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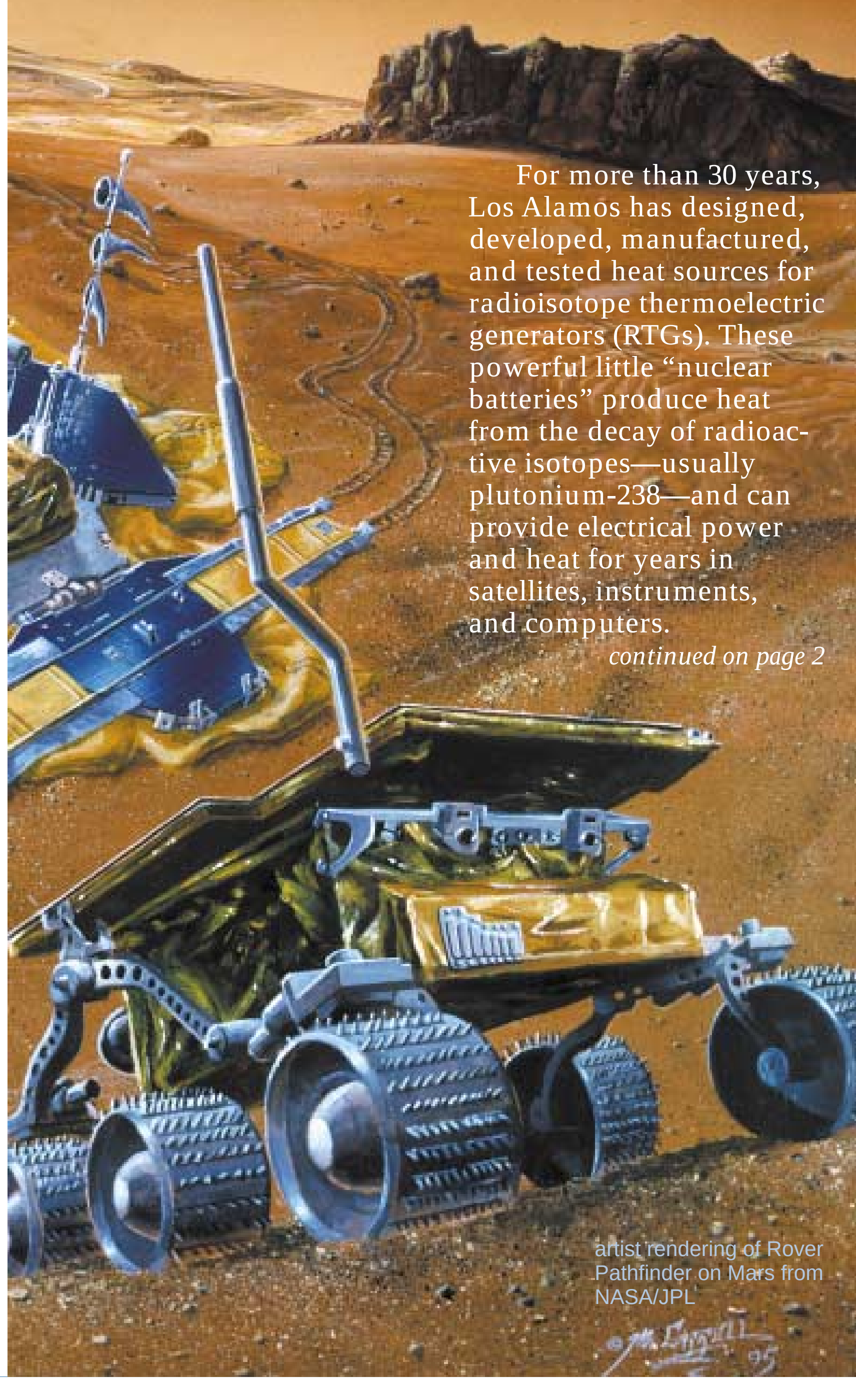
The Actinide Research Quarterly

Nuclear Materials Research and Technology

In This Issue

Researcher Provides a Historical Perspective for Plutonium Heat Sources



For more than 30 years, Los Alamos has designed, developed, manufactured, and tested heat sources for radioisotope thermoelectric generators (RTGs). These powerful little "nuclear batteries" produce heat from the decay of radioactive isotopes—usually plutonium-238—and can provide electrical power and heat for years in satellites, instruments, and computers.

continued on page 2

artist rendering of Rover Pathfinder on Mars from NASA/JPL

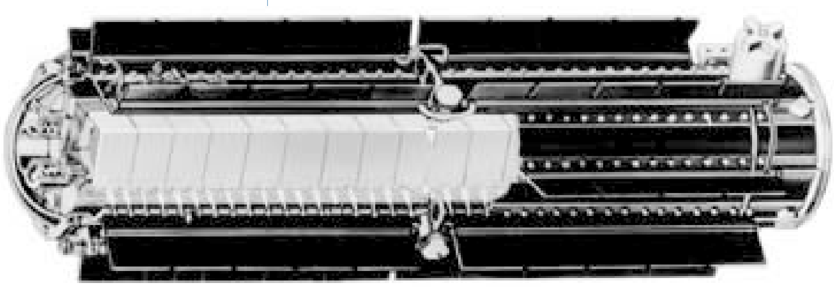
We begin the seventh year of *Actinide Research Quarterly* by focusing on major programs in NMT Division. The publication team also welcomes its new editor, Meredith "Suki" Coonley, who is assuming the position while Ann Mauzy takes on acting management duties in IM-1.

K.C. Kim

This article was contributed by **Gary Rinehart** (NMT-9)

Early development efforts from the mid-1960s through the early 1970s focused on fuel forms for space applications. The first, plutonia-molybdenum-cermet (PMC), was used on the Pioneer 10 and 11 missions to Jupiter and Saturn and the Viking Lander missions. PMC was fabricated by hot-pressing microspheres of molybdenum-coated plutonia into hockey-puck-shaped discs, which were then stacked and encapsulated in a refractory alloy.

During the same period, Los Alamos developed a medical-grade fuel for use in cardiac pacemakers and early artificial hearts. The fuel in the artificial hearts was made of 90 percent enriched plutonium-238 and provided up to 50 watts of power. Some of the early pacemakers are still in use; some have been returned to Los Alamos' Plutonium Facility for recovery.



Los Alamos developed a General Purpose Heat Source (GPHS) in the late 1970s to meet the larger power requirements of the Galileo, Ulysses, and Cassini space missions.

As electrical power requirements for spacecraft increased during the 1970s, so did the need to increase the power density of the heat source. Using "inert" materials such as molybdenum proved unattractive. Los Alamos began investigating fuel forms that used pure plutonia, which can generate more power in a smaller, lighter package.

The first pure plutonia fuel form developed at Los Alamos was the Multihundred Watt (MHW) for the RTGs used on the Voyager 1 and 2 missions to Jupiter, Saturn, Uranus, and Neptune. The heat source was a 100-watt hot-pressed sphere of plutonia encapsulated in iridium. Twenty-four heat sources were contained within the RTG. Heat was converted to electrical power by 312 silicon-germanium thermoelectric couples. Each Multihundred Watt RTG provided about 157 watts of power at the beginning of the mission.

To meet the larger power requirements of the Galileo, Ulysses, and Cassini missions in the late 1970s, Los Alamos developed the General Purpose Heat Source (GPHS). This RTG contained 572 silicon germanium thermoelectric couples inside a thermoelectric converter and provided 285 watts of electrical power at the beginning.

A General Purpose Heat Source (GPHS) fueled clad.

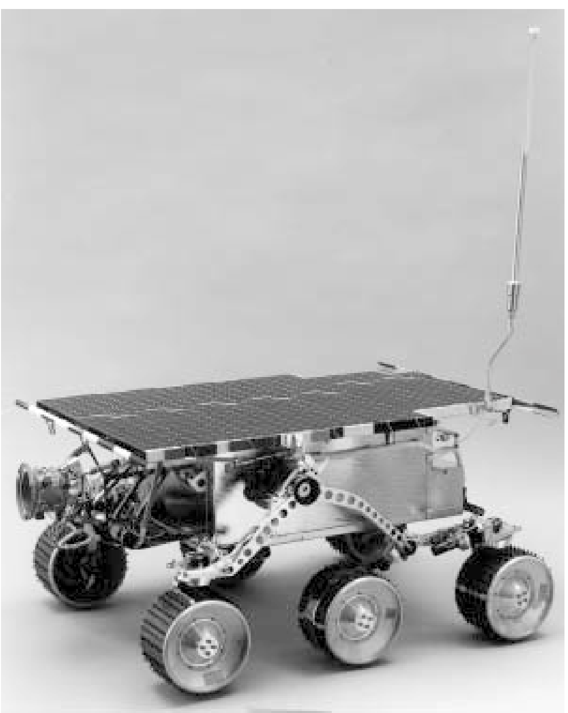
The heat source for these RTGs consisted of 18 GPHS modules. Each module had four fueled clads and each cylindrical fueled clad contained a hot-pressed 150-gram pellet of plutonium-238 dioxide encapsulated in an iridium-tungsten container.

Los Alamos fabricated the 216 GPHS fueled clads used on the Cassini mission. Each iridium clad contained a sintered iridium powder frit vent designed to release the helium generated by the alpha particle decay of the fuel. The iridium is compatible with plutonium dioxide at temperatures greater than 1,773 K and melts at 2,698 K.

In addition to developing RTGs to provide electrical power to operate instruments, Los Alamos also designed and fabricated heater units to keep equipment operating in the deep-freeze of space. The Light Weight Radioisotope Heater Unit (LWRHU) provided one thermal watt of heat and was used on the Galileo and Cassini spacecraft and Mars Pathfinder Rover. At the heart of this heater unit was a platinum-30 percent rhodium fueled clad containing a hot-pressed 2.67-gram pellet of plutonium-238 dioxide.

Los Alamos has also fabricated a large number of heat sources for the weapons program. From 1981 to 1990 more than 3,000 Milliwatt Generator (MWG) heat sources were fabricated and shipped to the Pinellas, Fla., plant for assembly into the MWG-RTG. These RTGs were used in devices that reduce the possibility of accidental detonation from a nuclear warhead. Each of the Milliwatt Generator heat sources had a nominal power of 4.0 to 4.5 watts. Los Alamos is currently recovering fuel from excess MWG-RTGs and performing shelf-life and stockpile surveillance on both the MWG heat source and the MWG-RTG. See *Actinide Research Quarterly*, Winter 1994, "Milliwatt Surveillance Program Ensures RTG Safety and Reliability."

Historically, reactors at Savannah River produced all of the United States' plutonium-238 until the late 1980s. With the shutdown of the Savannah River reactors, the United States has had to purchase plutonium-238 dioxide from Russia to supplement U.S. inventories for future NASA space missions. Recently, the DOE has proposed that plutonium-238 be produced at the Advanced Test Reactor (ATR) in Idaho and the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory.



The Mars Pathfinder Rover contained three Light Weight Radioisotope Heater Units (LWRHUs).

A significant amount of the heat source fuel in the Los Alamos inventory, including the Russian material and fuel from disassembled terrestrial heat sources, must be purified before it can be fabricated into new heat sources. Heat source fuel was previously recycled and purified at Savannah River. Los Alamos is qualifying a plutonium-238 aqueous recovery process in its plutonium facility to provide feed for the heat-source fabrication process.

A new glove-box line is being installed for this work and the full-scale aqueous recovery process is expected to become operational this fiscal year, which will have the capacity to purify 5 kilograms of plutonium-238 per year. In addition, Los Alamos has the capability of fabricating more than 5 kilograms of plutonium-238 into heat sources per year.

These improvements to the plutonium facility will ensure that Los Alamos can fully support future NASA requirements. The Europa Orbiter mission, scheduled for launch in 2006, and the Solar Probe mission, scheduled for launch in 2007, will each require approximately 3 kilograms of plutonium-238 if a Stirling radioisotope power system were used. If RTGs are used, approximately 8 kilograms of plutonium-238 will be required for each mission.

Over the next decade, several Mars exploration missions will carry LWRHUs, which will require approximately 0.3 kilogram of plutonium-238 per mission. In the long term—the next 20 to 35 years—NASA is expected to need 2 to 5 kilograms of plutonium-238 per year for its space missions.■

A Light Weight Radioisotope Heater Unit (LWRHU) before final assembly. The heat source consists of a graphite aeroshell, pyrolytic graphite thermal insulators, and a platinum-rhodium fueled clad. A sintered platinum powder frit vent is electron-beam-welded into the end cap of the fueled clad to release helium generated by the alpha decay of the fuel.

Pit Manufacturing Project Presents Many Challenges

This article was contributed by **David Mann** and **Sean McDonald**, NMT-5

Central to the function of a thermonuclear weapon is a plutonium pit, the trigger that initiates the sustained nuclear reaction. Los Alamos' experience in making pits dates back more than 50 years, to the Manhattan Project. Since that time, the Lab has produced a small number of pits—about a dozen a year—for research purposes and underground testing in Nevada. By comparison, the number of pits produced yearly at the now-closed Rocky Flats defense plant near Denver was in the thousands.

In 1993, the Department of Energy (DOE) requested that Los Alamos develop the manufacturing capabilities to produce war-reserve pits as part of the stockpile stewardship program. The designation "war reserve" means that the components meet the specifications required for use in a stockpiled nuclear weapon. Los Alamos was chosen in part because it has the nation's only full-capability plutonium facility. DOE plans call for Los Alamos to develop the capability to make 20 to 50 pits a year eventually.

A casting furnace in operation.

Los Alamos established the Pit Manufacturing Project to coordinate the activities of the many divisions across the Laboratory involved in pit manufacturing. With support from many Lab divisions—Engineering Sciences and Applications (ESA), Materials Science and Technology (MST), Chemistry (C), and Decision Applications (D—the Nuclear Materials Technology (NMT) Division is developing and implementing processes that range from casting the plutonium to the final assembly of the nuclear and nonnuclear components. Complicating matters are the changes that have had to be made in a substantial number of these processes because of the unavailability of the original equipment, the need to comply with new environmental regulations, or the ability to take advantage of improved equipment.

NMT has faced a number of challenges in setting up these capabilities. The first and probably most significant challenge has been to set up a formal manufacturing operation—with all its controls, infrastructure, and restrictions—in an existing research and development facility, and to do so without completely disrupting the existing programs.

To manufacture pits to the same specifications as Rocky Flats, each of the more than 100 processes involved has had to be installed, tested, and proven to function as it did at Rocky Flats. Currently, more than 98 percent of these processes have been installed and used in the development program designed to prove the effectiveness of either new procedures or significant modifications to procedures used at Rocky Flats.

With the suspension of underground testing following the advent of the Nuclear Test Ban Treaty, scientists currently have no way to prove absolutely that any production changes do not affect the pits. Because of this, each process that has undergone any significant change must go through a formal process qualification plan, which consists of a series of experiments designed to capture the possible variables of the new system. The process qualification plan is followed by an independent statistical analysis of the data by D Division before the process is fully approved.

The development program consists of 10 development pits, each of which tests one or more areas of concern to physicists or design engineers. As part of the development program, researchers will test the fabrication and assembly processes to identify and solve potential problems that may occur in the subsequent qualification and production lots. The development program also includes training personnel in nuclear manufacturing processes, providing destructive evaluation results for process feedback where this information can't be obtained nondestructively, and establishing an assembly information database for Los Alamos manufacturing methods suitable for predicting process yields for actual production runs.

The development pits will be followed by a series of qualification pits, which will be made completely to war-reserve specifications. These pits will be used in the certification program.

One of the manufacturing challenges is the selection of process materials to be used during fabrication, many of which have changed over the years. To remedy this, the War Reserve Materials Compatibility Board (WRMCB) has been established to evaluate process materials for use in war-reserve manufacturing. The WRMCB reviews historical data obtained from Rocky Flats to make a determination on whether or not a process material is compatible for use with plutonium or other war-reserve metals. If there isn't enough historical information to make a determination, the WRMCB commissions a compatibility study to be performed by the Materials Testing Laboratory in C-ACT.

Another challenge for project researchers has been the changing environmental regulations controlling the use of organic solvents. At Rocky Flats, plutonium components were cleaned with trichloroethane, which is now banned by the Montreal Protocols. Another solvent, trichloroethylene (TCE), is currently being used, but it is a suspected carcinogen. Besides its potential health risk, TCE is extremely costly to dispose of when it's contaminated with plutonium.

NMT Division is resolving these issues with a multilevel approach. NMT-11, in conjunction with C-PCS, has developed a hydrothermal technique for destroying TCE by reducing it to water, carbon dioxide, and hydrochloric acid. To reduce the amount of TCE produced while this system is being installed, NMT-5 and C-ACT have developed a cleaning system that reduces by 75 percent the amount of solvent used. The groups are also developing a method to recycle the TCE when it becomes too contaminated to effectively clean the components.

As a long-term solution, a new method using carbon dioxide as the cleaning agent is being developed to completely replace the solvent cleaning system. This will allow the plutonium components to be cleaned in an environmentally benign method, producing negligible waste.

In addition to a multitude of manufacturing challenges, NMT faces two challenges in the quality arena. A technical challenge is to provide a more formal method than what was used at Rocky Flats for qualifying processes and documenting the qualification.

A regulatory challenge is to institute a quality-assurance system that meets the DOE's strenuous requirements for war-reserve components, and to do so without the substantial resources that were devoted to the quality department at Rocky Flats. To meet the regulatory challenge, small, specialized teams have been formed to qualify processes and write a documented manufacturing manual.

Despite the large number of challenges facing the pit manufacturing process, the project has had many successes and is on schedule to meet all of the major milestones for producing a certifiable pit by 2003 and a fully certified pit by 2007.

This is a significant achievement, particularly in light of last spring's Cerro Grande Fire, during which the plutonium facility was completely shut down for several weeks. The first pit produced following the fire was made on schedule just weeks after the facility reopened. A second pit was produced several weeks later to test the quality- and production-control systems.

The next stage of development is to complete the process qualification plans and implement formalized work instructions for each process. These will be completed by the April 2002 milestone, along with all of the support and quality systems necessary to satisfy war-reserve requirements for documentation and quality.■

Editorial

Can Los Alamos Meet Its Future Nuclear Challenges?

Balancing the Need to Expand Capabilities While Reducing Capacity

NMT Division Director Tim George.

The opinions in this editorial are the author's. They do not necessarily represent the opinions of Los Alamos National Laboratory, the University of California, the Department of Energy, or the U.S. government.

Editor's note: Tim George is head of the Nuclear Materials Technology (NMT) Division. In this, his first editorial for Actinide Research Quarterly, he discusses some of the challenges facing the division.

Since the early 1980s, the vast array of Department of Energy (DOE) facilities once devoted to the study and use of actinide materials has undergone a dramatic restructuring. Sites such as Mound, Ohio; Pinellas, Fla.; Hanford, Wash.; and Rocky Flats, Colo., which once formed the backbone of the nation's weapons complex, have either closed outright or exchanged well-defined production and support missions for goals of decontamination and decommissioning.

DOE's remaining active sites are handicapped in the near term by deteriorating nuclear and high-hazard facilities, and infrastructure budgets that in most cases are inadequate to address a half-century of accumulated liabilities.

Although also burdened with its share of aging facilities, Los Alamos is unique in that it continues to operate the nation's only full-service plutonium facility. Building PF-4, which is located at TA-55, is both the newest (it opened in 1978) and only remaining facility in the DOE complex with the capability to conduct operations with all isotopes and chemical forms of plutonium, as well as other actinides. These diverse capabilities are packed into approximately 80,000 square feet of nuclear laboratory space.

Los Alamos also maintains significant capabilities for actinide research and processing in a much older facility, the Chemistry and Metallurgy Research (CMR) Building, which opened in 1952. The CMR Building consists of seven wings that house two banks of hot cells, laboratories designed for actinide materials science and analytical chemistry, and unique capabilities for working with actinide metals.

The seven wings of the CMR Building originally contained more than 50,000 square feet of nuclear laboratory space. By 2001, however, degradation of critical support systems resulted in a suspension of activities in one wing, increasingly stringent requirements for operational safety resulted in suspension of operations in a second, and planned decommissioning of a third wing reduced the amount of usable nuclear laboratory space to approximately 28,000 square feet.

In the 1990s, Los Alamos embarked on an aggressive program of upgrades to ensure continued safe operation of the CMR Building through 2010. By early 2001, approximately $76 million had been spent on the CMR upgrades, of which about one-half consisted of urgent maintenance items, with the balance directed toward upgrading building systems to meet regulatory requirements and to ensure continued safe operations.

Planned and completed upgrades included HEPA filter replacement in operational wings, upgrades to the fire protection system, improvements to exhaust stack monitoring systems, major upgrades of facility electrical systems, and safety-driven improvements to the building personnel accountability system.

The CMR Building, which opened in 1952 and consists of seven wings that house two banks of hot cells, laboratories designed for actinide materials science and analytical chemistry, and unique capabilities for working actinide metals.

Recent experience has demonstrated that substantial additional maintenance will be required to reduce the probability of unplanned outages resulting from the failure of aging and obsolete building systems.

Together, the Plutonium Facility and the CMR Building represent a lifeboat for preserving the nation's most critical nuclear technologies until they can be transitioned to the facilities of the future. In the near term, an increasing workload in support of production and support missions is competing for limited CMR and PF-4 floor space.

These missions currently include pilot production of nuclear defense components; surveillance of defense components; fabrication of components used in subcritical experiments; small-scale production of plutonium heat sources, analytical standards, and advanced nuclear fuels; materials surveillance; development and implementation of technologies for materials disposition; and investigative research.

Of these missions, the most difficult to prioritize is investigative research. However, history has repeatedly demonstrated that aggressive programs to understand today's bench-top curiosities are the only certain means to avoid being on the wrong end of tomorrow's technological surprises.

The challenge then, for the Nuclear Materials Technology (NMT) Division, which operates both PF-4 and the CMR Building, is twofold: to ensure continued success in current and future programmatic missions, and to preserve and expand technical capabilities while reducing the space and resources devoted to excess capacities.

The most critical factors to ensuring NMT's success in completing programmatic assignments are adequate and sustained budgets for facility operations and maintenance. Although the CMR upgrades project has addressed the most critical deficiencies in the facility, additional investment will be required to address the failure of aging and obsolete nonsafety-related systems.

The entrance to the TA-55 Plutonium Facility.

In the case of the Plutonium Facility, the outlook is for increased facility maintenance and operational costs as the facility ages. Because PF-4 has operated for nearly 25 years with no comprehensive plan for capital reinvestment and with limited budgets for facility maintenance and operation, unplanned outages will become increasingly common as components in key facility systems reach the end of their design lifetimes.

In addition, facility resources are stretched even further by requirements to meet regulatory and operational standards that were not in place, or even envisioned, at the time the facility was constructed.

The goal of reducing excess capacities while preserving and expanding technical capabilities will be much more difficult to achieve than completion of well-defined programmatic assignments.

The key factors to success in this area are by nature subjective. Assumptions must be made on the probabilities of increased or decreased program requirements for the outputs of various processes. Predictions must also be made on the significance and operational requirements of emergent technologies, such as room-temperature ionic liquids, that offer the promise of reducing the need for, or even replacing, current separations processes.

Both sets of assumptions and predictions must then be compared with existing facility configurations to identify specific laboratories and glove boxes (currently devoted to excess process capacities) that may be suitable for reconfiguration. Finally, funds must be identified to reconfigure these laboratories for other uses.

With sufficient budget, there are significant opportunities to reclaim the space occupied by excess process capacities. In PF-4, for example, which was originally designed as the nation's premier actinide research and development facility, a portion of the facility remains configured to separate and purify relatively large quantities of plutonium and other actinides.

Although these capabilities made significant contributions to the nation's defense in the early 1980s, it is unlikely that they will ever again be required to operate on that scale. Consolidation of the separations processes into a smaller footprint offers the potential to free up space that can then be used to support increasing programmatic workloads, emergent technologies, or waste reduction and treatment processes required to meet new regulatory standards.

Significant questions remain as to how long PF-4 and the CMR Building can be expected to remain operational given current and expected facility budgets and when new facilities will be available to house transitioned operations. Questions also remain about the long-term effects of compromises necessary to maintain production, programmatic support, research, and development within the limited space available in these two facilities.

Given the long lead time needed for construction of nuclear facilities and the limited remaining lifetime of the CMR Building, decisions must be made soon on the size, location, and capabilities of the DOE's reconfigured nuclear complex.

At Los Alamos, work needs to accelerate on replacing the CMR Building with a new facility (or a set of smaller, cheaper facilities), and on development and implementation of the Integrated Nuclear Park (INP) concept proposed by Gen. John Gordon, head of the National Nuclear Security Administration (NNSA). The INP, if implemented, would consolidate all Los Alamos nuclear operations into one area.■

Detecting and Predicting Plutonium Aging Are Crucial to Stockpile Stewardship

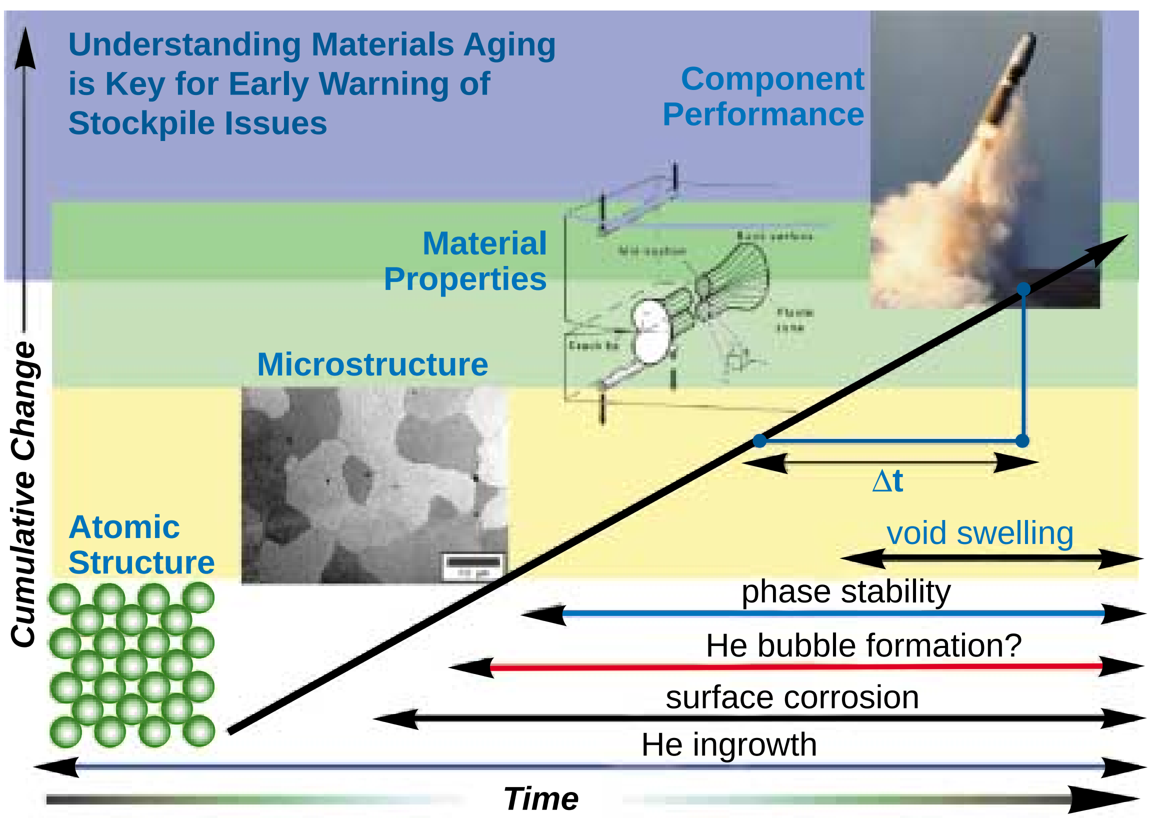
This article was contributed by **David Clark** and **Joseph Martz**, G. T. Seaborg Institute, NMT Division

During the past decade we have seen unprecedented changes in the world's political climate. The end of the Cold War, the breakup of the former Soviet Union, strategic arms reduction treaties—all have contributed to a decrease in nuclear arms buildup. These changes notwithstanding, nuclear weapons technology continues to play a key role in reducing the global nuclear danger.

However, the configuration of the weapons complex is far from static. The size and number of nuclear weapons within the U.S. arsenal have been dramatically reduced, nuclear testing has been curtailed, the weapons in the stockpile are aging, and downsized fabrication facilities are being tightly integrated and focused as much on maintaining capability as on delivering small numbers of new components.

Within this new environment, the Department of Energy (DOE) has implemented the Science-Based Stockpile Stewardship Program, which relies on the use of methods other than nuclear testing to ensure the safety, security, and reliability of the stockpile. These methods include advanced diagnostic equipment, data from critical new experiments, enhanced computational power, and retaining the very best scientists and engineers at the nation's nuclear research facilities.

Several new missions are growing in importance, including the analysis and surveillance of weapon systems and the associated measurement of the effects of aging on the weapons in the stockpile.



A qualitative representation of the connection between changes in atomic structure, microstructure, material properties, and component performance. The onset of potential aging effects in plutonium is included along the time axis. The goal is to identify the signatures of aging at the earliest possible time. This requirement has driven the program to atomic and nanoscale scientific investigations.

Stockpile Surveillance

The Stockpile Surveillance Program ensures that the stockpile is free of defects that may affect performance, safety, or reliability. The surveillance program has two elements: the Stockpile Evaluation Program and the Enhanced Surveillance Campaign.

The first element, stockpile evaluation, provides examinations and assessments of war-reserve stockpile weapons and components. The second element, enhanced surveillance, provides the means to strengthen the Stockpile Evaluation Program to meet the challenges of maintaining an aging stockpile in an era of no nuclear testing. Enhanced surveillance also provides lifetime assessments and predictions for Stockpile Life Extension Program (SLEP) planning.

The goal of the Enhanced Surveillance Campaign is to protect the health of the stockpile by screening weapons systems for manufacturing and aging defects to identify units that need to be refurbished. It also will be used to predict material and component aging rates as a basis for annual certification, refurbishment scope and timing, and nuclear weapon complex planning. Results of the work will be used to make improvements to the basic surveillance program.

Because nuclear weapons will be retained in the stockpile for lifetimes beyond our experience, the DOE needs to be able to determine when stockpile systems must be refurbished or reconditioned. If new refurbishment capability is needed, the DOE needs to know when these capabilities must be operational and what the required capacity should be, if the capacity for existing facilities is adequate, and when potential refurbishment for the various stockpile systems must be scheduled.

The DOE also needs to have a basis on which to characterize the functional reliability of aged components, which is part of the annual assessment process.

Plutonium Aging

Detecting and predicting age-induced changes in nuclear materials are perhaps the most challenging and technically engaging aspects of Science-Based Stockpile Stewardship. Indeed, “science-based” arises principally from this need, as opposed to a “production-based” alternative or the “test-based” strategy used in years past. Analysis, prediction, and mitigation of aging effects are key to ensuring long-term functionality.

However, changes in weapon performance as a result of aging represent the end in a series of events that began years or decades earlier. Changes occur first in the fundamental (or atomic-scale) properties of the materials within the weapon—properties such as composition, crystal structure, and chemical potential. Changes are later found in the applied behavior of these materials—behaviors such as density, compressibility, strength, and chemical reaction rates.

Only when the applied properties have sufficiently changed can we anticipate their impact on weapon performance. Therefore, the needs of the stewardship program have driven our studies toward nanoscale scientific investigations. The essence of this approach can be seen in the illustration on page 9, where changes at the atomic scale precede changes at the microscopic or macroscopic scale, which lead to changes in material properties, and ultimately, in device performance.

Analyzing, predicting, and mitigating aging effects in pits, specifically plutonium pits, are key to ensuring long-term safety and reliability in the primary stage of nuclear weapons. We are studying the many changes that result from aging, including engineering and physics performance characteristics such as equation of state, spall and ejecta formation, strength, density, geometry, corrosion resistance, and nuclear reactivity.

Our understanding of plutonium aging is complicated by the fact that plutonium displays some of the most complex physical and chemical properties of any element in the periodic table. Aging mechanisms that can cause changes in fundamental plutonium material and mechanical properties include the in-growth of decay products, uranium recoil damage and associated void formation, void swelling, changes in density, phase stability concerns, changes in surface chemistry, and a variety of environmental changes, including thermal cycling.

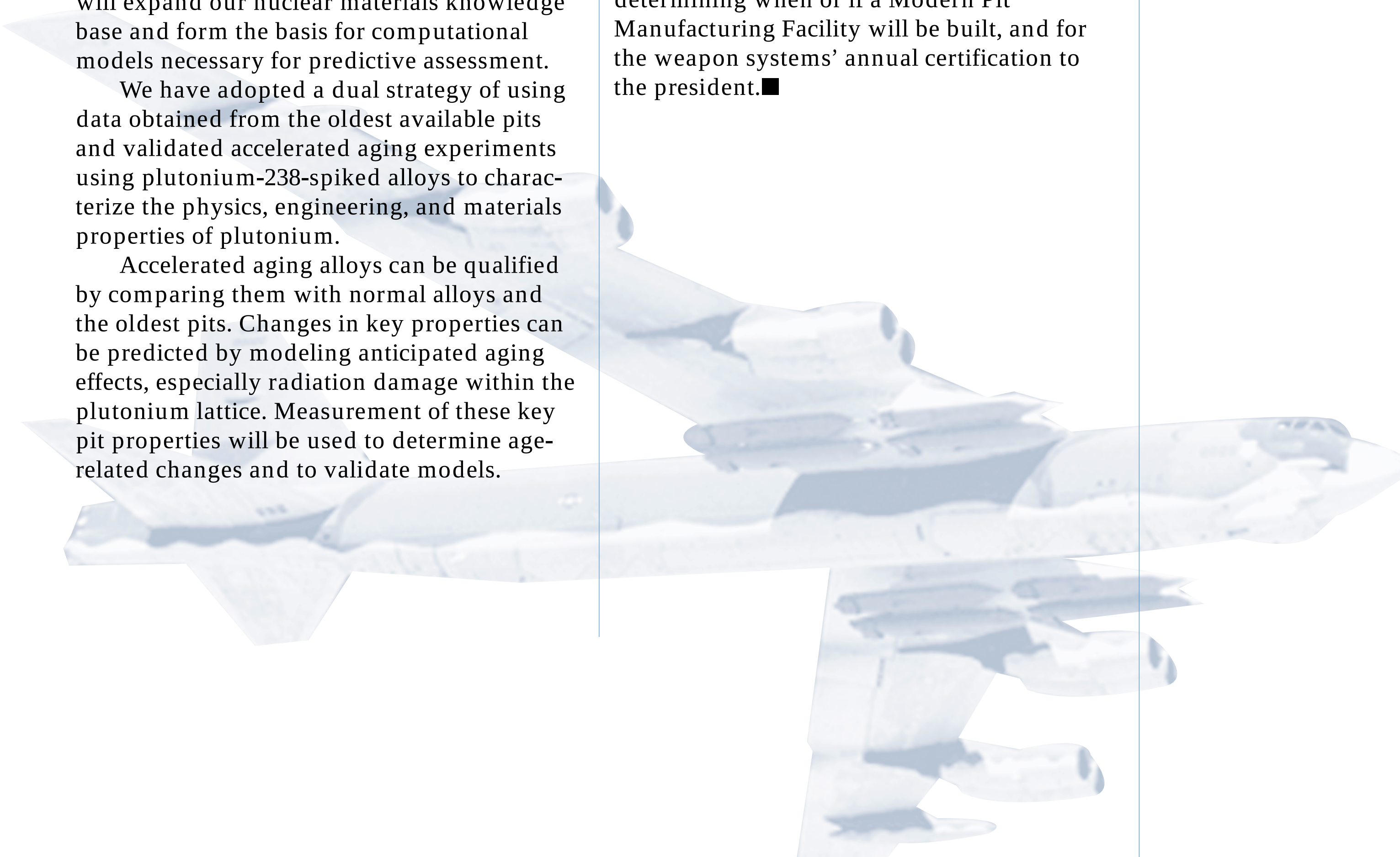
Developing advanced characterization tools to measure changes in these properties will expand our nuclear materials knowledge base and form the basis for computational models necessary for predictive assessment.

We have adopted a dual strategy of using data obtained from the oldest available pits and validated accelerated aging experiments using plutonium-238-spiked alloys to characterize the physics, engineering, and materials properties of plutonium.

Accelerated aging alloys can be qualified by comparing them with normal alloys and the oldest pits. Changes in key properties can be predicted by modeling anticipated aging effects, especially radiation damage within the plutonium lattice. Measurement of these key pit properties will be used to determine age-related changes and to validate models.

The Enhanced Surveillance Campaign and the needs of the Science-Based Stockpile Stewardship Program have supported the development of new science and technology, including resonant ultrasound measurements of the plutonium modulus, X-ray absorption spectroscopy and neutron-scattering measurements of plutonium structure, microstructure and surface characterization, positron annihilation spectroscopy, isochronal annealing studies of radiation damage, dynamic property measurements, and new theoretical models of radiation damage effects.

These tools will be useful in making stockpile life-extension decisions, determining when or if a Modern Pit Manufacturing Facility will be built, and for the weapon systems’ annual certification to the president.■



Pit Disassembly and Conversion Address a 'Clear and Present Danger'

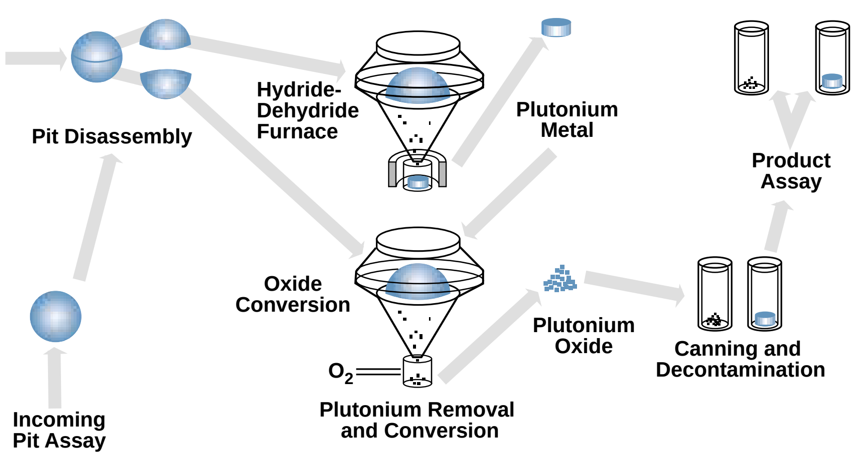
Contributors to this project are: **Timothy Nelson** (NMT-15 group leader), **Steven McKee** (NMT-15 deputy group leader), **Chris James** (U.S. Pit Disassembly and Conversion project leader), **Stan Zygmunt** (U.S./ Russian Conversion project leader), **Douglas Wedman** (ARIES project leader), and **David Kolman** (Pit Disassembly and Conversion Research and Development project leader)

For five decades, the world's superpowers sought to increase the number of weapons in their nuclear stockpiles. With the end of the Cold War and the advent of strategic arms reduction treaties and agreements, the United States and Russia are committed to retiring thousands of weapons from their stockpiles. But peace poses a dilemma: What should be done with the hundreds of tons of weapons-grade plutonium removed from these dismantled weapons?

In 1994, the National Academy of Sciences, in the report "Management and Disposition of Excess Weapons Plutonium," called the existence of this excess material "a clear and present danger to national and international security." The safe disposal of surplus plutonium is key to the U.S./Russia arms-reduction effort.

The heart of the disposition program is pit disassembly and conversion, which is led by Los Alamos. The technology includes dismantling pits, the core of nuclear weapons; converting the plutonium from pits into a form suitable for use as an actinide ceramic materials, mixed-oxide fuel; providing technical support for the design of the Pit Disassembly and Conversion Facility (PDCF) at Savannah River, slated to open before 2010; managing the Russian Federation pit disassembly and conversion; and supporting the Russian Federation nuclear fuel activities.

A flow chart of the ARIES glove-box line.



A major part of the Laboratory's pit disassembly and conversion responsibilities is the Advanced Recovery and Integrated Extraction System (ARIES), a state-of-the art prototype glove-box line operated at the TA-55 Plutonium Facility by NMT-15.

The ARIES line converts plutonium into an unclassified form that can be stored in sealed containers and examined by international nuclear material inspectors. The technology has been demonstrated to minimize waste and reduce worker exposure. Data collected from ARIES is being used to help design the PDCF at Savannah River.

ARIES incorporates a variety of basic and applied research, and development and demonstration activities, including gas-solid kinetics, materials corrosion, glove-box and container decontamination, pit machining operations, plutonium-conversion processes, tritium removal from contaminated plutonium, actinide electrochemistry, and long-term storage packaging.

Evaluation techniques used at ARIES include nondestructive assay, classified-part sanitization, and advanced separation. The work requires expertise in a variety of disciplines, including materials science, engineering, chemistry, physics, robotics and automation, and software development.

Housed in a sequential series of glove boxes, ARIES consists of five modules, each designed to carry out a specific function. Each module incorporates advanced technologies that increase operational efficiency.

The process begins when a pit is introduced into the system. The pit enters the pit bisection module, where it is bisected by a tool that works like a pipe cutter. The pit may also be disassembled using a lathe. However, unlike traditional lathes, the pit bisection tool and the advanced lathe operations produce minimal waste chips. From here, the pit undergoes a plutonium removal and conversion process.

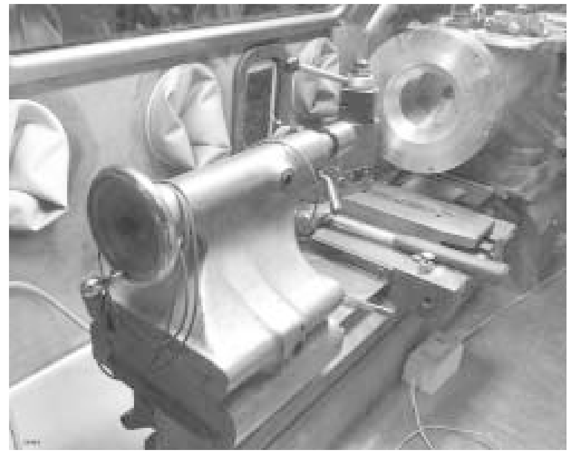
To convert plutonium into an oxide form—the preferred product form for mixed-oxide fuel (MOX)—the plutonium from the pit is oxidized in the direct metal oxidation (DMO) furnace. In some pits, the plutonium may be removed by a reaction with hydrogen, which forms plutonium hydride powder. The powder is thermally treated to form a metal puck that releases the small amount of hydrogen for reaction with more plutonium. To convert plutonium metal to oxide, the puck also can be processed through the DMO furnace. Researchers currently are investigating other oxide conversion processes, including one that involves a hydride/nitride process and oxidation.

Once the plutonium has been converted into either an oxide or a metal, it is packaged to meet Department of Energy (DOE) long-term storage criteria. This packaging involves three containers, two of which are hermetically sealed and leak-checked. Before the first hermetically sealed container can be removed from the glove-box line, researchers electrolytically clean the surface using a process similar to electropolishing.

An electrolyte that consists of a sodium sulfate and water solution uses electricity to induce a chemical reaction that removes a uniform layer of material and any contaminants on the cans. This module minimizes waste by recycling the electrolyte.

After the metal or oxide is packaged, a series of robotically operated nondestructive assay instruments confirms the quantity of plutonium in each package. These measurements are important for nuclear security and safeguards; similar techniques will be used by international inspectors to confirm the package contents without having to open them.

The pit bisector and hydride/nitride processes were collaborative efforts between Los Alamos and Lawrence Livermore National Laboratory. Currently, NMT-15 and NIS-5 are working with the Russian Federation to develop a similar nondestructive assay system for use in Russia.



A Fanuc™ robot positions a welded ARIES material can for leak testing before decontamination. This fully automated system reduces worker exposure during the packaging of plutonium oxide. The system is undergoing extensive preinstallation testing at TA-46 and should be operational within the TA-55 Plutonium Facility by the end of December.

ARIES has been supported since 1995 by the DOE Office of Fissile Materials Disposition, now known as NN-60 in the National Nuclear Security Administration. It was dedicated in September 1998. The ARIES line then went through a series of “hot” tests and completed its first integrated demonstration, a three-month production-type run that included seven pit types, in September 1999.

Since its first integrated demonstration, the ARIES line has been upgraded to allow for an increase in the size of the container. This change required adjustments to the nondestructive assay instruments and robot, electrolytic decontamination fixture, and inner and outer container welding station.

Other upgrades performed since 1999 include the development of a pit disassembly lathe, a process control system for the lathe, and a process-control system for the hydride/dehydride process.

ARIES is being readied for a second integrated demonstration later this year. After this demonstration, researchers will install a second set of upgrades that includes a fully automated packaging line, developed with Sandia National Laboratories; a part sanitization process; a uranium cleaning and burning glove-box line; two new direct-metal oxidation furnaces; a laser-ablation inductively coupled plasma mass spectrometer for elemental analysis; and uranium nondestructive assay equipment.

The upgrades also will include modifications to the special recovery line that removes tritium contamination from plutonium and adapting robotics for pit handling in conjunction with lathe operations. ■

Publications and Invited Talks

Attention, authors: Have you published a paper, book or book chapter, or given an *invited* talk? Please send the particulars to suki@lanl.gov and we'll publish your citation in a future issue of ARQ.

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Newsmakers

■ **Fellows Prize: David Clark** (NMT-DO) is one of three technical staff members named 2000 Lab Fellows Prize winners. The Fellows Prize recognizes high-quality published research in science and engineering having a significant impact on a particular field or discipline. Clark was recognized for his outstanding contributions to the understanding of the molecular behavior and solution chemistry of actinide ions. Recipients of the award received a $3,000 check and a certificate from Director John Browne.

■ **High school talk:** As part of NMT's outreach activities, **Derek Gordon** (NMT-14) recently gave a talk on nuclear energy to juniors at St. Michael's High School in Santa Fe. His talk covered the Los Alamos ARIES program and the current U.S.–Russia collaborations on weapons dismantlement and the use of mixed-oxide fuels.

■ **Pollution Prevention Award:** A team from NMT-9 has earned a 2000 Pollution Prevention Award from the Lab's Environmental Stewardship office for its development of an improved process to isolate plutonium oxide from scraped fuel. Plutonium-238 is used in heat sources and heat units for NASA deep-space missions. The innovation has cut the recovery waste stream by more than 75 percent and is helping the Lab move closer to meeting the DOE's 2005 pollution prevention goals. Team members include. **Gerald Allethauser**, **Jason Brock**, **Amy Ecclesine**, **Paul Moniz**, **Jonetta Nixon**, **Maria Pansoy-Hjelvik**, **Kevin Ramsey**, **Mary Ann Reimus**, **Mary Remerowski**, and **Gary Silver**.

New Energy Secretary Addresses Los Alamos Employees

Editor's note: The following excerpts are from Energy Secretary Spencer Abraham's April 19 all-hands meeting at Los Alamos.

… Los Alamos has a history that is a special one and, perhaps, can best be described as humbling to all of us. I'm sure when you think about the people in whose footsteps you have followed—the Oppenheimers, the Tellers, and others, it's on one hand inspiring and on the other hand kind of overwhelming. I suspect that's a daunting challenge, but I believe that the people working here today are every bit as able and talented as those who preceded you, and we look forward to accomplishing great things together.

You look at what has happened and what Los Alamos has been able to contribute to mankind, and in my judgment those benefits are incalculable, whether it was victory for the Allies in the second world war or it was victory for the West in the Cold War. But for you, breakthrough science would take place in another country. But for you, supercomputing would be a technology for us to purchase abroad, not develop and refine here at home. And, but for the people who've worked at this facility, we would now be living in the 55th year of the Cold War, instead of enjoying the eleventh year of the peace dividend.

… But we don't live in a totally peaceful world, even though the Cold War may be over. It's still a dangerous place. Our stockpile, the weapons that are built and maintained, is a result of no small measure of the work that's here, remain the vital factor that ensures the stability of America's national security in a changing and dangerous world. As much as we admire the work of the scientists who brought us the first weapons—Fat Man and Little Boy—it is clear that your scientific contributions are no less important than theirs.

… Gen. Gordon has pointed out to me that our labs are today again exploring territory that is virtually as uncharted and complex as that which was opened up by the scientists of the Manhattan Project. No one in history, as far as I know, has ever tried to confirm the reliability of weapons without testing them, and yet, that's precisely what we are doing now. It's really an astonishing technical and scientific enterprise, and it calls for the same qualities of genius that this facility has unleashed throughout its history.

At the same time, our mission today is broader and more difficult because we have added counter-proliferation and nonproliferation to our traditional missions of deterrents as we attempt to reduce a host of threats to our nation. I can't think of anything more compelling in terms of a mission or one that calls upon a greater degree of technical excellence than those that we confront today.

photo by LeRoy N. Sanchez

Energy Secretary Spencer Abraham.

… I consider nothing that I have in terms of responsibility more important then the duty that I share with the secretary of defense to certify to the president, along with our Lab directors, the fitness of our stockpile. … What I've tried to convey to the White House and to the other policymakers is the significant importance of the stockpile stewardship process that we are so integrally tied up with here in the department and the NNSA. In an era where we don't test, as you know better than anybody does, the work that we do to certify is the most critical component in many respects of America's national security that we have.

Our deterrent capability is only premised on the belief on the part of the rest of the world that the weapons we have will work in a reliable fashion. If we don't test those weapons, but in fact work through the science-based stockpile program to try to ensure that reliability, then the work you're doing is probably as central as anything could possibly be to the long-range security of this country.

It is my hope and my plan to work together with John Gordon to make sure that sufficient resources are provided to be able to do that work in the fullest sense. …

Newsmakers

■ Department of Energy Secretary **Spencer Abraham** recently made his first visit to Los Alamos since becoming energy secretary. One of his stops was TA-55, where he was given a lesson on how to work in a glove box and an overview of the Laboratory's plutonium pit fabrication program. He also was trained and performed a step in the pit fabrication and certification process. "What the trip today has so far done is reinforce my pride in and confidence in the people who work in our labs," Abraham said. "I wanted to come here early to just reinforce my already-held opinion of the quality of work done here and to try to assess some of the needs so I could be a more effective participant in the [national security] reviews." Abraham later told reporters he is working closely with NNSA Administrator Gen. John Gordon to identify challenges the DOE faces and how it can work with the National Security Council, Department of Defense, and other agencies. One of those challenges, he said, is long-range strategic decisions as to the U.S.'s nuclear forces, the nation's stockpile of nuclear weapons in relation to nonproliferation, and counter-proliferation programs. Gen. Gordon accompanied Abraham on his April 19 visit.

See page 15 for excerpts from Abraham's all-hands meeting.

photo by LeRoy N. Sanchez

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