The Future Role of

From the time the first gram of reactor-produced plutonium was shipped to Los Alamos in 1944 to process into pure metal, the Laboratory was called upon to develop the knowledge base and the technology to handle, process, and utilize this man made material for both wartime and peacetime uses. Now, over 50 years later, the Cold War is over and difficult problems regarding the safe dismantlement of nuclear warheads and deposition of plutonium are requiring development of new technologies. Again the Laboratory is being challenged to fulfill this responsibility.

Leading edge research on special nuclear materials such as plutonium, enriched uranium, tritium, and others naturally requires specially designed and managed facilities. It is not an accident that those facilities exist at Los Alamos, nor that they are configured to meet constantly changing national needs as well as the highest safety, health, and environmental standards. In fact TA-55, the modern plutonium facility at Los Alamos, is touted as one of the "Crown Jewels" in the Department of Energy's inventory of facilities.

But things didn't start out that way. D Building, the first facility at Los Alamos for handling plutonium, turned out to be less than adequate. It had been specially designed in the spring of 1943 to minimize contamination of plutonium by light-element impurities. When that need disappeared (see "Plutonium Metal—The First Gram"), it became very clear that the more serious problem was preventing plutonium contamination of the workers. Unfortunately, D Building was not ideally suited to meet that need, and so very soon after the building was occupied and plutonium began arriving in larger quantities, plans were made for erecting a new facility at DP Site. The structures were standard prefab metal buildings outfitted with high-integrity metal gloveboxes and carefully designed ventilation and plumbing systems to insure material containment and worker safety, at least during normal operation.

DP Site served as the nation's center for plutonium research and development through the 1950s and 1960s. The responsibility for fabricating plutonium weapon components, which Los Alamos had carried out during WWII, was transferred instead to the Rocky Flats Plant in north central Colorado starting in the early 1950s. In May 1969 a fire at the Rocky Flats facility, which was devastating to the physical plant, caused a temporary shutdown of the plutonium operations and prompted the Atomic Energy Commission (then in charge of nuclear technologies) to perform a "critical systems analysis" of the nation's plutonium infrastructure. The analysis pointed out that the infrastucture was fragile and shallow in nature. Improved handling practices as well as new facilities would be necessary to insure continuity of operation as well as the health and safety of workers, the public, and the environment not only under ordinary operations but also in the event of extraordinary circumstances (accidents, natural disasters, terrorist activities, and so on). The end result of the Commission's study was the decision by the U.S. Congress in January 1971 to build two new modern plutonium facilities, one to be located at Rocky Flats for the purpose of making of plutonium weapon components and the other to be located at Los Alamos for performing plutonium research and development.

The new plutonium facility at Los Alamos, referred to as TA-55 (TA stands for

Plutonium Technology

by Dana Christensen

technical area), was designed to withstand earthquakes, tornadoes and all manner of natural disasters. It was also designed to protect workers under extraordinary circumstances such as power failures, fires, and other accidental occurrences. When it became fully operational in December 1978, the major activities in the facility revolved around support of nuclear weapons research, development, and testing. The materials work included purifying plutonium metal, developing and testing new plutonium alloys, performing mechanical and structural strength tests, and making measurements of physical properties such as the equation of state of the various complicated phases of the metallic form of plutonium. On the fabrication side, research was done on manufacturing technologies, and the results were directly applied to the fabrication of components for the new designs being tested underground at the Nevada Test Site. Small-scale recycling (about 200 kilograms per year) of materials and residues from research and development activities was another essential component of the effort, and the Laboratory became involved in developing more efficient and safer chemical separation techniques to carry out those recycling activities. Surface analysis and material-aging studies in support of stockpile-lifetime analysis were also carried out on a modest scale.

In addition to weapons-related work, the facility housed a modest capability in the design, fabrication, and safety testing for plutonium-238 heat sources. These are very compact, long-lasting power sources developed especially for space missions (see Figure 1). Although the heat sources were fabricated and assembled elsewhere, the safety, design, and fabrication parameters were developed and demonstrated at Los Alamos. Finally there was a modest capability to design, fabricate, and test advanced nuclear reactor fuels, such as mixed uranium and plutonium carbides, nitrides, and oxides. The entire population at TA-55, at the time of start-up in 1978, totaled less than 150 employees, including all of the health and safety, and operational support personnel.

Over the years, this facility, designed in a modular fashion for flexibility and change, has undergone significant modifications and upgrades in response to new demands. Some of those demands began to appear in 1980 when the DOE realized that its new production facility at Rocky Flats would not be on-line in time to meet weapon-component production requirements. Los Alamos was therefore asked to produce pure plutonium metal on an interim basis. By 1983 when it became clear that the new facility at Rocky Flats would not operate as designed, the DOE asked Los Alamos to assist Rocky Flats with the selection and installation of technologies so as to expedite the start-up of their facility. Los Alamos was also asked to continue providing production assistance so as to maintain component production.

A formal program funded by the Department's Office of Production and Surveillance was soon established to support these production-assistance activities. The new program represented a significant change in direction and an increase in

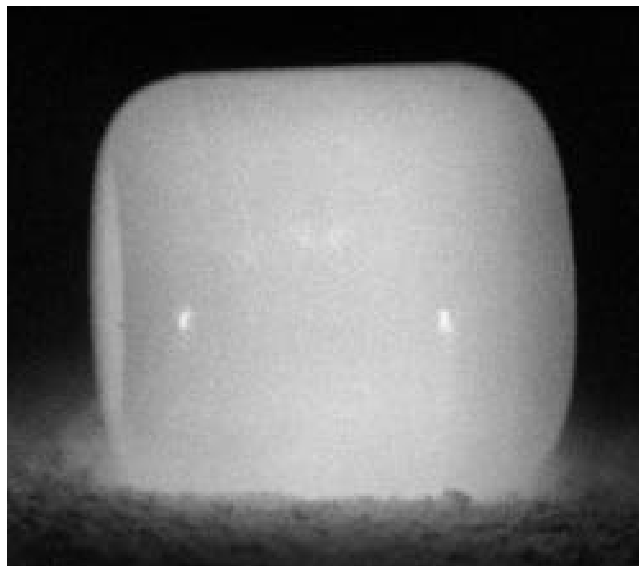
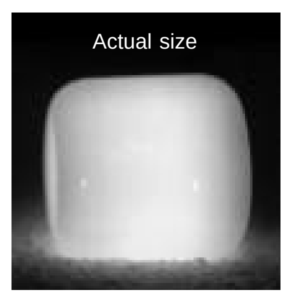


Figure 1. Power Source for Deep-Space Applications

This long-lasting radioactive power source of plutonium-238 oxide is very compact indeed. Its 150-gram mass fits into a cylinder having a height and a diameter of only 2.75 centimeters. The initial power output of 62.5 watts decays with a half-life of 87.4 years. The heat from this type of source is converted to electricity through thermal-electric converters, and the electricity is then used to power instruments onboard a spacecraft .



the level of activity at the Los Alamos plutonium facility. Research, development, and demonstration of chemical-separation technologies for plutonium recovery became the cornerstone activity, and pure plutonium metal continued to be prepared at Los Alamos and shipped to the Rocky Flats Plant.

Figure 2. High-Purity Plutonium Ring

This ring of plutonium metal has a purity of more than 99.96 per cent. It is typical of the rings that were prepared by electrorefining at Los Alamos and shipped to Rocky Flats for weapon fabrication. The ring weighs 5.3 kilograms and is approximately 11 centimeters in diameter.

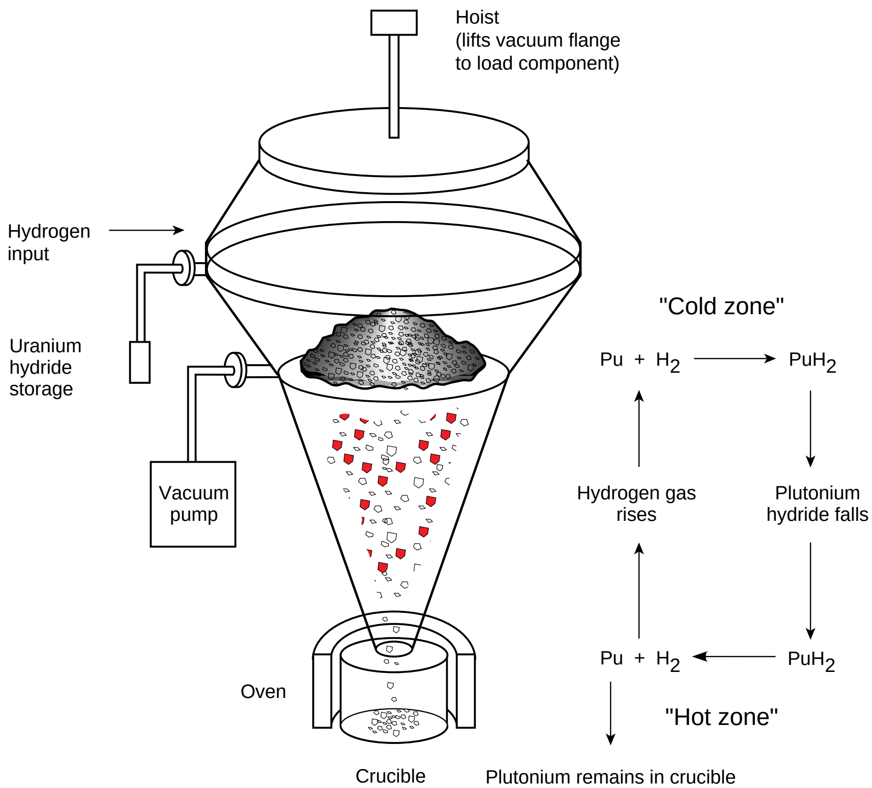
The new plutonium processing mission provided the seeds for innovation and discovery of new and novel separation/purification techniques. Dozens of patents were issued and an untold number of publications were prepared. The population of the facility grew rapidly to exceed 600 employees. Because of the facilities modular design, old technologies were easily removed and replaced by the latest technology available. Also, new health and safety features were easily incorporated as soon as the need was identified. As a result, the plutonium facility has been able to respond to constantly changing operational, and health and safety standards.

Today the combination of a very flexible facility and a very experienced staff is proving to be a tremendous asset in meeting the new demands on plutonium technology. It may come as a surprise that the demands have become more complex, not less, since the ending of the Cold War, and the Laboratory has been challenged more than ever to find innovative solutions. For example, the dramatic down-sizing of the nation's nuclear arsenal in accord with recent treaties requires new technologies to support safe, waste-free dismantlement of nuclear warheads under stringent regulatory conditions. The plutonium facilities ARIES project has become the approach of choice for cost-efficient, waste-free separation of plutonium from weapon components. This project is designed to bring in plutonium assemblies, remove the plutonium as either a metal ingot or oxide powder, and package the plutonium for long term storage according to the DOE Packaging Standard. Figure 3 shows the hydride-dehydride process, which is the centerpiece of the ARIES project. This technology base is being actively exchanged with our Russian counterparts.

The ultimate disposition of the excess plutonium, whether it be transmutation, energy conversion, vitrification as waste, or some other option must also be faced and will require a deep understanding of the fundamental science and technology involved in each as well as a definitive evaluation of the various trade-offs among them. The DOE has named Los Alamos the lead laboratory for plutonium stabilization, packaging, and storage research. The Laboratory is also involved in studying conversion of excess weapon materials into reactor fuels, transmutation of materials by either accelerators or nuclear reactors, stability of nuclear materials in waste forms such as glass or ceramics, and other long-term disposition options.

Surveillance of the remaining U.S. nuclear stockpile has also become more challenging. Since no new production of nuclear weapon components is taking place, the old approach of discovering manufacturing and material flaws at the time a weapon is retired and then correcting the flaws in the next-generation weapon is no longer acceptable. Now the goal is to understand phenomena that might cause changes in materials performance and to predict the rates of those changes so that deterioration in materials performance can be anticipated long before it affects the behavior of a weapon component . The plutonium facility has recently taken on the responsibility for the surveillance of all stockpile plutonium components. The idea is to implement a centralized cost-effective approach for determining safe and

Figure 3. Hydride-Dehydride Recycle System—An Elegant Technique for Nuclear-Warhead Dismantlement



The hydride-dehydride recycle process for extracting plutonium from a warhead exploits the fact that, when plutonium comes in contact with hydrogen gas, it reacts with the hydrogen to form a hydride at a rate that is thousands of times faster than that of any other metal. The diagram shows the vacuum chamber in which the process takes place. (The chamber is installed inside of a glovebox to insure that no plutonium escapes into the work environment.) The heated crucible at the bottom of the chamber is the "hot zone" and the upper part of the chamber, where the weapon component is placed, is the "cold zone." Hydrogen from a heated uranium-hydride storage bed flows into the cold zone where it reacts with the plutonium to form plutonium hydride. The hydride falls as a powder into the hot zone, and there it decomposes into hydrogen gas and pure plutonium. The released hydrogen rises to the cold zone where again it can combine with the plutonium and "carry" that plutonium down to the crucible below. The cycle continues until all the plutonium has been separated from the weapon component. The signal that the process is complete is a sudden rise in the pressure inside the chamber, indicating that all the hydrogen has been released. The hydrogen gas is then pumped out of the chamber and re-absorbed by the uranium-hydride bed. When the process is complete, 99.9 per cent of the plutonium in the weapon component is in the bottom of the crucible where it will be melted and incorporated into a storage-ready ingot. Thus plutonium recovery is contained from beginning to end within a compact unit that occupies a 36-square-foot glovebox.

Standard acid-leach plutonium recovery methods generate hazardous mixed chemical and radioactive waste that are very difficult kind to dispose of. In contrast, the new hydride-dehydride recycling method is essentially a zero-waste process—generating no mixed or liquid waste of any kind.

reliable stockpile lifetimes. A comprehensive program involving both destructive and non-destructive testing of stockpile weapon components and systems is being put in place. Also, new approaches and technologies are being developed that are predictive in nature so that the goal of predicting accurate lifetimes can indeed be realized. (For example, ultrasonic techniques can be used to pinpoint changes in physical dimension that occur over time as a result of radiation effects on various materials.) In addition to surveillance, the facility will also maintain the technology base for component fabrication so that, if weapon components need replacement, they can be refabricated quickly and efficiently.

Plutonium-238 heat-sources are still the best power sources for unmanned deep-space exploration. Recently the plutonium facility has been declared the nation's center of expertise in that technology, and its historic involvement in research and development has now been expanded to include the actual production of heat sources. Figure 4 shows elements of the latest project—the heat sources to power the deep-space probe to Saturn and the Saturn moon, Titan (Cassini mission). Future heat-source requirements for similar missions will be supplied out of TA-55.

Finally, the end of the Cold War has opened up new opportunities for technical exchange and collaboration regarding plutonium technology. Whereas in the past, the plutonium technology base in each of various countries was kept secret and closed, today that knowledge is being more openly discussed. In particular, the states of the Former Soviet Union (principally Russia) are beginning to participate through interactions with the U.S. national laboratories in the control of nuclear materials and the stabilization of excess materials and facilities. This initiative enhances the non-proliferation of weapon technology and materials to non-declared states and terrorist organizations.

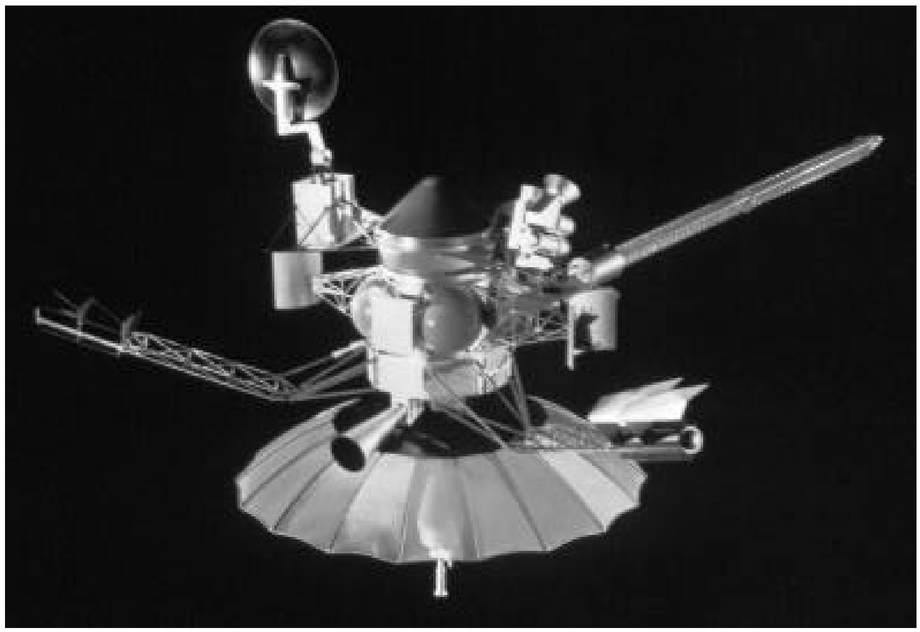


Figure 4. Plutonium-238 - Powered Deep-Space Probe

This deep-space probe (right) is typical of those that are powered by radioisotope thermoelectric generators. Those electric generators run on power from plutonium-238 heat sources like the one shown below. The Cassini mission to Saturn will require three thermoelectric generators, each loaded with 72 of those heat sources.

New cooperative agreements are being formulated to bring consistency to the way that nuclear materials such as plutonium are identified, controlled, stabilized, packaged, and stored. Indeed, most of the weapon production facilities of the past are no longer needed, and safe decommissioning and dismantlement can now begin. Those activities, however, require a significantly new technology base. Scientists at the plutonium facility have been working on those problems and have already developed several exciting new technologies including plasma and electrolytic methods for removing plutonium contamination from solid surfaces (see Figure 5). Those methods render the equipment free of contamination and therefore disposable through standard industrial routes rather than through transuranic-waste routes. Another demonstrated approach is liquid waste-stream polishing whereby liquid wastes can be stripped of plutonium and other noxious contaminant's prior to discharge. That technology is now being demonstrated in treating liquid effluents from TA-55.

The end of the Cold War has opened up opportunities to reduce nuclear arsenals and to minimize the availability of weapons-grade plutonium. It also means that the country and the world must wrestle with decisions on the clean-up of plutonium residues, facilities, and contamination, and on the eventual disposition of excess plutonium. Clearly a strong, reliable technology base is essential to implement the technical and political decisions as they are made. Realistically, the country will down-size its investment in nuclear facilities and infrastructure, which will make the remaining infrastructure even more important for future missions. A stronger investment in science and technology will be essential to overcome the inherent vulnerability associated with reduced production capacity. It will also be essential for solving the problems of the plutonium disposition and for making future generations free of this difficult Cold War legacy.

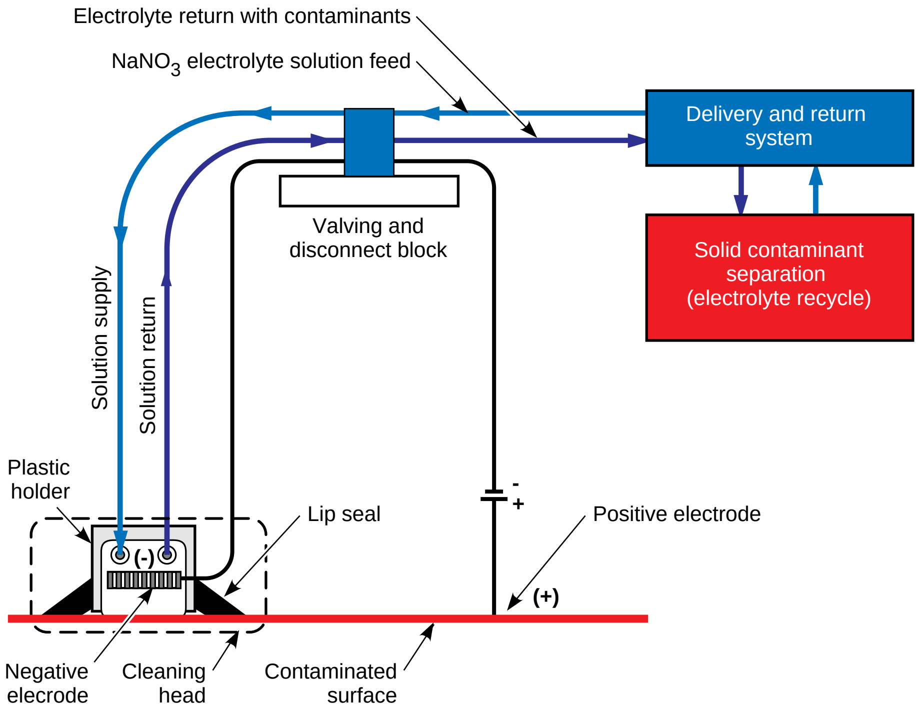


Figure 5. New Solution to Glovebox Decontamination

This new clean-up technology uses sodium nitrate as an electrolyte to remove plutonium and other contaminant's from metal gloveboxes. The surface to be cleaned functions as the anode and the cleaning head functions as the cathode. Plutonium ions and other contaminant's are pulled into solution by the voltage difference as the electrolyte passes through the layer between the cleaning head and the contaminated surface. The electrolyte then passes through a unit where the contaminant's precipitate out of solution. Thus there is no primary waste stream from this process. The system is designed to handle gram quantities of plutonium. Different cleaning heads are used to accommodate different glovebox-surface configurations. Numerous successful demonstrations of this methodology on a variety of surfaces have been done.

Dana C. Christensen is Deputy Division Director of the Nuclear Materials Technology Division at the Laboratory and is internationally known for his work in nuclear materials management, principally plutonium. Dana joined the Laboratory in 1979 after completing a research associate position at Battelle Pacific Northwest Laboratory. Since that time he has held a number of program and group management positions within the Laboratory, and has served on numerous national and international committees focused on chemical separations, waste minimization and pollution prevention, as well as facility design and operation, and weapon materials management. Dana has established and manages technology exchange activities in the field of actinide materials management with other DOE contractors and in foreign countries. Dana's research interest in the pyrochemical separation processes for extracting and purifying actinide elements led him to co-found the Actinide Pyrochemical Workshop, now in its fourteenth year. Dana received his B. S. and his M. S. in chemical engineering from New Mexico State University and earned a master's degree in business management from the University of New Mexico - Anderson School of Management.