FATHER OF PLUTONIUM

GLENN SEABORG REMEMBERS THE SCIENCE AND THE SILLINESS

Fifty-five years ago, Glenn Seaborg co-discovered plutonium, an element integral to the making of the first atomic weapon. During World War II, he headed the group of scientists at the University of Chicago's Metallurgical Laboratory that devised the chemical extraction processes used to produce plutonium for the Manhattan Project.

Seaborg, now a professor of chemistry at the University of California at Berkeley, said he and his colleagues named plutonium, element 94, after the planet Pluto because it came after neptunium on the Periodic Table. Logically, the element should have been named "plutnium," but Seaborg liked the way "plutonium" rolled off the tongue. They also assigned plutonium the "Pu" symbol, instead of the more logical "Pl," as a prank and waited for criticism from the scientific community. To date, no one has questioned the label.

← In 1941, Glenn Seaborg (below) and three colleagues at Berkeley discovered plutonium. They displayed their sample in an old cigar box for a photographer. Photo courtesy of Lawrence Berkeley Laboratory

Seaborg and his colleague Arthur Wahl, a Los Alamos chemist, submitted a secret report that described the chemical properties of neptunium and plutonium to the Uranium Committee in Washington in 1942. The report was declassified in 1948 for publication in the Journal of the American Chemical Society.

It wasn't the only time Seaborg took a circuitous route in announcing his discoveries. In 1945, a few days before he planned to announce the discovery of two transuranium elements at a scientific conference held by the American Chemical Society at Northwestern University in Chicago, Seaborg served as a guest scientist on the "Quiz Kids" radio show. The show's format featured exceptional youngsters aged 5 to 15 who answered difficult academic questions.

At the end of the show, the host reversed the format and Seaborg accepted questions from the children. Asked if any new chemical elements had been discovered, Seaborg spilled the beans about elements 95, americium, and 96, curium. The Laboratory audience listened to a taped recording of the show that ended with the advertising jingle, "When your tablets get down to four, that's the time to buy some more." It was the only time in the history of the world that the discovery of chemical elements was announced under the sponsorship of Alka Seltzer, Seaborg recalled.

Seaborg has co-discovered nine transuranium elements beyond plutonium. He continues to search for new chemical elements to extend the Periodic Table; a difficult job because radioactive half-lives decrease drastically as atomic numbers increase.

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NEW TECHNOLOGIES CONVERT FISSILE MATERIALS FOR INDEFINITE STORAGE

DISPOSITION PROGRAM IS A SOLUTION TO THE PROBLEM OF EXCESS PLUTONIUM AND URANIUM FROM NUCLEAR WEAPONS

Management of fissile materials is an essential aspect of Los Alamos efforts to reduce the nuclear danger. Fissile materials are required to maintain an adequate nuclear stockpile for credible national defense. However, if left in chemically unstable forms or stored with inadequate safeguards, fissile materials such as plutonium and some forms of uranium present not only a potential safety hazard and danger to the environment but also a risk of diversion for nuclear weapons proliferation.

The national fissile materials disposition program focuses on fissile material that has been declared excess to the weapons programs of either the United States or Russia. Los Alamos plays a very broad role in this program. Two essential Los Alamos disposition technologies are ARIES, the technology for removing and declassifying plutonium from a weapon's core or "pit"; and the Laboratory's MOX nuclear-fuel-fabrication capability, which enables the use of nuclear reactors as a near-term option for disposition of excess plutonium from the weapons complex.

ARIES: THE ADVANCED RECOVERY AND INTEGRATED EXTRACTION SYSTEM

Thousands of nuclear weapons built during the Cold War are now slated for dismantlement. The Advanced Recovery and Integrated Extraction System, or ARIES, is the scientific solution to President Clinton's 1995 promise to "withdraw 200 tons of fissile material from the defense stockpile, never again to be used for nuclear explosives."

This is the nondestructive assay system for ARIES. A robot moves sample containers from detector to detector; the detectors are mounted underneath the table top. The operator controls the telescoping gantry robot with a computer.

ARIES makes possible the direct recovery of plutonium and other special materials used to produce nuclear weapons. As a result, ARIES will reduce the international proliferation threat of these materials. ARIES integrates existing technologies into a modular system that removes plutonium from nuclear weapons components without generating environmentally toxic byproducts. The system converts the plutonium into an unclassified form that is stored in hermetically sealed canisters and can be examined by international inspectors.

ARIES incorporates a number of technologies and procedures developed through collaborative efforts at Los Alamos and Livermore national laboratories. A two-year integration and demonstration program is under way — led by Los Alamos and funded by the Department of Energy's Fissile Materials Disposition program — to demonstrate the multi-step, disassembly line process. The seven subsystems include:

PIT BISECTION MODULE. Researchers use a pit bisection tool that operates similarly to a can opener — it creases through the fissile component rather than sawing a groove or producing the waste chips a standard lathe would leave. This approach eliminates contribution to the waste stream. This first module consists of the pit bisection tool mounted in a glove box.

HYDRIDE-DEHYDRIDE PROCESS. The hydride-dehydride subsystem of ARIES takes advantage of plutonium metal's strong affinity for hydrogen gas, producing a reaction that forms plutonium hydride. This key breakthrough component of ARIES technology, using continuous hydrogen recycling, was declared one of 1995's one hundred most significant inventions by R&D Magazine. It is explained below in detail.

The hydride-dehydride reaction takes place in a vacuum chamber contained in a glove box, where a heated crucible in the lower part of the chamber creates a hot zone. A worker places a nuclear pit hemisphere in the upper cold zone and introduces a small amount of hydrogen gas emitted by a heated uranium-hydride storage bed.

ARIES IS COMPOSED OF SEVEN SUBSYSTEMS:

- pit bisection, which physically separates the various components that comprise a weapon pit
- a hydride-dehydride recycle module to remove the plutonium from weapon components and cast it as a metal ingot
- a parallel hydride-oxide, or HYDOX, module to remove plutonium from a weapon component and convert it to plutonium-oxide powder
- a canning module that packages the ingot or the powder in a double set of stainless steel cans that are filled with helium and sealed with welds
- an electrolytic process that decontaminates the outer surfaces of the inner stainless steel cans so that the fissile material or waste packages can be removed from the glove box environment
- an assay module that non-destructively tests the storage and waste containers of all special nuclear material packaged by ARIES
- the facility assembly and system integration module that makes it possible for the six processing modules to function as a process line

The gas reacts with some of the plutonium in the weapon component and forms plutonium hydride, which falls as a powder into the hot crucible below. The heat decomposes the plutonium hydride releasing the hydrogen gas — the dehydriding reaction — and it escapes upward to the cold zone to react with more plutonium.

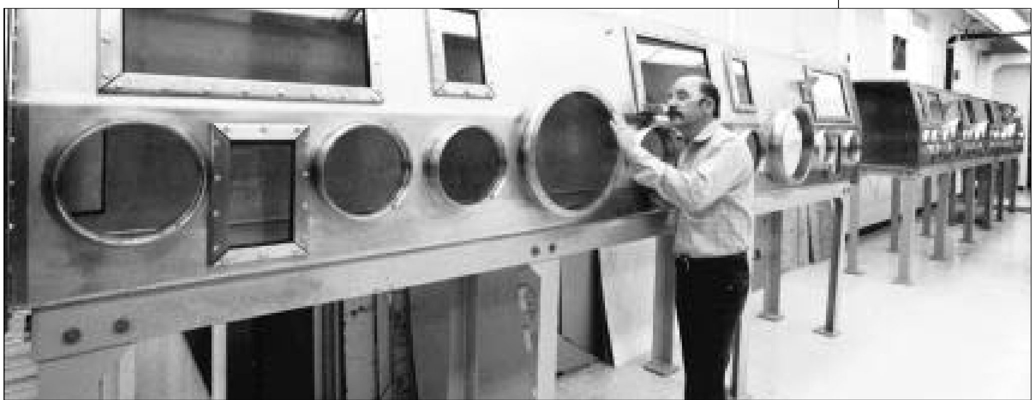
This recycling of hydrogen gas continues until all the plutonium is recovered from the weapon component. The hydrogen gas is then pumped out, to be reabsorbed into the uranium-hydride bed. Plutonium collected in the bottom of the crucible is in the form of a metal ingot or button that can be placed in hermetically sealed containers for long-term storage.

The entire subsystem is contained within a 36-square-foot, argon-filled glove box. No hazardous materials are released into the environment, and worker exposure to radiation is significantly reduced. The plutonium hydride stays within the recycling unit, mitigating the possibility of fire as plutonium hydride oxidizes rapidly in air. The hydrogen gas is created and recycled within the unit, eliminating the need for high-pressure gas cylinders and their potential danger of explosion. No hydrogen gas escapes the processing unit.

The previously used extraction method — acid leaching — was a multistep process in which plutonium was leached out with acids, isolated, converted to an oxide, and reduced to a metal. However, this traditional method generated about 360,000 kilograms of mixed waste a year. Mixed waste is the most difficult type of waste to dispose of because it contains both hazardous and radioactive components. Because the United States has no long-term mixed-waste repository, Congress banned further generation of mixed waste, rendering acid leaching obsolete.

The hydride-dehydride process has other advantages over acid leaching. It is simpler, a single step vs. a multistep process; faster, five hours vs. 16 hours, including formation of the final ingot; and more efficient,

The glove box line for the ARIES Pilot Demonstration, a two-year program initiated in October 1995 by the DOE Office of Fissile Materials Disposition.



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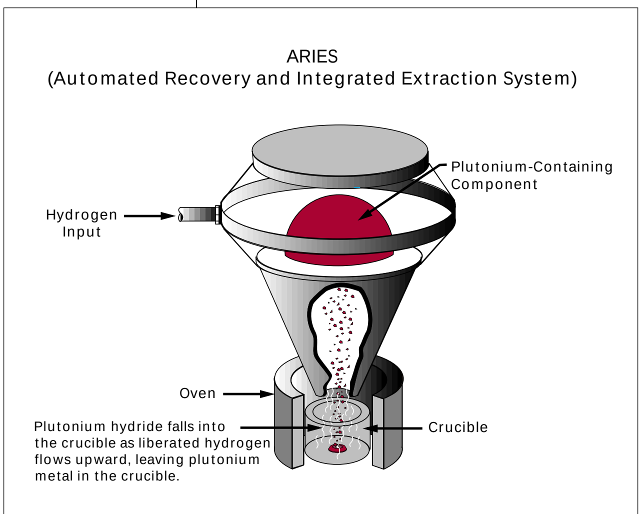

ARIES is one approach to pit conversion. It relies on the fact that plutonium quickly combines with hydrogen, forming a powder. The entire operation takes place in a fully automated glove box.

99.9 percent of a weapon's plutonium is recovered within a 36-square-foot glove box vs. acid leaching in which 96 percent of the plutonium is recovered in 40 times the space. The resulting plutonium ingot represents a far less complicated storage problem than does mixed waste and the process is safer because it isolates dangerous materials from workers and the environment.

HYDOX MODULE. Several recovery and immobilization options require that plutonium be recovered as plutonium oxide, a powder, rather than as a button of plutonium metal. In the HYDOX process, plutonium hydride is formed and collected in a furnace similar to the one used in the process described above. However, rather than converting the hydride to a metal, the process admits oxygen to react with the plutonium hydride to form plutonium oxide.

CANNING MODULE. The canning system receives the plutonium button or plutonium oxide powder and places it into a container. This "material container" is then hermetically sealed by welding and subsequently tested for leaks. Each can is labeled with a bar code for easy identification. After electrolytic decontamination of the material can, it is taken outside the glove box and placed inside another "boundary container." This container is also hermetically sealed and tested for leaks. The final package, after decontamination, is acceptable for long-term storage as defined by current Department of Energy standards.

ELECTROLYTIC DECONTAMINATION. The purpose of the electrolytic decontamination module is to decontaminate the material container so that subsequent operations can be performed outside a glove box. Moreover, decontamination of the material container reduces by one the number of boundary containers needed for a long-term storage package. The need for only one boundary container also limits processing operations while reducing the waste stream. Electrolytic decontamination has been demonstrated on stainless steel and other conductive materials at a number of DOE sites as well as Los Alamos. It is the current baseline technology for the decontamination of highly enriched uranium for the DOE complex.

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NONDESTRUCTIVE ASSAY SYSTEM. This system accurately measures the fissile material content of the product and waste containers without sampling or destructive analysis. Therefore, it is an essential component for material accounting for ARIES as well as the stepping off point for the application of international inspection and safeguards.

The NDA system consists of four computer-based assay instruments, automated loading, and a host computer to monitor the system, control the instruments, schedule measurements, archive assays, and direct automation support for continuous, 24-hour operation. The NDA system assays special nuclear materials for both the long-term storage container and the waste containers produced by the ARIES demonstration system. The system currently is in the cold testing stages.

FACILITY ASSEMBLY AND SYSTEM INTEGRATION. This task entails the overall integration of the ARIES project into the Los Alamos Plutonium Facility. Work will include acquisition and installation of most of the glove boxes; building a waste-canning station; the declassification of spent parts; engineering support; numerous drawings; room preparation; quality assurance; and environment, safety, and health requirements.

Within the confines of future treaty agreements, Los Alamos is lessening the global nuclear danger by planning to share ARIES with other nations so that as they reduce their own nuclear arsenals, they can recover and convert their surplus plutonium into unclassified forms for international safeguards and ultimate disposition.

MOX FUEL PELLETS PRODUCED WITH PLUTONIUM FROM DISMANTLED WEAPONS

Los Alamos and other Department of Energy installations are looking at different methods of disposing of surplus weapons-grade nuclear materials. One technology developed at Los Alamos recovers plutonium from nuclear weapons and converts it into a mixed oxide fuel pellet.

The “MOX” pellets will allow the plutonium recovered from surplus weapons to be used as fuel in commercial power reactors. The technology will make it possible to convert much of the surplus weapons-grade plutonium into energy-rich reactor fuel rods.

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Following "burning" of the fuel in a reactor, the remaining plutonium is less attractive for making weapons and, in the spent fuel, is in a highly radioactive matrix, making theft or diversion difficult to accomplish and easy to detect. To make a MOX fuel pellet, researchers first recover the plutonium from a weapon component using the ARIES process described in the previous section. Gallium, an alloying agent used in weapons plutonium, is removed by heat treatment.

↑

Researchers have developed the technology to make mixed oxide (MOX) fuel pellets (shown at right) from plutonium dioxide (bottom) recovered from nuclear weapons.

Next, they sieve and mix the plutonium dioxide with depleted uranium dioxide in a ratio typical of those proposed for fuels that could be used in commercial power reactors operating in the United States today. The mixture of the two dioxides, known as MOX, then is milled, pressed into pellets, and sintered to obtain a material of high density. Sintering heats the pellets in a furnace to a high enough temperature that the particles fuse to one another without melting.

Plutonium recovered from commercial reactor fuel has been added to light-water reactor fuel in Europe for several years now and has been tested in commercial reactors in the United States. Light-water reactors use ordinary water in their cooling systems in contrast to the deuterated water, or heavy water, predominantly used in Canadian reactors.

However, that plutonium was recovered from reprocessed reactor fuel that does not contain gallium or have the americium levels found in weapons plutonium. Los Alamos researchers are using their expertise to demonstrate that weapons plutonium can be used in commercial power reactors.

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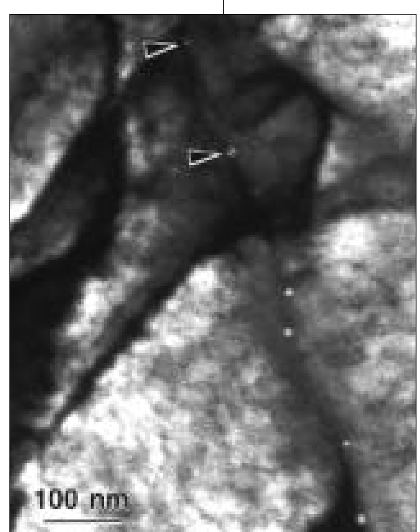
LOS ALAMOS DEVELOPS NUCLEAR TECHNOLOGIES FOR THE NEW MILLENNIUM

FROM WASTE TO SPACE

The end of the Cold War, the negotiation of arms reduction treaties, and the declining budgets of recent years have brought significant changes in national security activities at Los Alamos. The Laboratory's mission has shifted from designing, developing, and testing new nuclear weapons to one of reducing the global nuclear danger. The technologies described below support this mission.

ENHANCED SURVEILLANCE



➔ Plutonium aging is one focus of enhanced surveillance. Helium bubbles can cause structural instability in aged nuclear materials. This electron microscope image shows helium bubbles (indicated by arrows) in 20-year-old plutonium.

With underground testing of nuclear weapons no longer permissible, Los Alamos is developing a new suite of tools and technologies that will allow scientists to predict, up to 10 years in the future, potential problems in the enduring stockpile of nuclear weapons. These new techniques will place a premium on improved understanding of how and why weapons age, more careful and continuous monitoring of stockpiled weapons, and nondestructive evaluation of weapons components.

Because much of the former nuclear weapons complex is no longer available for manufacturing new parts or weapons in the event of stockpile problems, scientists must be able to anticipate early the need to resume a manufacturing operation. Therefore, they must have the investigative tools to diagnose potential problems before they affect the stockpile.

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. Scientists at the Los Alamos Neutron Science Center, or LANSCE, are exploring the use of fast, thermal, and cold neutrons for a number of enhanced surveillance applications.

Also available at LANSCE are neutron scattering techniques that can assess the quality, uniformity, performance, and expected lifetime of weapons components. These techniques will be increasingly important for stockpile certification and rebuilding. 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.

Los Alamos 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 are assessed.

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. Los Alamos scientists are conducting two types of experiments to gain this information: the first uses traditional neutron scattering methods to characterize the microstructure and other material properties of high explosives; the second employs a new technique called neutron resonance radiography to study temperatures and velocities in the interior of reacting high explosives.

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

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The scientific methods described above are among those that will help us to ensure the safety, security, and reliability of nuclear weapons and weapon components in the absence of nuclear testing and in an era of extended lifetimes, decreasing arsenals, and limited production capacity.

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PLUTONIUM REPACKAGING

↑ A failed nuclear materials container.

Los Alamos has an inventory of more than 8,000 containers of nuclear materials stored in vaults. The containers were intended for short-term storage until the material could be processed for long-term storage or designated for a specific use. Unfortunately, since the end of the Cold War in 1989, when this inventory became dormant, the condition of the containers has deteriorated.

To comply with a plutonium-storage standard issued by the Department of Energy in 1994, Los Alamos is implementing a project to repackage its nuclear materials in containers that meet the DOE's most recent and most stringent criteria for long-term storage of up to 50 years.

To package plutonium for long-term storage, Los Alamos researchers have developed a nested, two-container system that meets the requirements of the DOE long-term storage standard.

The inner stainless steel container, called a material container, is in direct contact with the plutonium. It is 4.5 inches in diameter, 9.4 inches in length, with a 0.065-inch wall thickness.

An improved long-term storage container is removed from a glove box. ↓

➔ A radiograph of the new nested, two-container system and its contents (in this case contaminated rubber gloves). A bellows at the top of the container signals any change in pressure, indicative of container failure or other problems.

The outer container, called a boundary container, provides the final barrier between the radioactive contents in the material container as well as additional pressure containment. The boundary container, also stainless steel, is 5 inches in diameter, 10 inches in length, with the same wall thickness.

Both the material and boundary containers are welded shut in glove boxes filled with helium. The helium atmosphere provides an inert cover gas for storage and the ideal gas for leak-testing, and it provides high thermal conductivity for heat removal.

The procedures for assembling and welding the containers were developed during fiscal year 1995. Los Alamos researchers are now repackaging the Laboratory's vault holdings for long-term storage.

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MODULAR CONCEPT FOR ENVIRONMENTAL REMEDIATION

A number of Department of Energy and Department of Defense sites have many square miles of soil contaminated with environmentally hazardous materials. In most cases, the level of contamination is low. Because conventional remediation methods cannot extract such minute amounts of contaminants without generating secondary waste, Los Alamos is developing a transportable modular system that employs advanced chemical processing technologies for cost-effective and timely eradication of this difficult Cold War legacy. Each module will address a particular type of contamination and one or more of the modules can be operated at a remediation site, depending on what type of cleanup is needed. One of the completed modules, magnetic separation of waste, is discussed on the next page.

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MAGNETIC SEPARATION OF WASTE

Los Alamos has tailored a process known as high-gradient magnetic separation for soil remediation. This technology is used in Georgia's kaolin industry to remove impurities from white clay — a substance used by paper mills to coat paper.

Through a cooperative research and development agreement, Los Alamos and Lockheed Environmental researchers have adapted the process to remove actinide compounds, such as uranium and plutonium, from soil. The process will greatly reduce the cost of soil remediation at sites such as Rocky Flats, Colo., Hanford, Wash., and Fernald, Ohio.

HGMS is a physical separation process based on the magnetic properties of waste particles. All uranium and plutonium properties are slightly magnetic while most host materials are nonmagnetic. The process operates by passing contaminated fluid or slurry through a magnetized volume.

The volume contains a magnetic matrix material such as steel wool that extracts the slightly magnetic contamination particles from the slurry. The process concentrates the contaminants to less than 10 percent of the original waste volume. The remaining 90 percent of the soil can be returned to the local environment, thereby avoiding the costs associated with waste treatment, transport, and disposal.

Preliminary results at Los Alamos using nonradioactive surrogate materials indicate that HGMS can successfully remove more than 99 percent of the paramagnetic components from mixtures.

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PIT FABRICATION

The plutonium in a nuclear weapon primary is located in a component called the pit. It is the heart of the warhead stage that multiplies the chemical energy contained in conventional high explosives to the thermonuclear energies of fission and fusion reactions.

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The pit itself is an extremely precise and sensitive component. Slight changes in the geometry, chemistry, or metallurgy of the plutonium can have a dramatic impact on weapon function. Inevitably, as the stockpile ages, some of the plutonium pits will need to be replaced.

At the time scientists designed the weapons in the existing U.S. stockpile, no one envisioned the day when large-scale production and nuclear testing would no longer exist. Stockpile stewardship is more challenging in a world with no nuclear testing and in one where nuclear weapons will remain in the stockpile long beyond their originally designed lifetimes.

The ARIES pit-bisection tool developed at Livermore for bisecting weapon pits. The pit rests in the cup like a golf ball on a "T" while the tool creases through the pit like a can opener.

As part of its mission of reducing the nuclear danger, Los Alamos is charged with stewardship of the existing nuclear weapons stockpile, or keeping those weapons that the nation needs safe, secure, and reliable. A major aspect of the stockpile stewardship program involves determining just how plutonium changes with time and how such changes affect safety and reliability.

The Department of Energy's preference that Los Alamos establish a limited capacity to manufacture plutonium pits for the nuclear weapons stockpile of the future will require more than $300 million worth of upgrades to the Laboratory's plutonium-processing infrastructure.

The majority of upgrades were needed anyway due to aging building systems and laboratories. The improvements will give Los Alamos the capability of producing 20 to 50 pits a year. As a comparison, the yearly pit production at the now inactive Rocky Flats defense plant near Denver was in the thousands.

Los Alamos has always made pits for research purposes and underground testing in Nevada. At the peak of this work, Los Alamos scientists made about a dozen pits a year.

From a fabrication standpoint, the physical processing required for research or stockpile units is nearly identical. However, the quality assurance standards applied to them differ because research pits, used soon after being manufactured, were one-of-a-kind products that did not have to satisfy all the specifications necessary for long-term residence in the stockpile.

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Historically, Los Alamos has improved, replaced, and upgraded nearly every processing technology used for pit production. The small-scale manufacturing capability being developed at Los Alamos will be configured in such a way as to further reduce radiation exposure to workers, minimize the production of nuclear waste, and minimize the storage requirements for nuclear material.

↑ A crater being formed during an underground test at the Nevada Test Site. During the Cold War, Los Alamos made pits for the nuclear weapons testing program.

For example, Los Alamos has nearly eliminated the need for machining oils, a historically large source of waste at Rocky Flats. Another large source of waste at Rocky Flats came from initial processing of the raw plutonium. Due to excess plutonium in surplus nuclear weapons, scientists have a ready source of plutonium metal, which they can recycle into new pits. This savings eliminates a good portion of the waste stream at the outset.

Work on the infrastructure upgrades is slated to begin in 1998, with the improvements in place by 2005.

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POWER AND HEAT FOR DEEP SPACE PROBES EXTRACTED FROM PLUTONIUM FOR NASA MISSIONS

For more than 30 years, Los Alamos has designed, fabricated, and tested heat sources for NASA deep space probes. These sources produce heat from the decay of plutonium-238, an elemental isotope with a half-life of 87.7 years, and are used in thermoelectric generators to provide electrical power for years. These “nuclear batteries” provide electricity and keep computers, communications gear, and mechanical instruments working in the deep-freeze environment of space.

Heat sources produced or designed at Los Alamos powered the two Voyager missions, the first to leave the solar system. Los Alamos heater units also provided electric power for the Pioneer probe to Venus, the Viking landings on Mars, the Galileo mission to Jupiter, and the Ulysses solar explorer. Los Alamos' latest assist in man's exploration of the final frontier will culminate in the 1997 Cassini mission to Saturn's rings.

Los Alamos makes two types of heat sources: those that are assembled into radioisotope thermoelectric generators, or RTGs, to produce electric power; and those used in light-weight heater units that warm the spacecraft.

RTGs are simple, highly reliable power sources that make electricity using the heat from plutonium-238. They are ideal power sources for space missions lasting decades. They are the only practical option on missions to the outer planets. Each gram of plutonium-238 produces about half a watt of thermal energy.

One general-purpose heat source consisting of a 150-gram pellet of plutonium-238 inside a thin, iridium shell has a nominal thermal power of 62 watts. Four heat sources are loaded into a graphite aeroshell, with 18 aeroshells stacked inside an RTG. The RTG is a highly efficient thermocouple that converts the heat generated by its heat sources into usable electrical power.

The lightweight radioisotope units used for warming the craft each consist of a 2.6-gram pellet of plutonium-238 inside a thin shell of platinum and 30-percent rhodium. Each capsule is loaded into a set of three pyrolitic graphite cylinders which in turn are loaded into a cylindrical aeroshell. They are attached to the spacecraft in locations where instruments or mechanical devices must be maintained above the sub-zero temperature of space.

The Los Alamos plutonium facility (see related article on Page 27) is the only U.S. facility capable of performing the various operations — fuel processing, pellet fabrication, encapsulation, and testing — necessary to produce plutonium-238 heat sources.

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LOS ALAMOS RECOVERY PROJECT RETRIEVES AND DESTROYS SEALED NEUTRON SOURCES FROM SCHOOLS, GOVERNMENT AGENCIES, AND INDUSTRY

A damaged americium-beryllium neutron source recovered from a private company by Los Alamos.

A plutonium-beryllium neutron source is a small cylindrical capsule of nuclear material sealed inside a canister of stainless steel. When combined in a certain configuration, the two substances generate neutrons — a very penetrating and useful form of radiation. Since the mid 1950s, more than a dozen U.S. companies have manufactured these neutron sources for use by the defense complex, the oil and gas industry, and medical and academic laboratories.

The U.S. Nuclear Regulatory Commission estimates nearly 27,000 small, encapsulated sources of different types of highly radioactive material are no longer needed or wanted by the various organizations that own them.

Since disposing of a sealed neutron source in a commercial or government waste facility is not permissible and since transferring a neutron source to another licensed organization is prohibitively expensive, licensees have had no alternative other than to keep their sources and continue to pay a licensing fee. A few incidents of sources being illegally "dumped" in areas accessible to the public have made recovering unwanted neutron sources a serious concern of the Department of Energy.

To help alleviate this problem, Los Alamos has established the 239Plutonium-Beryllium Neutron Source Recovery Program under sponsorship of the DOE. Plutonium-239 is the isotope of plutonium used in nuclear weapons. This program retrieves these sealed neutron sources and destroys their neutron-producing capability.

The majority of unwanted plutonium-beryllium neutron sources reside at colleges, universities, and U.S. Navy installations. Schools that obtained neutron sources years ago for research and teaching no longer want the responsibility or economic burden of owning a source. The Navy, on the other hand, has surplus sources from decommissioned ships and nuclear submarines. In some cases, these sources have been warehoused for years.

Since 1979, Los Alamos has received approximately 900 neutron sources from Department of Defense installations, defense contractors, and universities. Los

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Alamos currently has a waiting list containing more than 300 of these neutron sources with more being added to the list each day. Because of the stringent requirements for shipping nuclear material, Los Alamos works closely with organizations to insure they are in compliance with all regulations governing nuclear material shipments.

After the sources arrive at Los Alamos, they are placed in interim storage at the Plutonium Facility until they can be destroyed. The Los Alamos Plutonium Facility can store up to 200 sources at a time.

Sealed plutonium-beryllium neutron sources have a serial number inscribed by the manufacturer on their outer containers. These numbers appear in databases maintained by Los Alamos and other tracking organizations. After verifying a source's serial number, workers dismantle it by cutting open the outer, stainless-steel cladding. Next, the inner container and its radioactive contents are dissolved in hydrochloric acid. At this stage, the material ceases to be a neutron source. Plutonium is removed from solution using traditional chemical-processing techniques. Workers convert the elemental plutonium to plutonium oxide powder, which is then stored.

Over the past two years, Los Alamos has improved the chemical processing procedure to enhance worker safety and eliminate waste byproducts. Improvements include a remote decladding system, a remote dissolution system, and additional processing capabilities that reduce the need for interim storage in the Plutonium Facility vault. All of these improvements reduce the likelihood of workers being contaminated by plutonium. The new remote decladding system also eliminates the generation of mixed waste by completely removing the stainless steel outer capsule before dissolution.

Within the United States there is no avenue for the removal and destruction of neutron sources containing plutonium-239 other than the method just described. At present, Los Alamos workers process at least 100 of these sources a year.

Because of the great success dealing with the 239plutonium-beryllium neutron sources, DOE is considering expanding the program to accept neutron sources containing 238plutonium-beryllium, and 241americium-beryllium neutron sources. While this program is not yet in existence, Los Alamos has supplied support to the public in emergency cases because of its expertise with these materials.

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REDUCING THE NUCLEAR DANGER ONE NEUTRON SOURCE AT A TIME

In her role as administrator of the 239Plutonium-Beryllium Neutron Source Recovery Program at Los Alamos, Sherry Jones has help retrieve neutron sources from all kinds of people in all kinds of places. In some instances, the sources were stored for years without being used. In other cases, they were abandoned or mishandled and required emergency action.

Sherry Jones is administrator of Los Alamos' 239Plutonium-Beryllium Neutron Source Recovery Program. Mockups of four sources sit on top of her computer.

Typically, an organization's radiation safety officer is saddled with the problem of an unwanted neutron source and is often pressured by colleagues or citizen groups to dispose of it. A phone call to Jones starts the ball rolling.

Because government regulations for the packaging and shipping of nuclear materials are complicated and often difficult to interpret, Jones said her involvement begins long before a source arrives at Los Alamos for processing. "Most radiation safety officers have never packaged and shipped nuclear material and most never will again," Jones said. "So I serve as an adviser all the way through the process to make sure their organization is in compliance with all regulations governing nuclear material shipments."

As a courtesy to the shipping organization, Los Alamos supplies a shipping packet, which contains detailed packaging procedures, radiation monitoring procedures, shipping procedures, placards and labels, and all required shipping papers and forms. Los Alamos also supplies the shipping container.

Special problems arise if an institution gave a source to another organization without recording the transfer with the proper government authorities. Fortunately, these sources can be tracked to their original owners by their serial numbers. Jones maintains a Los Alamos database of source serial numbers to identify the original owner and help the shipping party correct the documentation so it can ship the source.

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The job has sent Jones on some interesting errands. One of her favorite stories involves a small, poor college run by a community of Catholic nuns. The college no longer wanted its source and could no longer afford the licensing fee. In fact, the nuns didn't have enough money to hire a professional to package the source and prepare the shipping documents.

Jones solved the college's dilemma by calling on a nearby radiation safety officer whom she had worked with to ship his source. He packaged the source for the nuns and shipped it to Los Alamos as a voluntary service to help solve a potential problem from arising. "Later, I received a letter of appreciation telling me that the nuns included my name in a 'Novena of Masses' as a permanent benefactor of their college," Jones said.

Another request involved the U.S. Navy. Due to defense downsizing, neutron sources from decommissioned nuclear submarines and ships are making their way to Los Alamos. The Navy contacted Jones about an unwanted source located at a U.S. military installation in Japan. The job involved numerous logistical problems, including a time difference that had her working in the middle of the night to coordinate the shipment. The source accidentally "missed the boat" in Japan and when it did arrive in the United States, the San Diego shipyard refused to receive it. After lengthy paperwork changes, many late nights, and dealing with a chain of military personnel, a truck delivered the shipment to Los Alamos at 2 a.m.

➔ Workers retrieve a damaged americium-beryllium source from a site in Texas.

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A neutron source recovery specialist is monitored for radioactive contamination by a colleague during the emergency recovery in Texas.

Jones has also responded to six emergencies in five different states. Leaking sources, abandoned sources, and sources held by companies that have gone bankrupt are all considered emergency requests.

The worst case, she recalled, was a recent job in Texas where Los Alamos and Texas radiation experts recovered an americium-beryllium source that had been drilled into by an oil well logging company. To aggravate the problem, the source was removed from the drilling site to the owner's garage, resulting in a trail of contamination that will cost millions of dollars to clean up.

"The owner had been trying to give up the source for years," Jones said. "Because a Los Alamos program for americium-beryllium does not yet exist, he had no choice but to hang onto it. In this case he loaned it to another well logging company as a favor and they wound up with a contaminated well site, garage, and truck."

Workers load the shipping container onto a plane headed for Los Alamos.

After Los Alamos reclaimed the source, Jones received one of many letters of appreciation she has on file from satisfied customers. In spite of the aggravations and dangers of her job, Jones and her colleagues have the satisfaction of knowing they are reducing the nuclear danger for thousands of Americans.

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THE LOS ALAMOS PLUTONIUM FACILITY

A WORLD-CLASS MODEL

The principal Los Alamos plutonium facility, known locally as Technical Area 55, is the only fully operational plutonium facility in the nation. Construction began in 1973, and it has operated continuously since its opening in April 1978. The four-acre facility was built for about $70 million; replacing it today would cost about $1 billion. The facility includes a 150,000-square-foot plutonium processing area that was designed to withstand all types of natural and human-caused disasters, including earthquakes, storms, and fires. TA-55 also incorporates non-plutonium laboratories, administrative and staff support buildings, and an access center located outside the secured area.

↑ Los Alamos researchers perform a "bagout" procedure in which the waste contents of a glove box are transferred into a drum for long-term storage.

TA-55 is the model for plutonium-handling facilities around the world because of its research achievements, exemplary operations record, and well-developed infrastructure. About 400 scientists, engineers, technicians, and support personnel work at TA-55. Their efforts focus on three scientific areas:

• plutonium metallurgy includes research on chemical and physical characteristics of metallic actinides, actinide surface studies, and plutonium-component fabrication technologies;

• actinide ceramics focus on the development and testing of plutonium-238 heat sources for space missions and mixed-oxide fuels for disposition; and

• actinide chemistry is research on nuclear material chemistry and development of a strong technology base in nuclear-materials separation, processing, and recovery.

TA-55 also contains a waste-handling area. Waste-management workers at the site routinely handle several types of waste, including hazardous waste such as used chemicals and toxic metals; mixed waste, or combinations of radioactive and hazardous materials; low-level radioactive waste; and transuranic waste, which has a higher level of radioactivity than low-level waste. TA-55 generates no high-level waste.

A researcher transports nuclear materials inside the Los Alamos Plutonium Facility.

The transuranic waste stream, the type of waste intended for deep geologic disposal at the Waste Isolation Pilot Plant near Carlsbad, N.M., includes items such as worn rubber gloves, used cleaning materials, glassware, and broken tools. Items that can no longer be used are bagged out of glove box lines and sent to waste management disposal.

A Los Alamos researcher seals a drum of transuranic waste.

Workers analyze and document the waste for radionuclide and hazardous content so that it can be handled appropriately. They use nondestructive or noninvasive assay techniques to measure the radionuclide content of the waste. Extensive documentation tracks the waste from point of generation until ultimate disposal.

All this processing costs about $13,000 for every drum of transuranic waste that is packed and sealed at TA-55. Due to the expense, Los Alamos minimizes the transuranic waste generated by its plutonium-handling processes and, whenever possible, recycles the materials used in these processes.

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CREATING THE NUCLEAR FUTURE

"THE FUTURE IS NOT SOME PLACE WE ARE GOING TO, BUT ONE WE ARE CREATING. THE PATHS ARE NOT TO BE FOUND, BUT MADE, AND THE ACTIVITY OF MAKING THEM CHANGES BOTH THE MAKER AND THE DESTINATION."

— JOHN SCHAAR
PROFESSOR AT U.C. SANTA CRUZ

The end of the Cold War and other dramatic changes in global geopolitical relations provide both an opportunity and an incentive to examine the future of nuclear technology. The Nuclear Vision Project launched last year at Los Alamos gives people with a broad spectrum of perspectives and opinions an opportunity to do just that. A broader understanding of the complex global nuclear picture and a consensus on how to resolve pivotal issues are the intended products of the project.

Those who participate explore how the evolution of nuclear technology might progress over the next half century toward a global vision that realizes the benefits of nuclear technology and minimizes nuclear dangers.

The Los Alamos Nuclear Vision Project has three components: workshops with participants from inside and outside the Laboratory, internal Los Alamos research and analysis projects, and an outreach program that links work conducted at Los Alamos with related work elsewhere.

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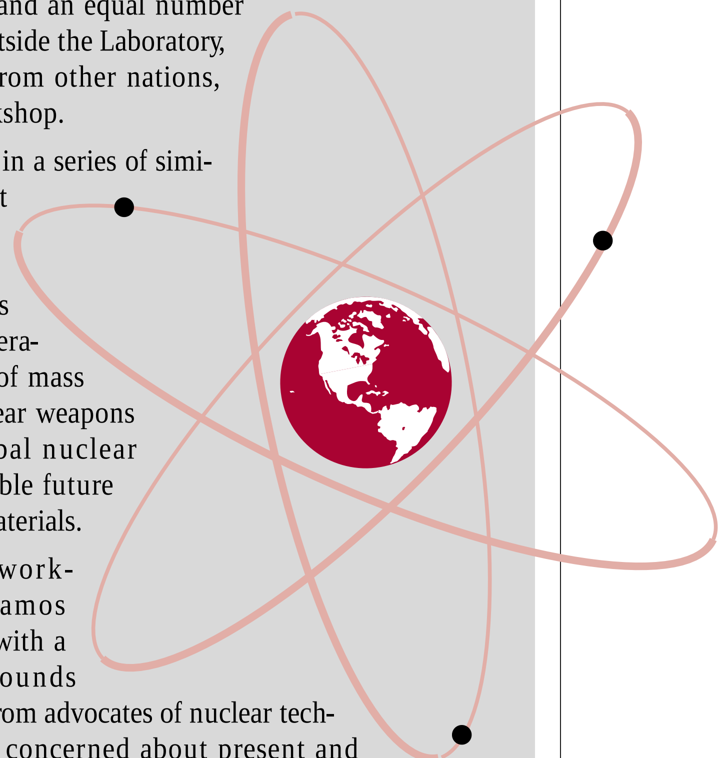
In August 1995, the Laboratory launched the Nuclear Vision Project in Los Alamos with a two-day workshop on "Securing the Nuclear Future." About 25 members of the Los Alamos staff and an equal number of people from outside the Laboratory, including some from other nations, attended the workshop.

This was the first in a series of similar workshops that will extend into next year. Other workshop topics include the proliferation of weapons of mass destruction, nuclear weapons technology, global nuclear energy, and possible future uses of nuclear materials.

At all of these workshops, Los Alamos includes experts with a range of backgrounds and opinions — from advocates of nuclear technology to others concerned about present and future nuclear activities.



The second component of the Nuclear Vision Project — research and analysis — provides for long-range investigations into areas such as modeling of global energy needs; nuclear power scenarios; assessment of the impacts of nuclear technology developments on global nuclear materials inventories; exploration of how the global spread of nuclear power and nuclear materials affects proliferation; and identification of nuclear weapons roles in future, complicated security environments.

As an example, the Nuclear Vision Project can weigh benefits of extracting available energy from recycling spent reactor fuel against potential materials handling and proliferation issues associated with such recycle. The effort also can weigh short-term risks and benefits against potential environmental hazards of storing large amounts of nuclear waste for tens of thousands of years.

The third component of the project fosters collaborations between Los Alamos researchers and individuals and groups in places outside the Laboratory. The focus is on a number of nationally and internationally known groups working in areas that are synergistic with the Laboratory's efforts described above.

March 1996 was the 50th anniversary of the Acheson-Lilienthal Report. This report marked the beginning of efforts at the end of World War II to place all applications of nuclear science and technology under international control. This did not come to pass. However, during the ensuing 50 years, a fabric of bilateral, multilateral, and international arrangements and behaviors related to nuclear affairs, both civil and military, has been woven.

The implications for mankind of the potential, for good and ill, of the energy of the nucleus are still global; in fact, more so today than in 1946. The need for a global approach to creating the nuclear future is the driving force of the Nuclear Vision Project.

Whatever political decisions and economic pressures influence the nuclear vision, Los Alamos will play a key role in developing new technologies for using, managing, and ensuring the safety of the world's nuclear materials.

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DATELINE: LOS ALAMOS

BRIEFLY ...

THE PLUTONIUM LEGACY EXHIBIT AT THE LOS ALAMOS BRADBURY SCIENCE MUSEUM ATTRACTS MORE THAN 130,000 VISITORS EACH YEAR. The exhibit informs visitors about the plutonium legacy from 50 years of weapons work and asks them to select one of three possible solutions for disposing of excess plutonium — burying it, using it in existing nuclear power reactors, or storing it until techniques are developed to dispose of it completely. The results of this informal poll are forwarded to Department of Energy headquarters. Plutonium is one of the heaviest elements on Earth. The cone demonstrates the volume of excess weapons-grade plutonium — 89 tons — that exists in the United States today.

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LOS ALAMOS NATIONAL LABORATORY — WHERE SCIENCE MAKES A DIFFERENCE

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