# Inside the Superblock

*Take a look behind the fences that surround Livermore's Superblock, where scientists are studying plutonium.*

WELCOME to Lawrence Livermore's Superblock, home to one of just two defense plutonium research and development facilities in the U.S. Here, behind fences, guards, and ultrathick walls, scientists are developing ways to dispose of plutonium left over from the Cold War arms buildup. They are researching what happens to plutonium's physical properties over time, important knowledge in light of our aging stockpile of nuclear weapons. Technicians are machining parts for subcritical tests that help assure the safety and reliability of our nuclear stockpile. To a lesser extent, scientists and technicians in the Superblock also work with enriched uranium and tritium—a radioactive form of hydrogen.

To say that they work carefully is to put it mildly. They know what plutonium can do. One plutonium isotope, plutonium-239, releases huge amounts of energy when split (fissioned). A quick release of this energy drives a nuclear weapon. A slow, controlled release is what powers a nuclear reactor. The controlled release of another one of plutonium's isotopes can power a heart pacemaker or a deep space probe.

Only small quantities of any fissionable material can be together in one place in the Superblock at any time. If enough material is in the right configuration to form the critical mass needed to sustain a fission chain reaction, a criticality incident results. Joe Sefcik, leader of Livermore's Nuclear Materials Technology Program, which manages the Superblock, is pleased to note, "In our years of working with plutonium and other fissile materials, there has never been a criticality incident in the Superblock. We currently have one of the most robust criticality safety programs in the DOE complex."

The Department of Energy rules and regulations that govern operation of the Superblock are similar to those used by the Nuclear Regulatory Commission for nuclear reactors. Activities in the Superblock also come under the scrutiny of the Defense Nuclear Facilities Safety Board, an independent agency chartered by Congress and appointed by the U.S. president. It is charged with providing safety oversight of the DOE's defense nuclear facilities.

A safety analysis report has been developed for each facility in the Superblock, and all are updated annually. Worker safety during daily operations is key. In addition, a multitude of systems provides protection from fire and any other event that might threaten the public. The Superblock is a very safe place to work.

Security at the DOE facilities has been much in the news over the past year, and security at all DOE sites has been tightened as a result. Getting into the Superblock has always been a challenge, even for those who work there every day. Entering the Radioactive Materials Area is even more complicated. Lists of allowed personnel, metal detectors, x-ray machines, and searches are the norm. Two fences around the Superblock with a "no man's land" in between, elaborate electronic security, a guard tower, and other precautions protect the Superblock from external threats.

### A Look behind the Fences

The Superblock houses modern equipment for research and engineering testing of nuclear materials. The Plutonium Facility is the largest building in the complex and was the first to become operational, in 1961. As the place where plutonium expertise is developed, nurtured, and applied, it is the cornerstone of Livermore's plutonium capability. Research on highly enriched uranium also is performed here.

Engineering tests to simulate weapon environments are performed in the Hardened Engineering Test Building, which is a separate facility. That building also houses equipment for taking radiation measurements of plutonium- and uranium-containing assemblies. Two other buildings house the Tritium Facility, which will likely produce the tritium and deuterium targets for the National Ignition Facility, the 192-beam laser that will be an important experimental tool of DOE's Stockpile Stewardship Program to assure the safety and reliability of our nuclear stockpile.

Adjacent to the Superblock are a building for high-energy radiography of plutonium and plutonium-containing components and another for metallurgical characterization of small samples. Any work there, as well as the transport of parts and samples to and from the Superblock, is done under the watchful eye of armed security escorts and health and safety technicians.

In these facilities, the Nuclear Materials Technology Program has the capability to handle all phases of virtually any project related to plutonium or uranium. A typical project often begins with analysis, design, and perhaps some research. It proceeds through an in-depth analysis of any potential hazards that might result from the project and the development of appropriate measures to assure worker and public safety. Next comes the construction of necessary equipment, performance analysis, and demonstration of the project's product. A typical project often ends with deployment of a new process, sometimes throughout the DOE complex. Several projects discussed in this article typify this end-to-end capability.

Most work in the Superblock falls into one of two categories. It is related either to the stewardship of our nation's arsenal of nuclear weapons or to finding safe ways to dispose of surplus plutonium components from the Cold War. Physicist Booth Myers, deputy program leader for Programmatic Operations, oversees this work.

Behind the scenes, other activities support the ongoing work. Under the

## Just How Dangerous Is Plutonium?

Most of the nuclear material in the Superblock is plutonium, a dense, gray metal. Yes, plutonium is dangerous. But it is by no means the world's most dangerous substance. Many common chemicals are at least as hazardous, if not more so.

Plutonium occurs naturally in trace quantities in uranium ore. But most plutonium is produced from irradiation of uranium in nuclear reactors. Plutonium is heavy, weighing 75 percent more than lead and nearly 20 times more than water. There are 18 different isotopes of plutonium, all of which are unstable and decay into other elements by emitting various types of radiation. Because of the radioactivity, a piece of plutonium is warm to the touch.

Plutonium-239 is an essential fuel for nuclear weapons and is the form of plutonium most often used at Livermore. When it decays, plutonium-239 emits a helium nucleus (two protons and two neutrons, also called an alpha particle) to become uranium-235, which then decays further, eventually into an isotope of lead. The alpha particle from plutonium-239 travels only a short distance before grabbing two electrons to become harmless helium. This range of the danger is just an inch or two in air. Alpha particles are easily shielded; they cannot penetrate a sheet of paper or even the thin dead layer of skin.

The danger from swallowing plutonium is not much greater than from other heavy metals such as lead or mercury. Very little plutonium is absorbed by the body. Most of it passes out in feces. In fact, accidentally swallowing a small amount of parathion, a widely used agricultural insecticide, would more likely result in death than ingesting a somewhat larger amount of plutonium.

The real danger from plutonium is from inhalation. If small particles of it or its oxide are inhaled into a person's lungs, they may become trapped there. Without any protective skin, the cells that line the lung can be damaged by the decaying plutonium, eventually resulting in lung cancer and perhaps death after many years. Inhaling chlorine gas would produce about the same effect.

Workers in the Superblock who handle plutonium are keenly aware of its hazards. Keeping it outside the body is the aim of the many health and safety rules that govern the handling of plutonium.

direction of engineer Alan Copeland, deputy program leader for Facility Operations, a staff of about 80 maintains the equipment and assures that all operations are carried out safely and securely. Health physicists, industrial hygienists, fire safety personnel, security professionals, and health and safety technicians are constantly reviewing procedures that control work in the Superblock. Any proposed new operation receives special attention. Detailed procedures that ensure safety and security are prepared before any new operation proceeds.

With the end of nuclear testing in 1992, most of the DOE's production facilities closed or had their operations cut back severely. The only other site in the DOE complex with facilities comparable to those in the Superblock is Los Alamos National Laboratory. The Nuclear Materials Technology Program is responsible for keeping the Plutonium Facility fully operational to ensure that work related to plutonium for the Stockpile Stewardship Program can proceed without interruption.

## Safety First

Caution is always the watchword when working with or around fissile materials. A criticality incident, where a critical mass could produce a burst of radiation, would be the most serious safety problem for workers. A greater threat to the public would be a fire spreading contamination off the Laboratory site. As discussed in the box on p. 6, another danger from handling plutonium is breathing it. All manner of safety systems and work control procedures come together to protect workers in the Superblock's Radioactive Materials Area as well as the general public from any of these dangers. Considerable protection is also provided to prevent the theft of materials.

Depending on the specific work being done, there are 25 different sets of criticality controls to provide protection. Individual workers likely know four or five such controls that cover their authorized activities. Work controls cover handling of fissile material, industrial hazards, fire, and so on.

Virtually all handling of plutonium is done in a glovebox to protect workers from any airborne particles. The air pressure in the glovebox is slightly lower than the pressure in the room, which is lower than in the hall, and so on. This pressure control assures that the flow of air is always directed inward to contain and capture any plutonium that might escape the glovebox in an accident. A complex air handling system is needed that includes electrical power, fans, and a complete backup system. A filtration system prevents leakage of any potentially dangerous material into the atmosphere.

All fissile material must be accounted for. Following any operation that causes plutonium debris, such as cutting or machining, the waste crumbs are brushed into a tray and weighed. The weight for all material—both usable and residue—must be within a gram of the total weight prior to cutting. This system of weights and records, maintained by a dedicated computer network, verifies that all the Laboratory's plutonium can be accounted for at any time, day or night.

A two-person surveillance system is required when an operation involves more than a specified quantity of plutonium. The issue again is accountability. Two workers must together open the work room, and both must stay in the room, each within sight of the other at all times. If a visitor happens to be present, a fourth person must watch the visitor.

All Superblock workers must participate in the Laboratory's Personnel Security Assurance Program. It is aimed at assuring the highest levels of reliability and personal responsibility in all plutonium workers.

Implementation over the past year and a half of an integrated safety management system has increased attention to safety throughout the Laboratory. A similar program was put in place in the Superblock a full year ahead of the rest of the Laboratory, in the fall of 1998.

All of these procedures are only as good as the people implementing them. Says Copeland, "It takes a long time to get a skilled technician up and running in the Plutonium Facility. Acclimation and training take at least 12 to 18 months. At the same time, people tend to stay. We have very little turnover."

Machinist Bill Poulos, a trained fissile material handler, weighs a machined plutonium part in a glovebox in the Plutonium Facility's Radioactive Materials Area. He is using a certified balance that is part of the plutonium accountability system. Virtually all handling of plutonium is done in a glovebox such as this one.

## Stewardship in Action

In the Superblock, work on stockpile stewardship includes nonnuclear testing of components of weapons that are now sitting in the stockpile (including fundamental physics and engineering experiments on plutonium) and investigating technologies for remanufacture of plutonium parts in nuclear weapons. Every year, the Livermore and Los Alamos national laboratories provide the technical basis for certification to the U.S. president that the nuclear weapons for which they are responsible are safe and reliable. Much of the research in the Superblock contributes to this annual process.

With no new weapons being designed to replace aging weapons in the stockpile, concern focuses on what is happening to existing weapons as they get older. Inside the Plutonium Facility, a "spiked" alloy of plutonium has been created that accelerates the metal's aging process.

Pyrochemist Karen Dodson leads the work on production of spiked plutonium, which incorporates more of the isotope plutonium-238 than would normally be found in weapons-grade plutonium, 7.5 percent rather than the typical 0.036 percent. Because plutonium-238 is more radioactive, the spiking process accelerates the formation of defects that occur within the metal during alpha decay of plutonium. The new alloy ages more quickly, on the equivalent of 16 years for every year of actual aging, which makes it perfect for experiments on plutonium decay. Information from experiments with the spiked alloy will be compared with and will supplement results generated from tests with naturally aged weapons material.

To produce the spiked alloy, plutonium-238 oxide is reduced to metal and combined with standard weapons-grade plutonium in molten salt. The metal is purified by electrorefining, and salt residues are filtered and/or scrubbed with calcium to recover all of the plutonium before disposal. The metal is then cast into "cookies" that are rolled, heat-treated, and machined to produce test samples for gas-gun experiments, tensile testing, examination by transmission electron microscopy, and other experiments (see "Plutonium Up Close . . . Way Close," pp. 23–25). Equipment for machining the samples was cold tested (that is, without plutonium) before actual machining of the spiked alloy began. This year, Dodson will be producing additional spiked plutonium alloys with varying amounts of plutonium-238.

Several steps in producing "cookies" of a spiked plutonium alloy are shown here, culminating in machinist Paul Benevento's work in a glovebox (photo at lower left). The spiked alloy has an increased percentage of the more radioactive plutonium-238, which accelerates the material's aging process. Experiments on aging plutonium are a critical part of Livermore's stewardship of the U.S. nuclear arsenal.

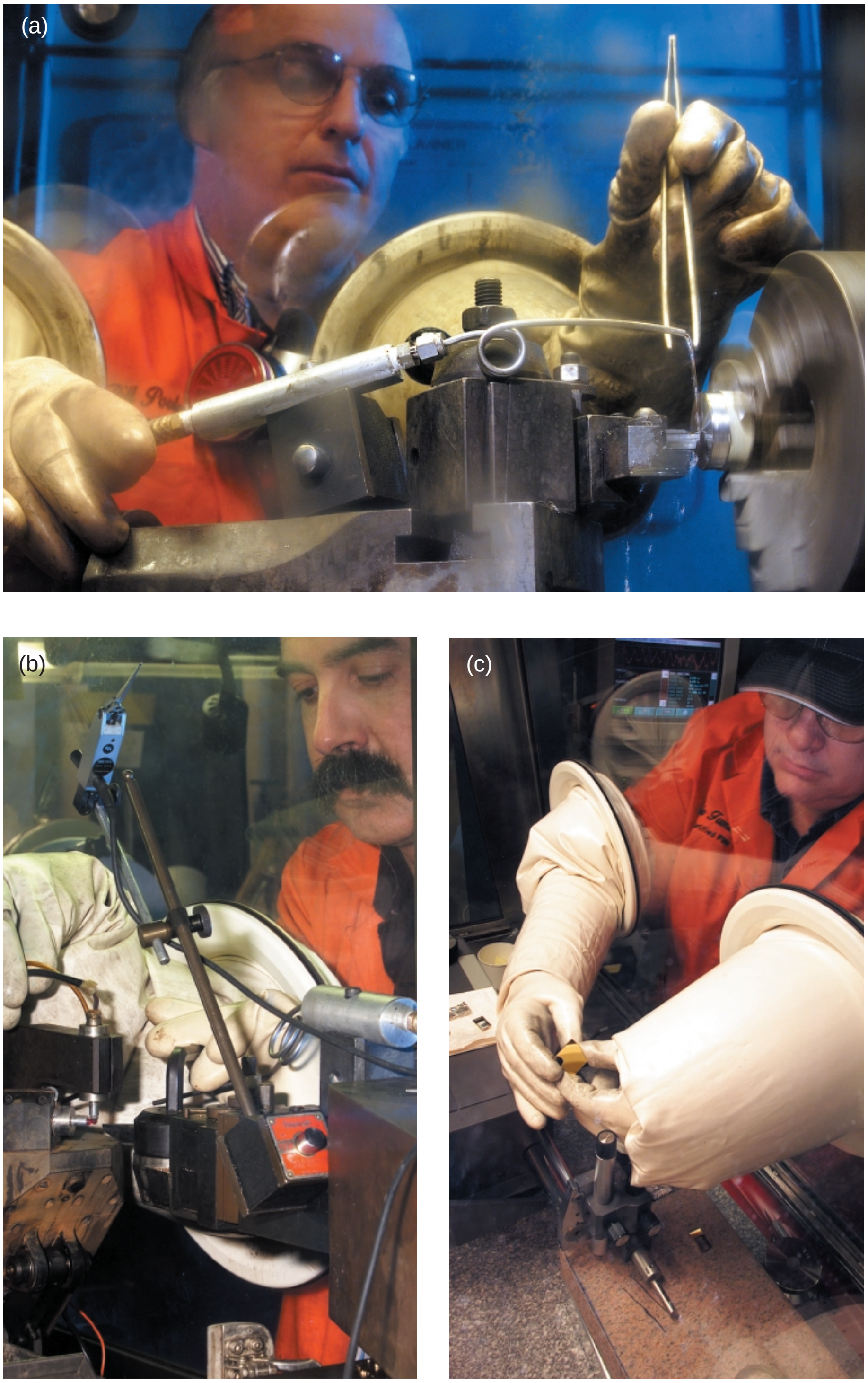
Subcritical tests of plutonium at the Nevada Test Site are another key feature of the DOE's Stockpile Stewardship Program. Subcritical experiments, which are tests that by design cannot create a fission chain reaction, provide a better understanding of the fundamental nature of plutonium and how aged plutonium affects the performance of a weapon (see *S&TR*, July/August 2000, pp. 4–11).

Engineer James Sevier oversees the production of plutonium samples in the Superblock for subcritical tests. Certified fissile material handlers cast a log of plutonium alloy and then slice it into disks that are machined and finished into the size and shape required for a particular test. The samples may also be heat-treated and put through a rolling mill to produce the grain structure needed. Says Sevier, "The resulting material looks and more or less behaves like weapons plutonium. The physicists who design a test must certify that the samples they have asked for do not contain enough material in the right geometry to go critical."

Plutonium test pieces are also used in experiments on the Los Alamos gas gun. And various alloys of plutonium, including spiked ones, will soon be used in Livermore's new, more powerful two-stage gas gun, JASPER (for Joint Actinides Shock Physics Experimental Research), at the Nevada Test Site (see *S&TR*, September 2000, pp. 12–19). The JASPER facility will be coming on line this year. Shock experiments help scientists determine the properties of materials at high pressures, temperatures, and strain rates.

## Certifying a Weapon

Tests that shake, drop, heat, and cool samples of fissile materials take place inside the Superblock's Hardened Engineering Test Building. These tests are designed to duplicate as nearly as possible the likely environments for a weapon during its lifetime, known as its



(a) Bill Poulos machines a plutonium part to be used in an experiment. (b) Ed Thomas sets up a tool on a Moore T lathe in preparation for computerized machining of plutonium parts. (c) Dale Tumlin inspects the gold that has been deposited on a glass slide. The thickness of the gold is 1.5 micrometers. All of these technicians are trained fissile material handlers.

stockpile-to-target sequence. Such tests have been performed on weapons and their components since the early days of the nuclear weapons program. Mock high explosives and other carefully engineered materials stand in for many real substances to prevent potentially dangerous interactions with fissile materials.

Livermore engineers and technicians have performed several such tests as a service to Los Alamos. In 1999, Livermore vibration tested parts of Los Alamos's W76 weapon. In the spring of 2000, it shock tested part of the B61 bomb. This year, it is performing thermal and vibration tests of the W88 weapon. These tests at Livermore are a "critical step in the certification process," according to Sefcik.

Says Myers, "One version of the B61 bomb must penetrate the earth before it detonates, so it encounters severe shock. Our 4-meter-high drop test machine can simulate that tremendous shock." For this kind of test, mock high explosive is wrapped around a plutonium pit inside an aluminum case. The case has flanges that simulate the mounting to a warhead case. It is mounted to the test fixture, which in turn is mounted to the drop machine's carriage. When the test unit is dropped, the speed of its fall usually depends just on gravity. (Although in the testing of Los Alamos's B61, carefully arranged bungee cords pull the test fixture downward to create acceleration and velocities greater than those that could be achieved by gravity.) The unit comes down onto a chunk of steel that is suspended on hydraulic cylinders—to isolate the rest of the machine from the shock pulse. The steel is layered with felt to calibrate the shock pulse to known shock data for the test unit.

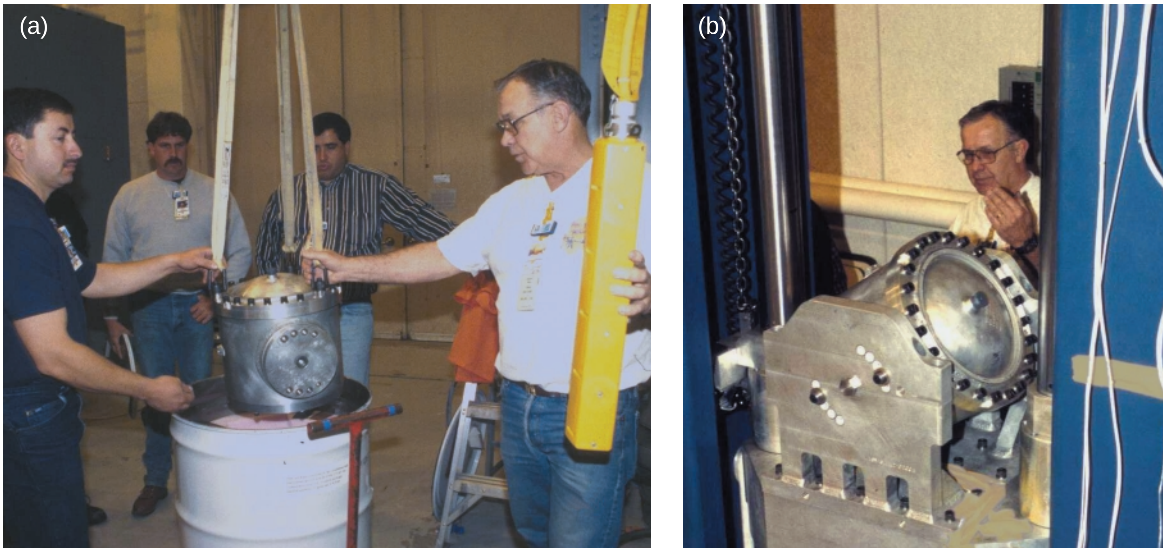
The test is performed just once with plutonium in the mock warhead, but practice runs assure that velocities, shock pulse, and other parameters are properly calibrated. The photos below show some activities of the calibration runs that preceded the shock test of the B61.

Before the shock test, the plutonium pit is radiographed. Afterward, the whole test assembly is radiographed to ensure there are no broken pieces. Then it is disassembled, and the pit is radiographed alone to see what changes, if any, occurred during the test. In the case of the B61, no change or damage resulted from the test. Says Alan Brooks, project engineer for these environmental tests, "Los Alamos's design work was indeed correct."

## New Parts Needed

Some of the experimental work includes disassembly of a weapon to determine its continued safety and reliability. The plutonium pit is taken out for analysis and is often subjected to destructive testing. Because no new weapons are being produced, reassembly of the weapons may be required, and then a newly manufactured pit is needed.

The traditional method for manufacturing a pit includes casting a disk (blank) of plutonium, rolling and pressing it to the right size and overall shape, and machining it into its final shape. This was the process predominantly used at the Rocky Flats pit manufacturing plant in Colorado before it shut down in the early 1990s. While effective at producing parts, this method was expensive, generated considerable waste, and required a large amount of plutonium to be recycled in the plant. An alternative approach being developed in the Superblock is to cast the parts to their near-final shape in a precision mold, which avoids the rolling,



(a) Gerard Martinez of Los Alamos (left) and Richard Ring of Livermore remove the B61 test object from its shipping container. (b) The B61 test object is mounted on the carriage of the shock machine for a drop test. The shock test is part of the annual stockpile certification process.

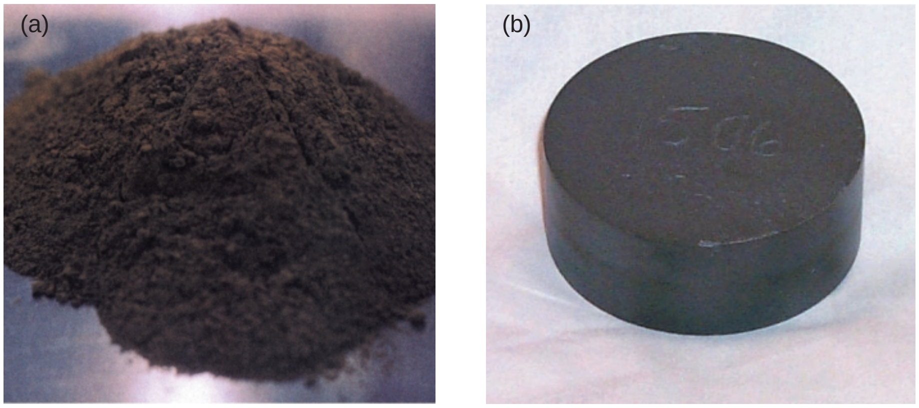
pressing, and extensive machining. This process also reduces waste generation in the machining process and thus the amount of plutonium that must be recycled.

## Solutions for Surplus Plutonium

The other major facet of program work in the Superblock centers on disposal of surplus plutonium from dismantled U.S. nuclear weapons. Livermore researchers are continuing the development and demonstration of systems to bisect weapon pits, remove the plutonium, and convert the material into either plutonium oxide, which is suitable for disposal by immobilization, or into mixed oxide fuel for nuclear reactors (see *S&TR*, April 1997, pp. 4–13). The technology for plutonium oxide production will be transferred to DOE's Savannah River Site. As other DOE sites, such as Hanford, Rocky Flats, Livermore, and Los Alamos, process their surplus plutonium, they will ship it to the Savannah River plant where the oxide feed will be mixed with a ceramic material to produce inert, puck-shaped disks that immobilize the plutonium for long-term storage and, ultimately, underground disposal.

The Savannah River plant is expected to begin the immobilization effort late in this decade. In the meantime, a way is needed to store the oxide as well as any other excess plutonium metal from DOE sites. A method of "canning" plutonium has been developed by British Nuclear Fuels Limited, and Livermore is working to perfect it. Dodson is leading this effort.

In the method, processed plutonium oxides or metal are transferred into a "convenience can," which is itself sealed into an inner and then an outer can. Both inner and outer cans are laser welded. Says Dodson, "This canning process eliminates any organic materials that might react to produce unwanted gases in the package. In addition, the inner and outer cans are filled with helium that is used to check for any leaks." The laser welds must meet acceptance criteria established by the Savannah River Site, or the cans will not be allowed into storage. That qualification process was just completed earlier this year.



Livermore is developing the technology and the hardware to immobilize DOE's excess plutonium. (a) Plutonium oxide powder is blended into a ceramic material and then granulated, pressed, and baked to produce (b) ceramic "pucks" for long-term storage.

There are three configurations of the "convenience can" used for storing plutonium oxide and other excess plutonium metal. These three configurations are shown, from left, by the first stack of two cans, second can, and third can. Each convenience can will be crimp sealed or screw sealed and placed inside an inner can (fourth one from left), and it is then welded shut. The inner can is itself placed inside an outer can (fifth from left), which is also welded shut.

In another project, workers in the Superblock are recovering the plutonium from some weapon parts stored at Rocky Flats and destroying the shapes of the parts. The plutonium can then be processed and sent to Savannah River.

## U.S. Needs Plutonium Facility

Livermore's Plutonium Facility and the Superblock in which it resides are one of the foundations of the DOE's research on plutonium. The National Nuclear Security Administration, the recently formed arm of the DOE for governing the national laboratories, has three missions: nonproliferation, stockpile stewardship, and meeting the Navy's needs for reactors. Livermore is home to active programs in two of these three missions. Says Sefcik, "The DOE's Stockpile Stewardship Program could not succeed without our Plutonium Facility and the research we do there. There is only one other plutonium R&D facility for defense programs in the country, at Los Alamos, and parts of it are not currently operating. So the experiments we do are key to certifying the weapons in the stockpile."

He continues, "The DOE also has to clean the plutonium out of Hanford, Rocky Flats, and other DOE sites housing a surplus of plutonium parts. We are taking the lead in research and development of technologies to dispose of the material. The Plutonium Facility and other buildings associated with it in and near the Superblock are essential to cleaning these sites up and preventing the material from falling into the wrong hands."

*—Katie Walter*

**Key Words:** fissile materials, material disposition, Plutonium Facility, plutonium immobilization, radiography, Stockpile Stewardship Program, subcritical tests, Tritium Facility.

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## About the Scientist

**JOSEPH A. SEFCIK** is program leader for the Nuclear Materials Technology Program at Livermore. He is responsible for the research and development programs associated with special nuclear materials and for managing Livermore's Superblock complex. He received his B.S. in applied and engineering physics from Cornell University and his Ph.D. in nuclear engineering from the Massachusetts Institute of Technology. He joined the Laboratory in 1981 to work on issues in nuclear nonproliferation, export control, and strategic defense. Later, he participated in the design of thermonuclear devices shot at the Nevada Test Site and led one of the directed-energy weapons programs. With the moratorium on nuclear testing, he focused on applying Laboratory-developed defense technologies to commercial industry. Before his current assignment, he led the Advanced Design and Production Technologies (ADAPT) program to bring modern fabrication and integration technologies into the aging plants in the DOE complex. Sefcik is the recipient of two Department of Energy Awards of Excellence and shares an R&D 100 Award for the development of femtosecond laser materials processing. He is the author of numerous publications on nuclear nonproliferation, nuclear design, and directed-energy technology. His current focus is on nuclear facility safety and security.