ACTINIDE RESEARCH QUARTERLY

LOS ALAMOS NATIONAL LABORATORY

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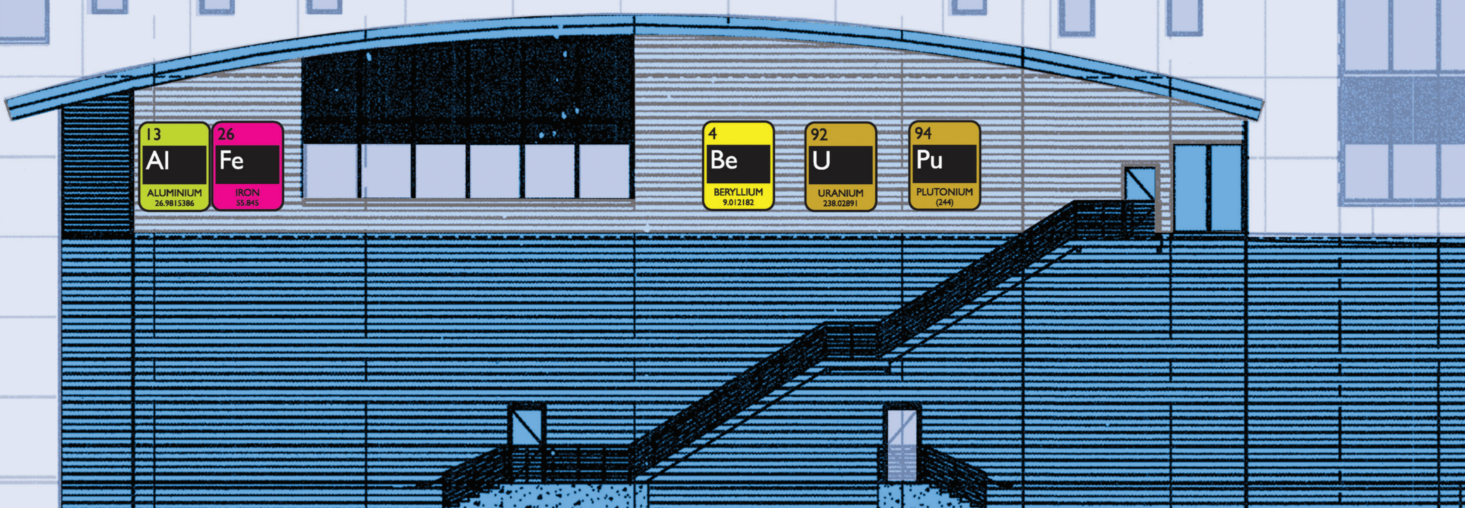
INNOVATIONS in ACTINIDE MANUFACTURING



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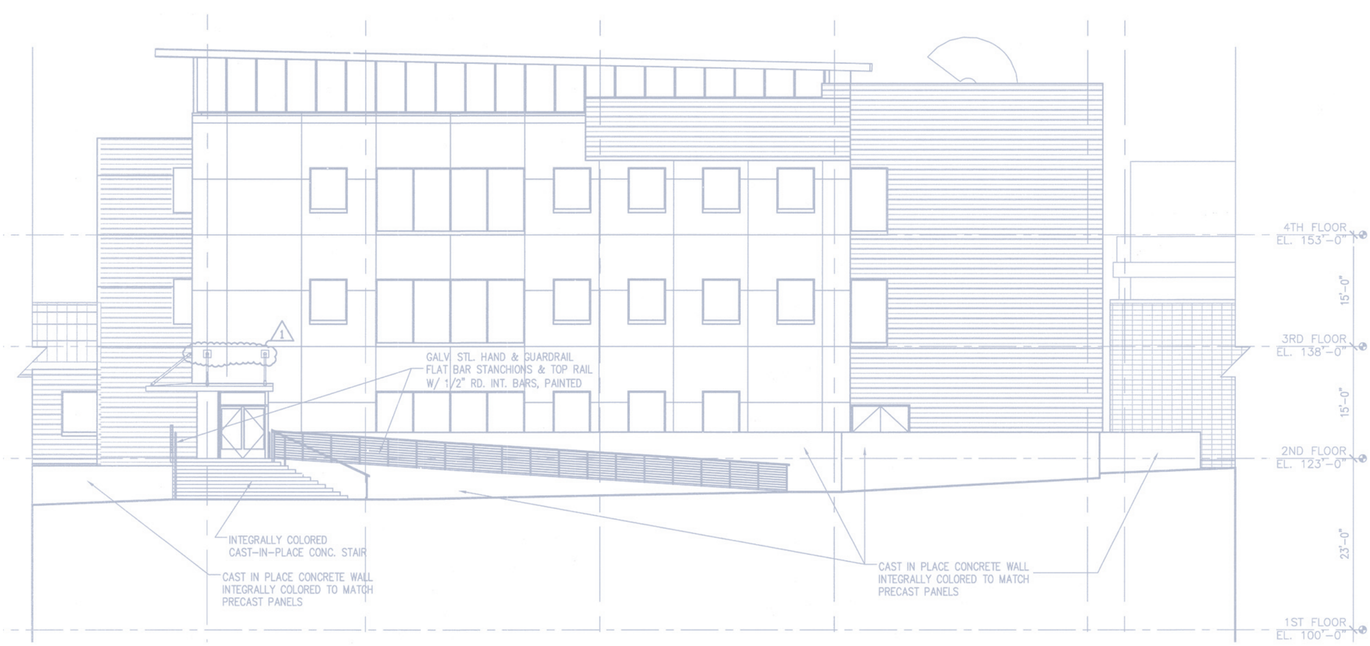


Introduction

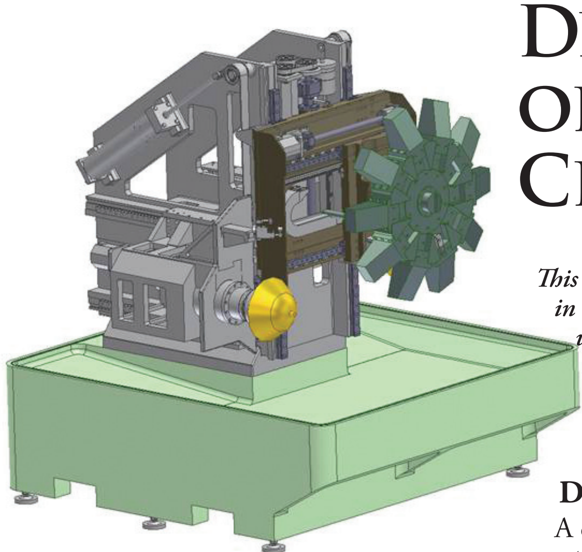
This issue of the Actinide Research Quarterly focuses on collaborations within the NNSA complex to improve manufacturing of actinide materials. The articles explain many facets of our country's manufacturing mission—from basic research on the actinide materials, joint development efforts to bring new technologies into our facilities, and the manufacturing processes required to fabricate these materials. Each article details an area of cooperation that is important to our continued success. As resources become tighter, future collaborations of this nature will be even more important to manufacturing for the U.S. stockpile.

When the Plutonium Facility at Technical Area 55, PF-4, was given the mission of recapturing the capability to manufacture pits for the stockpile, plutonium manufacturing assumed a new importance. The articles in this issue provide an overview of the odyssey to accomplish this mission and more recent developments to introduce innovations in the manufacturing processes. The introduction to innovative technology begins with a multiyear effort resulting in a new machining center, allowing workers to machine parts to extremely high tolerances while substantially improving the safety of machining operations. A study of turnings and chips from the machining process further improves safety and product quality and has become a critical part of the waste reduction of streams within the TA-55 facilities. The high-energy density welding article that follows describes a new manufacturing collaborative effort. There is an introduction to our newest TA-55 facility, the Radiological Laboratory, Utility, and Office Building, which will be fully operational in 2013. We introduce Jeffrey Yarbrough, the new LANL Associate Director for Plutonium Science and Manufacturing. A material compatibility team is essential to any good manufacturing process, and a team within the U.S. complex is evaluating improved fluids for cleaning, machining, and making density measurements of plutonium. A sixteen-month study of direct casting of uranium components completes the discussion of our current innovations. Then, we take you on a journey back to the W-88 days of pit manufacturing. So much has changed.

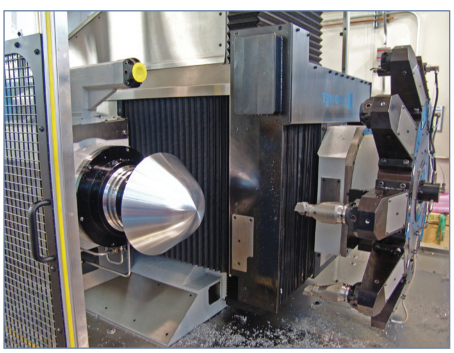
Actinide science is the cornerstone of our nuclear security mission. The collaborations between U.S. scientists in national laboratories, universities, and industry provide the new actinide science to meet our mission needs in the future.

Timothy C. George
Deputy Associate Director, Plutonium Science and Manufacturing
Los Alamos National Laboratory

Design and Fabrication of a Modern Turning Center



This article was contributed by Howard Granzow and Jody Niesen. Granzow works in the Los Alamos Integrated Program Management Division. Co-author Niesen works in the Prototype Fabrication Division. Niesen assisted with initial oversight of the design and fabrication by Hardinge Inc. of a new turning machine being installed at Los Alamos; Granzow and Niesen oversaw the final stages of its development with Hardinge.



A conceptual image (top) of the Hardinge TS350 and the actual machine (below). Even though several years elapsed from concept to final design, it is remarkable how closely the two resemble each other. In the conceptual drawing, the base (shown in light green) supports the remainder of the machine and eliminates vibrations from the moving parts of the machine. The gold disk represents the part being cut on the left spindle of the machine. The right spindle is not shown. The gray portion of the machine is stationary and holds the spindle and the turret support. The turret support is shown in black and holds the turret (shown in dark green). The photograph shows the same part on the right spindle and the right side of the turret. The door of the safety enclosure is moved to the left to expose the machine.

Design and Fabrication of a Modern Turning Center

A collaborative effort between the National Nuclear Security Administration (NNSA) sites and the Hardinge Company, located in Elmira, New York, developed a modern turning center customized for machining nuclear weapons parts in a contained environment. A turning center uses numerical controls to direct a lathe that performs turning, boring, drilling, and threading operations, all on the same machine. Standard industry machines present installation and operational challenges when fabricating parts from unique materials requiring controlled conditions. The customized turning center, made with the latest technology, has the enormous benefit of improved safety and ergonomics while yielding tighter part tolerances.

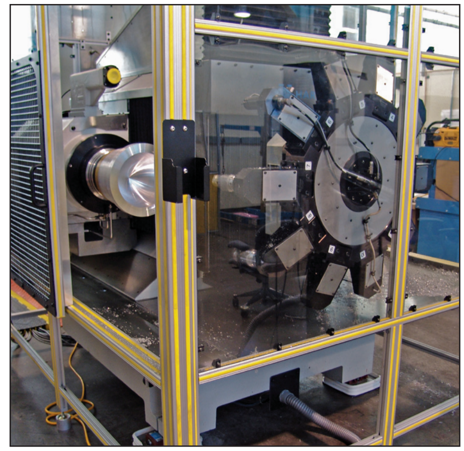
Technical experts from Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and the Oak Ridge Y-12 Site addressed these opportunities by developing a modern turning center that met the requirements for machining weapon component metals in challenging environments. The ultimate function was to perform metal actinide machining in an inert environment with full material containment. Four different teams created design concepts for a prototype turning machine that addressed requirements for reliability, maintainability, process function and capability, and environmental health and safety. Then an independent team evaluated the proposals based on established selection criteria.

The design concept developed by LLNL and Hardinge Inc., a manufacturer of precision turning, milling, and grinding equipment, was selected as the best fit to the requirements. Detailed design and fabrication of a prototype were performed under the pit capability—and later the plutonium sustainment—program. Thus began a multiyear collaboration between the U.S sites and Hardinge that has continued their many past collaborations. The advisory experts from the Oak Ridge Y-12 site, LLNL, and Independent Quality Labs (a machine tool optimization and manufacturing process improvement service), conducted design reviews and provided technical advice. As part of the enhanced collaboration, LANL awarded a contract to Hardinge for the design, engineering, and fabrication of the prototype machine. The conditions of the design prioritized operational activities above maintenance activities. The focus was on ergonomic ease of part loading and unloading and unobstructed access to parts inside the glovebox. Other features included automating tool changes, real-time data acquisition, and ease of calibration adjustments. Material accountability features were improved by easier chip recovery and glovebox cleanup. Swarf (machining waste) management was critical. The selected design allowed the swarf to fall to the bottom and away from the spindle during cutting, preventing damage to the machined part. The design divided the maintenance activities into two categories: maintenance that can be performed within the confines of the glovebox and maintenance that requires breaching of the glovebox. Cost and production delays are prohibitive when breaching a glovebox, so the ability to design the key components to be repaired, removed, and replaced without breaching the glovebox are essential to keeping a machine operational. Activities performed within the confines of the glovebox include replacement and servicing of the axis motors and feedback scales; replacement of the optical tool locator as a separate unit; maintenance of the counterbalance system, spindle encoders, brakes, drawbars, vacuum unions, all hoses, and turret components; and obtaining geometric measurements during calibration. These parts can be serviced without breaching the glovebox, making the design of this turning center unique. Activities that require opening the glovebox to the outside environment include replacement of any major system such as the spindles, full turret, and the Y-axis ball screws.

Improved part handling and glovebox containment were outcomes of detailed ergonomic analysis. Special attention was on mitigating worker injuries by using computers to model ideal ergonomic positions and incorporating them into the design. Los Alamos and Hardinge then began the fabrication. Thorough testing at each stage of the fabrication ensured the design requirements were met. The initial test artifacts produced on the new turning center have met consistent and tight tolerances.

The initial acceptance testing was completed at Hardinge's fabrication shop, and then the turning center was disassembled, shipped, and reassembled at Los Alamos. Because there are two other turning centers installed in PF-4 at TA-55, the prototype became known as the "3rd Turning Center."

Once rigorous part-cutting trials are performed using the 3rd Turning Center, the machine will be used frequently, providing improved ergonomics, safety, and efficiency in manufacturing for a variety of programs at Los Alamos. Collaborations of this nature will allow Los Alamos to maintain high standards of quality as resources become more constrained. The use of modern machine tool technology enables machining of high tolerance parts for the U.S. weapons program well into the future.



The 3rd Turning Center machine housed inside a temporary Plexiglas safety enclosure. A port with its inside diameter cut is visible on the left spindle.

Unclassified stainless steel parts cut by the 3rd Turning Center machine. The part on the right shows the rough-cut piece. The elongated end fits into the part holder, which is then fitted onto the left spindle so the interior portion of the part can be cut. The center piece shows the sprue and the rough-cut part (flat surface). The part on the left side shows the final cut part.

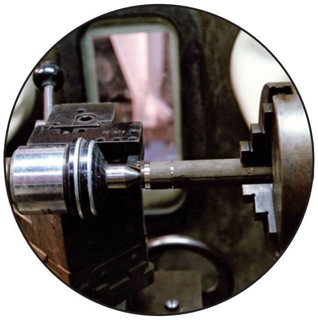
The Hardinge design team.

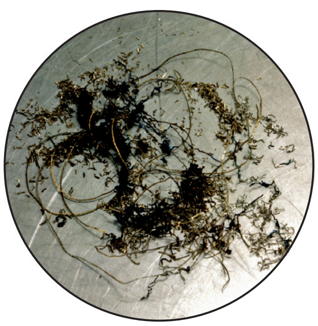
Swarfology: the Study of Turnings and Chips

This article was contributed by Doug Kautz and David Gubernatis. Kautz works in Manufacturing Engineering Technology and has 30 years experience in manufacturing of weapons components. Gubernatis is a MET R&D engineer and has been at LANL 15 years.

There are several terms for the material removed from stock during machining operations, including "turnings" and "chips." The general term to cover these waste materials is "swarf." In practice, when swarf does not break up into small manageable pieces, it is called a turning. When the material does break into smaller pieces, these pieces are called chips. Many parameters influence the type of swarf produced during machining, including machining parameters, tool insert design, and material properties. How well a material responds to machining depends on its mechanical and physical properties. Some brittle materials and alloys that are formulated for enhanced machinability will generally produce chips over a wide range of parameters and tool insert designs. Other very ductile materials (that deform under stress) are extremely difficult to machine without producing continuous turnings. Turnings may cause surface finish problems and safety issues during machining, therefore, adequate chip-breaking designs for tool inserts have been painstakingly developed by manufacturers. Tool insert manufacturers and end users have developed effective chip-forming inserts for most engineering materials.

Defense applications frequently use materials that are extremely brittle to ductile. Because these materials are not often machined in the industrial workplace, it is difficult to develop methods that work. Beryllium metal, with its hexagonal close-packed crystal structure, has excellent chip-formation qualities, but me-



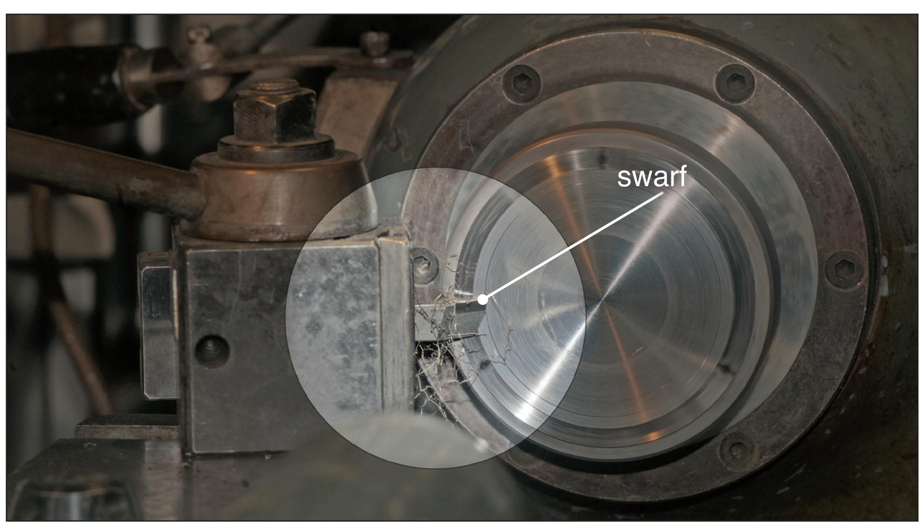


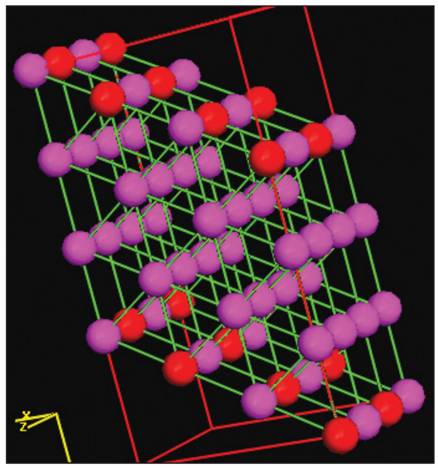
Top: Turning of a plutonium bar stock on a lathe. The rough plutonium bar is grayish due to oxidation of the surface.

Middle: Plutonium turnings where chip breaking has worked well. Note that the turnings are one-half-inch long and have broken into manageable pieces.

Bottom: Little chips of oxidized plutonium mixed with long turnings of plutonium. Chip breaking did not occur and resulted in the long turning. The long turnings pose a danger in glovebox operations because the turnings are sharp and whip around during machining. The whipping motion of the metal could potentially cause glove breaches and hand injuries.

Right: Machining process showing swarf.

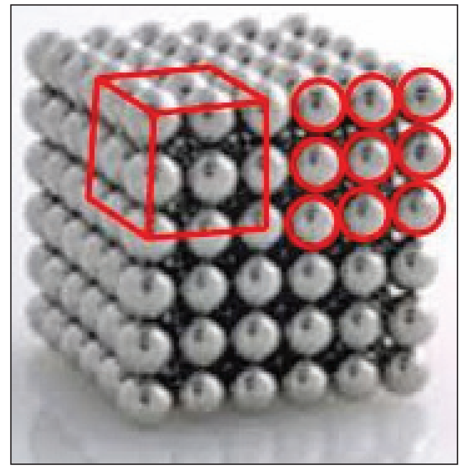




chanically induced twinning (when a material mechanically deforms to form low-angle grain boundaries) causes its already low ductility to be reduced even further, increasing the likelihood of surface crack formation. Beryllium chips are readily recycled to produce new beryllium metal products, decreasing hazardous waste produced during processing. On the other end of the spectrum, delta-phase plutonium produces continuous turnings similar to other very soft face-centered cubic crystal structure materials such as aluminum and copper. The pure plutonium alpha-phase material is more readily machinable because as it is machined it chips easily due to the brittle nature and high levels of defect structure in the metal machine stock. Plutonium is reactive with most tool insert materials, so machining feed rates must be kept fairly low to reduce tool wear and frictional heating. More common materials are also used for fabricated products needed in the defense industry; these include stainless steels, aluminum alloys, and titanium alloys. Austenitic stainless steel (made stable by being alloyed with nickel) readily adapts to the use of chip-breaking technology. It requires deep cuts during machining because surface phase transformations work-harden a thin layer on the surface of the material; other stainless steel alloys tend to machine like high alloy carbon steels, which have been studied extensively by industry. Aluminum alloys are readily machined and are compatible with chip-breaking tool inserts that have been designed to remove large amounts of material quickly and efficiently. An exception is the 1XXX series, commercially pure aluminum alloys. These alloys can have problems with chip-breaking, but due to the deep cuts possible in this alloy series, problems are not as serious as those encountered with plutonium*. Most titanium alloys, aside from commercially pure grades, provide for excellent chip-making during machining, but these materials also are very abrasive to machine tool inserts, resulting in frequent stops to change inserts during machining. If dull tools are used with these alloys, smearing of the surface occurs that may cause embrittlement problems. Uncorrected defects could be passed to the customer, resulting in part failure during high-temperature applications.

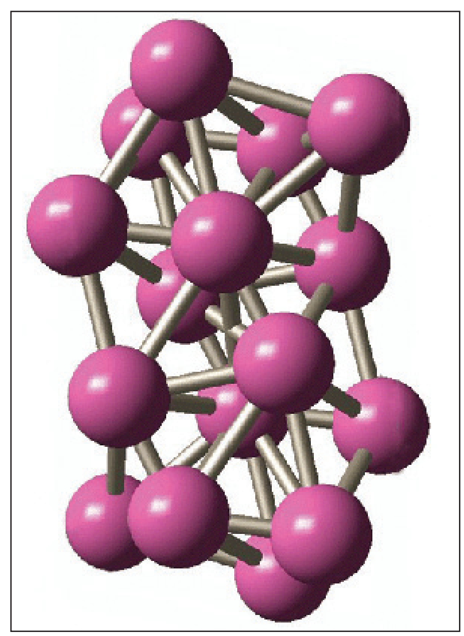
Defense applications require the use of many nonstandard materials with properties that make fabrication difficult. LANL engineers have developed effective tooling and processes for these materials, minimizing waste and maximizing swarf recycling.

Chip-breakers are designed to cause breakage at a certain depth of cut. If the cut is not deep enough the chip-breaking mechanism is not employed. In very thin cuts, it is difficult to find a tool with a chip-breaker to support the operation because the thin cutting edge will wear more quickly due to heat buildup.



***Above left:* Beryllium structure, showing hexagonal close-packed crystal structure.**

***Above:* Aluminum face-centered cubic structure.**



Pure alpha-phase plutonium monoclinic structure.

U.S. High-energy Density Welding

This article was contributed by Patrick Hochanadel, Doug Kautz, and John Elmer. Hochanadel is the LANL Deputy Group Leader for Materials Science and Technology: Metallurgy. He has worked at Los Alamos for 15 years as a metallurgical engineer. Kautz, in Manufacturing Engineering Technology, has over 30 years of experience in manufacturing of weapons components. Elmer is the group leader for Materials and Joining in the Physical and Life Sciences Directorate at Lawrence Livermore National Laboratory.

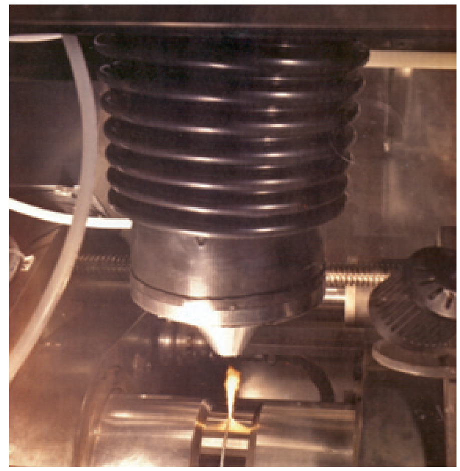
Conduction mode weld showing lack of fusion following faying, or joining, at the root because of surface oxide.

The Joining Collaboration is a U.S. effort on welding and joining of materials. This collaboration has a long history of solving problems and exchanging information in the nuclear weapons complex. Most recently, the team has been working to update the U.S. welding technology and equipment for high-energy density welding (electron beam and laser beam welding). The U.S. has developed a roadmap to determine the best uses of high-energy beam welding and joining methods, taking into consideration the constraints of a stringent regulatory environment.

Previously, engineers could use various technologies that would make acceptable welds on products, but were difficult to maintain in a glovebox environment. Electron beam welding (EBW) needs a vacuum environment that shields the materials during welding to provide a very clean and oxide-free weld. However, using EBW in a glovebox environment is more problematic because the EBW chamber and column would need to be part of the glovebox line. Several years ago, pulsed neodymium-doped yttrium aluminum garnet (Nd:YAG) laser beam welding was introduced as a viable alternative for welding in a glovebox environment.

Lasers adapt well to glovebox use because they use fiber-optic delivery of the beam to the workpiece and produce an acceptable weld profile compared with the previously used EBW technology. However, the laser welding technology has evolved so quickly that the current pulsed Nd:YAG laser technology is obsolete and no longer supported by the manufacturer. Based on this challenge, the collaborative team recommended technology that is acceptable for welds within glovebox environments and that meets the needs of various sites. LANL chose the Yb fiber laser to replace the pulsed Nd:YAG laser. This laser has been purchased/proved-in and is being installed in a glovebox. The glovebox is scheduled to be operational by the end of 2012.

As a byproduct of these interactions, the team took the collaborations a step further and developed a path forward on high-energy density welding. Members wrote a position paper that outlines the technology and discusses technologies available for needs within the DOE-NNSA weapons complex. This roadmap is a living document that is updated regularly. It has been used in meetings with various design and production agencies to describe preferred technologies. As resources become more limited within the NNSA complex, interactions become increasingly important. The goal is to produce the best quality products at the least cost to the complex. Economies of scale once available are no longer present because suppliers have reduced their product lines. But a broader pool of potential customers now helps suppliers achieve improved cost effectiveness. Similar interactions in other areas of development and manufacturing will allow the team to move operations forward while still providing cost-effective solutions to customers.



Photograph of the window boot fiber-optic delivery system currently used with the Pulsed Nd:YAG laser welding system in the glovebox. This system also will be used with the Yb fiber laser welding system.

The 6-kW Yb fiber laser welding system now being installed in TA-55 will replace the 1-kW pulsed Nd:YAG system no longer supported by the manufacturer.

Plutonium Science & Manufacturing Facility
at Los Alamos National Laboratory

Support to PF-4 includes the following:

Chemistry and Metallurgy Research (CMR) Facility. The CMR Facility's primary mission is analytical chemistry conducted in support of the pit manufacturing and surveillance programs at TA-55.

The TA-55 Radiological Laboratory, Utilities, and Office Building (RLUOB) contains 19,500 square feet of radiological laboratory space that will be used to study actinide materials science and chemistry (see article in this issue).

Radioactive Liquid Waste Treatment Facility (RLWTF) treats all Laboratory low-level radioactive liquid wastes, including those from TA-55.

TA-54 Radioactive Solid Waste Operations manage solid radioactive wastes, including those from TA-55.

The Los Alamos National Laboratory Plutonium Facility (PF) is located at Technical Area 55 (TA-55), approximately one mile southeast of the central Laboratory facilities, on about four acres. The main TA-55 complex has five connected buildings for administration, technical and office support, warehousing, and the 150,000-sq-ft main plutonium processing building known as PF-4. PF-4 is the only fully operational, full capability plutonium facility in the nation. It supports pit manufacturing, surveillance, and special plutonium recovery. An access center and other office buildings are outside the secure facility. More than 1,000 people work at TA-55.

At TA-55 are grouped the capabiliites for recovering, purifying, and converting plutonium and other actinides into many compounds and forms. Additional TA-55 resources include the means to safely and securely ship, receive, handle, and store nuclear materials, and manage wastes and residues.

Core capabilities include basic and applied research in the chemistry of plutonium and other actinides for the study of nuclear materials and a strong technology base in nuclear materials separation, processing, and recovery. The facility also supports research in plutonium metallurgy; actinide surface studies; plutonium-component fabrication technologies, including pit manufacturing and surveillance; and actinide ceramics for heat sources and mixed-oxide (MOX) fuels. The broad competencies include recovered-material conversion into plutonium metal or stable compounds; metal and ceramic fabrication; materials testing and analysis; and material purification. In addition, analytical capabilities, techniques for materials control and accountability, and a substantial research and development base support core capabilities.

In a separate section of TA-55, ceramic-based reactor fuels are fabricated and plutonium-238, used to make radioisotope heat sources and radioisotope thermoelectric generators (RTGs), is processed. These heat sources and RTGs have provided heat to maintain instrument operating temperatures and electrical power for every deep space mission of the United States, including Voyager, Pioneer, Galileo, Cassini, and most recently, the Mars Curiosity rover.

Construction of TA-55 began in 1973 and it has operated continuously without a long-term interruption since April 1978.

RLUOB | Radiological Laboratory, Utility, & Office Building

Laboratory's first LEED-certified building

The newest facility at Los Alamos National Laboratory, the Radiological Laboratory, Utility, and Office Building (RLUOB), is located on the Pajarito corridor at Technical Area 55. Its design and construction have recently been recognized with three awards. RLUOB received the U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) at the Gold level, the first LANL building to earn LEED certification. The National Nuclear Security Administration (NNSA) also recognized RLUOB with its 2010 Best-in-Class Award for Sustainable Design/Green Building. The Department of Energy gave RLUOB the 2010 EStar Award for exemplary environmental sustainability practices.

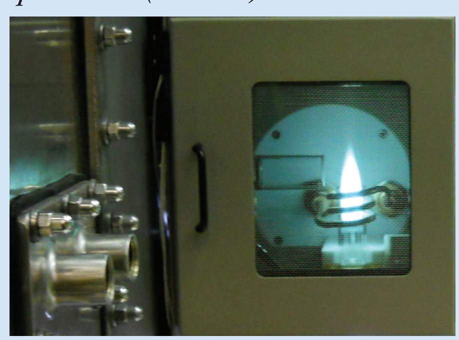
RLUOB is a multifunction facility that provides 19,500 square feet of laboratory space for chemical and material analysis. It also has a facility operations center, 350 office spaces for workers, a classified media library, a centralized training facility with classrooms and two nonradiological training labs, a facility incident command center, and a centralized utility building for all CMRR facilities. The office space and training area have been open for business since October 2011. Laboratory operations will begin in 2013.

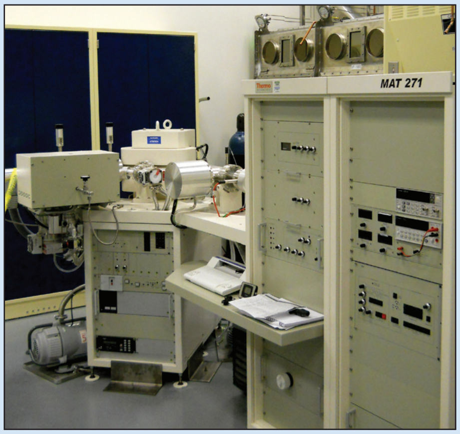
The radiological laboratory space will be used for actinide analytical chemistry, material characterization, and research and development (R&D); it is designed to handle radiological nuclear materials according to DOE-STD-1027

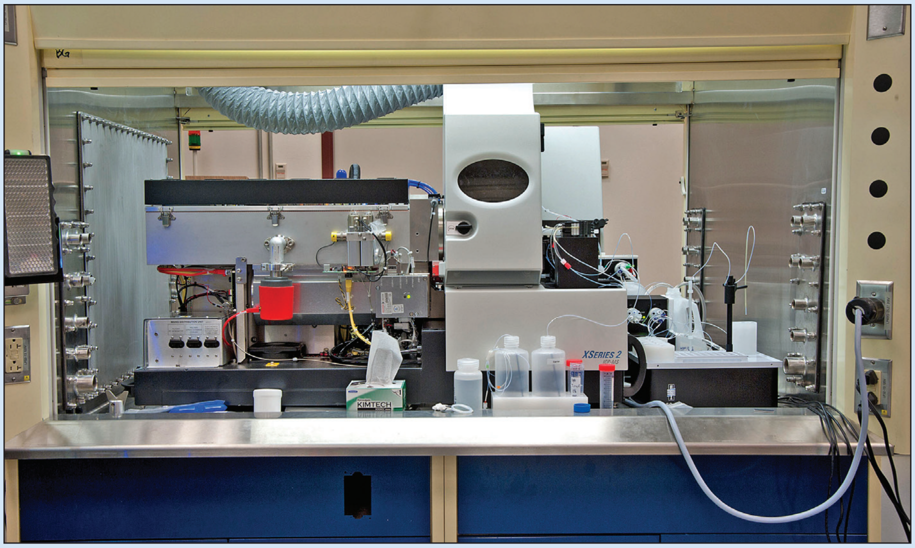
This article was contributed by Amy S. Wong, LANL Chemistry Division. She has been at LANL for 18 years. For the past 7 years Wong has served as the project-owner representative for the planning and construction phases of RLUOB.

Above: LANL Radiological Laboratory, Utility, & Office Building (RLUOB) at TA-55, the first phase of the CMR Replacement Project.

A close-up view of a RLUOB inductively coupled plasma atomic emission spectrometer (ICP-AES).







RLUOB laboratory equipment includes this thermal ionization mass spectrometer (TIMS) for isotopic analysis of actinide materials.

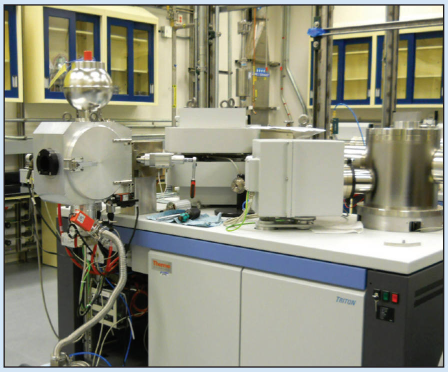
Above left: A high-resolution gas mass spectrometer.

Bottom left: Gloveboxes and open-front hoods in the RLUOB. Coated enclosure surfaces provide the infrastructue for safely handling radioactive materials and corrosive chemicals.

RLUOB has these green design features:

- Building envelope design (orientation, materials and insulation) yielded a 20 percent improvement in energy performance
- Incorporation of building materials with 24 percent recycled content
- Diversion of 72 percent of construction-generated materials through reuse, recycle, and salvage
- Roofing comprising 93 percent highly reflective materials to reduce heat island effects
- High efficiency, gas-fired hot water boilers, air-cooled chillers, thermal storage systems, and variable frequency drives for compressors, fans, and pumps
- Energy efficient lighting for interiors, exteriors, process glove boxes, and fume hoods
- Water efficient fixtures resulting in 30 percent reduction in usage
- Low emission paints and carpeting for improved indoor air quality
- Landscaping that doesn't require permanent irrigation
- Comprehensive transportation alternatives, including public transportation, bicycle storage, and changing rooms, and a refueling station for government vehicles using alternative fuels

and its Supplemental Guidance. Half of the laboratory modules were furnished, including two chemical preparation labs, two chemical storage labs, and four analytical chemistry labs for trace element analysis, mass spectrometry, and radiochemistry, . The other half of laboratory modules are unfurnished and available for future programmatic mission needs. The finished laboratory rooms are equipped with state-of-the-art analytical instruments, gloveboxes, open-front boxes, and fume hoods to support analytical chemistry analysis.



Installation in the RLUOB of an inductively coupled plasma mass spectrometer (ICP-MS).

A RLUOB installation of an inductively coupled atomic emission spectrometer (ICP-AES).

This article was contributed by Sue King, ARQ editor, and is based on an August 21 interview.

Introducing LANL Associate Director, Jeffrey C. Yarbrough

Jeff Yarbrough is the new Associate Director for Plutonium Science and Manufacturing (ADPSM) at Los Alamos National Laboratory. He did not come as a stranger. Beginning his new position at Los Alamos in March of this year followed a 29-year career at Pantex, the sole US nuclear weapons assembly and disassembly facility, located near Amarillo, Texas. Jeff had worked on many projects in cooperation with Los Alamos, Livermore, and Sandia national laboratories, and had travelled here often. “It was an easy transition for me,” he said.

Although just settling into the job, Yarbrough is multitasking; working on a 30,000 ft view of the ADPSM Directorate’s future, an interim strategy for the Plutonium Facility (PF), Conduct of Operations, addressing seismic issues and changes to gloveboxes, and reconfiguration of PF-4. Employee safety and quality management are always on his list.

Attention to safety comes after many lessons learned, Yarbrough says, telling what happened at Pantex in 2001 when he was a part of senior management with a previous contractor (now Babcock & Wilcox (B&W) Technical Services). The plant had a safety rating of at least 3 (a safety rating of “0” is an accident-free workplace, and the higher the number, the more accidents). He and the other managers had the opinion that a rating of 3 was pretty good. With an increasing workload and security training ongoing, there were always some injuries. “So when B&W came in and said that 3 was not acceptable, what followed was a long collaborative effort, a long journey.” Before he left to come to Los Alamos, the safety rating at Pantex had dropped to a 0.3. “The safety rating for PSM (as of July 2012) is a 3.45, and here at LANL, I hear some of the same rationalizations,” Jeff said. Working with the DOE Voluntary Protection Plan (VPP), he plans to refocus, to be more proactive about improving safety. He is meeting with his first-line managers in skip-level meetings to encourage them to take ownership for safety. Another initiative was a requirement for safer footwear for all PSM employees, as most of the facilities are located in an area of active construction, in an effort to reduce the number of slips, trips, and falls.

He learned quality management when an engineering major at Texas Tech University, and later at West Texas Tech University where he earned his Master’s in Business Administration. He was introduced to, and continues to follow, the Deming (W. Edwards Deming, 1900-1993) quality approach, “although you do not hear that name too much anymore," he said. Its foundations are continual improvement, taking a systems approach, and Yarbrough uses the Deming vocabulary and basic principles as his own. He plans to focus on increasing built-in quality rather than inspection at LANL. To that end, he has created a new organization in PSM, Manufacturing Quality and Control (MQC).

"The biggest lesson I learned at Pantex was that a good secure mission helps people increase their safe behavior. Quality, conduct of operations, and safety all get better together. The more productive a group is, the more efficient, the more the quality of all aspects of the work goes up. That is my job as a leader, to mold a vision."

Los Alamos is often thought of as a "company town," and Yarbrough knows about that, too. He grew up in Phillips, an unincorporated community for the workers of the world's largest inland refinery, operated by Phillips Petroleum, about 40 miles from Borger, Texas. He calls himself an oil field brat as his father and brother worked for Phillips. Homes, two churches, a convenience store, and schools were all there was to the town. Today, Phillips no longer exists as houses were moved to other locations or were torn down.

Yarbrough said that when he first read the LANL ADPSM job announcement, it seemed as though all the experiences of his career at Pantex, where he had worked since the month after he graduated from college in 1982, were preparation for this position. He led the Pantex directed stockpile work (DSW) and weapons science campaigns and the applied technology/research and development division. He managed engineering and design, high explosives manufacturing, R&D, certified material testing, and waste operations. From 2002 to 2005, Yarbrough led the Pantex manufacturing division, which includes nuclear facility management, assembly and disassembly of nuclear weapons, and special nuclear materials operations.

Los Alamos National Laboratory thought he would be a good fit, too. "Apart from Jeff's stellar reputation, rigorous interviews left our selection committee convinced of his outstanding leadership abilities, integrity, deep expertise, and commitment to excellence in science and technology," said Laboratory Director Charlie McMillan in announcing his selection. Yarbrough succeeded Carl Beard who was promoted to the position of Principal Associate Director for Operations and Business in May 2011. Tim George, now the Deputy Associate Director of PSM, was the acting ADPSM while the nationwide search was conducted.

Welcome, Jeff.

Divisions of the Plutonium Science and Manufacturing Directorate

- Integrated Program Management
- Manufacturing Engineering and Technologies
- Manufacturing Quality Control
- Nuclear Component Operations
- Nuclear Process Infrastructure
- Seaborg Institute

Different angles of the milling of stainless steel using a colloidal suspension of machining oil and water as a coolant and lubricant. The high-pressure application of the suspension removes chips away from the cutting tool, causing splashing and housekeeping issues within the glovebox. If this were a plutonium milling process, a radioactive liquid waste would be generated and polymerization of the oil in the water would require very difficult glovebox cleanup.

Evaluating Fluids for Plutonium Component Manufacturing

This article was contributed by Leisa Davenhall. Davenhall is a technical project leader in the LANL Chemistry Division. She has studied the compatibility of materials used in component manufacturing for many years.

Have you ever used a favorite product for a long time and find out that in two months it will no longer be available? Even if you buy all the remaining stock, you will either run out or the product shelf life will expire. In our business of manufacturing plutonium components, a change in processing fluids could negatively affect delivery of the final nuclear weapon product.

For example, since Los Alamos National Laboratory began the manufacturing mission, four different fluids used in plutonium machining were discontinued and now a fifth fluid is no longer being produced. Qualifying fluids for a war reserve manufacturing process (a war reserve component is one that meets the specifications required for use in stockpiled nuclear weapons) is time consuming and expensive, but it has to be done every time a fluid becomes unavailable. Unlike conventional metals, the unique properties of plutonium create further challenges in the identification of materials compatible for use. Out of this necessity, the Universal Fluid Initiative was created as a partnership between the U.S. production sites to minimize the impact of the qualification activities for the replacement fluids.

Fluids are essential in the manufacture of weapons components to lubricate and cool the part during *machining*, to make precise *density* measurements, and to remove unwanted manufacturing residue by *cleaning*. The Universal Fluid Initiative, a cooperative effort of Los Alamos and Lawrence Livermore national laboratories is formalizing a long history of joint evaluation of fluids and related process materials used in plutonium component manufacturing. The effort assesses a wide variety of products to ensure compatibility, corrosion potential, and impact on downstream processes. It guarantees that manufacturers will provide reliable future supplies and cost-effective bulk procurement. The initiative also seeks "greener" products that are safer for workers to use and have less impact on the environment.

History

The War Reserve Materials Compatibility Board was established at Los Alamos in the late 1990s to ensure that all process materials used in the pit rebuild program would not negatively impact the parts being manufactured. The board, based on an organization at the former Rocky Flats Plant known as the Technical Advisory Board, comprised representatives from product engineering, the design agency, materials science, chemistry, and quality and production control. The board meets regularly to evaluate the compatibility of materials and to create specifications for the certifiable procurement of these process materials.

Early collaborative efforts

An early task of the War Reserve Materials Compatibility Board was to help identify a solvent to clean plutonium components. The cleaning solvent of choice used at Rocky Flats, trichloroethane, could no longer be used due to its classification as an ozone depletor under the Montreal Protocol on Substances that Deplete the Ozone Layer (1989). Los Alamos researchers turned to other colleagues for their recommendations. Studies have shown that trichloroethylene has been used to clean plutonium components and the reports, procedures, and product information aided Los Alamos in its decision making process. Los Alamos adopted trichloroethylene without duplicating cleaning studies, corrosion studies, or research. This was the beginning of a useful exchange of process material compatibility knowledge that provides positive benefits in support of plutonium component manufacture without impacting the production schedules.

Recent exchanges

Since 2008, Los Alamos has conducted technical information exchanges with the Pantex Plant and Lawrence Livermore National Laboratory (LLNL) regarding process materials and their compatibility. During this time, the collaborative exchange of experience and data has assisted in the assessment of more than fifteen process materials, including gloves for component handling, wipers for use in component cleaning, and materials for component packing and storage.

Universal Fluid Initiative

The Universal Fluid Initiative was implemented to capitalize on the successful exchange of technical compatibility information already occurring. There is still much to do to evaluate fluids used for machining, density analysis, and cleaning. Los Alamos does not use a coolant for general machining, but uses a now-discontinued fluid to machine features and a hydrocarbon lubricant for final passes. Although this hydrocarbon lubricant is not hazardous in itself, it requires subsequent cleaning steps using trichloroethylene. Livermore uses trichloroethylene as a coolant. Los Alamos uses the density media monobromobenzene and Perklone™-D, a stabilized perchloroethylene solvent, respectively. In addition to the undesirable health and environmental impacts of both of these solvents, Perklone™-D is no longer produced. Livermore uses FC-43 (a perfluorotributylamine-based product) manufactured by the 3M™ Company for density determinations. Trichloroethylene is currently used to clean plutonium

A chemist measures out Novec fluids for an experiment.

*Azeotropes are a mixture of at least two different liquids. Their mixture can either have a higher boiling point than either of the components or they can have a lower boiling point. Azeotropes occur when fractions of the liquids can't be altered by distillation.

components at Los Alamos and Livermore, and although effective, is heavily regulated because of environmental, safety, and health risks. Additionally, suppliers have discontinued the solvent grades used at Los Alamos that has put even greater pressure on the availability of the solvent.

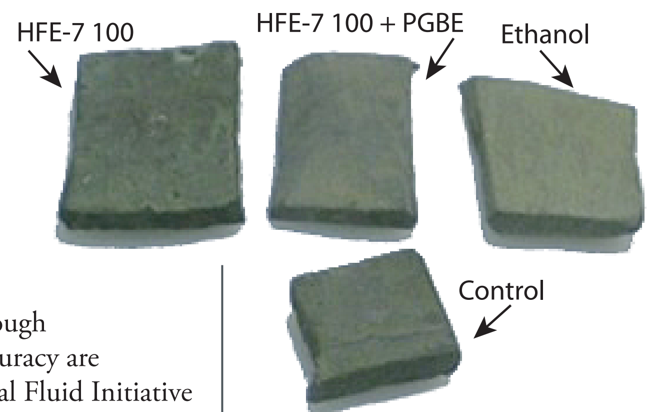
Machining fluid replacement

Three 3M™ Novec™ products have been identified as possible alternative coolants. These homologous (similar but differing by a fixed group of atoms) hydrofluoroether products (HFE-7000, HFE-7100, and HFE-7200), while predominately advertised as cleaning fluids and available as azeotropes*, could all be used neat (undiluted) as machining coolants or with a small amount of lubricant blended in. All three have physical properties that would provide cooling at rates similar to those currently required and have more favorable health and environmental impacts, which reduces the burden of regulatory compliance. In addition to these three fluids, 3M™ also makes a metal working fluid, MW-2410, which consists of 98 percent HFE-7100 and 2 percent lubricant additive.

Studies are underway regarding the use of these hydrofluoroethers to replace ethanol for use as a coolant in support of plutonium component manufacture. As the incorporation of a lubricant could offer improved machining capability in comparison with neat HFE-7100, research was conducted to identify suitable lubricants to address the commercial unavailability of MW-2410. Literature research identified the use of glycol ethers as potential lubricants. Propylene glycol butyl ether was shown to be the most suitable on the grounds of reduced galvanic reaction, even at the 20 percent level. Consequently, it was selected as the preferred product. To date, cutting trials on simulated material indicate that the presence of this lubricant additive in HFE-7100 results in a slight improvement in the reliability of the process when compared with the use of neat HFE-7100.

In addition to machining trials, a study has been conducted that involved immersing plutonium coupons in the fluids under consideration for eighty-six days. After that time the coupons were removed from their vials, visually inspected, photographed, and weighed. A direct comparison of the appearance of the coupons after the extended time period indicated a visual difference in the coupons immersed in the different fluids. Some surface oxidation of these plutonium coupons was expected as they were located in an air glovebox. However, while the visual difference is noticeable, subsequent weighing of the coupons indicated that there was no measurable weight difference for any of the four coupons after the eighty-six-day immersion. Color changes on the surface of oxidizing plutonium metal are well known, and the visual differences may represent small differences in an oxide layer on the coupon. Work is in progress to characterize the nature of the surface layer.

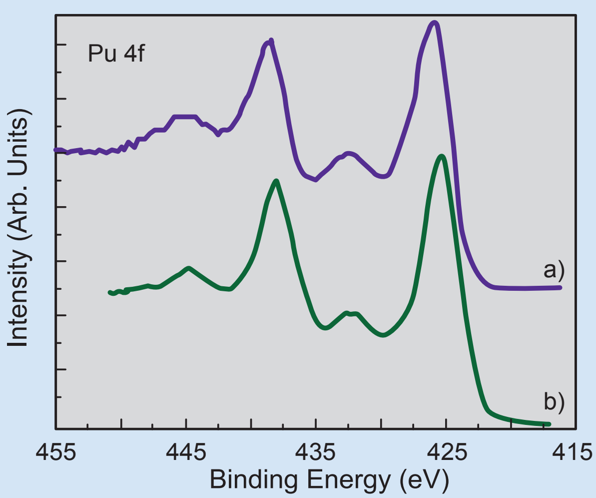
Los Alamos has surface residue evaluations, nonvolatile residue studies, and characterization work on HFE-7000 underway. Residue studies are in progress using x-ray photoelectron spectroscopy. It is anticipated that these fluids will not leave volatile residues that will require subsequent cleaning steps, but this will be confirmed through the residue study. Once a replacement machining fluid has been selected, vapor-phase corrosion studies will be carried out on plutonium. Compatibility with the materials in glovebox fixtures also needs to be determined.



Photographs obtained after an eighty-six-day immersion of plutonium coupons in coolants.

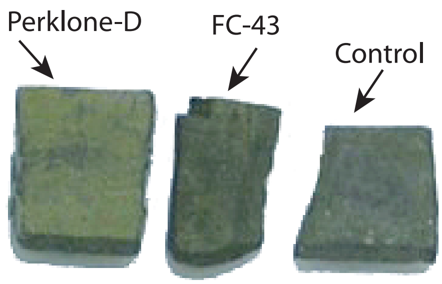
Finding a less-hazardous fluid for density measurements

Density measurements based on Archimedes' principle, though simple in theory, are complicated when high precision and accuracy are required for a plutonium component. Support for the Universal Fluid Initiative has already come from the Los Alamos Plutonium Sustainment Program in response to worker safety concerns with monobromobenzene. Given the practical precedent of using the 3M™ FC-43 for density determinations, combined with its desirable chemical and physical properties, FC-43 is being considered as a replacement for the Los Alamos density measurements. Extensive studies have already been completed at Los Alamos in support of this objective. For density medium evaluation, studies of plutonium compatibility, glovebox fixture



This chart shows the results of an x-ray photoelectron spectroscopy comparison of plutonium 4f spectra. Line a shows a plutonium surface exposed to laboratory air, and line b shows a plutonium surface that has been exposed to FC-43 and subsequently cleaned. There are no obvious differences in plutonium surfaces because no residue remained after the cleaning.

Archimedes' Principle states that the weight of the object is reduced by its volume multiplied by the density of the fluid. If the weight of the object is less than this displaced quantity, the object floats; if more, it sinks. The amount of fluid displaced is directly related (via Archimedes' Principle) to its weight.



Photographs obtained after an eighty-six-day immersion of plutonium coupons in density mediums.

compatibility, radiation stability, cleaning, and residue have been completed on FC-43. (See "Compatibility Testing of Fluorinert Solvent FC-43 for Use as a Substitute for Monobromobenzene in Density Operations," LA-UR-10-03946.) An important part of this study was to ensure that the use of a fluorinated fluid would not result in fluorine contamination on parts. A sample x-ray photoelectron spectra shows that the surface of a plutonium coupon exposed to FC-43 and subsequent cleaning is similar to that of a plutonium surface that has not been exposed to FC-43.

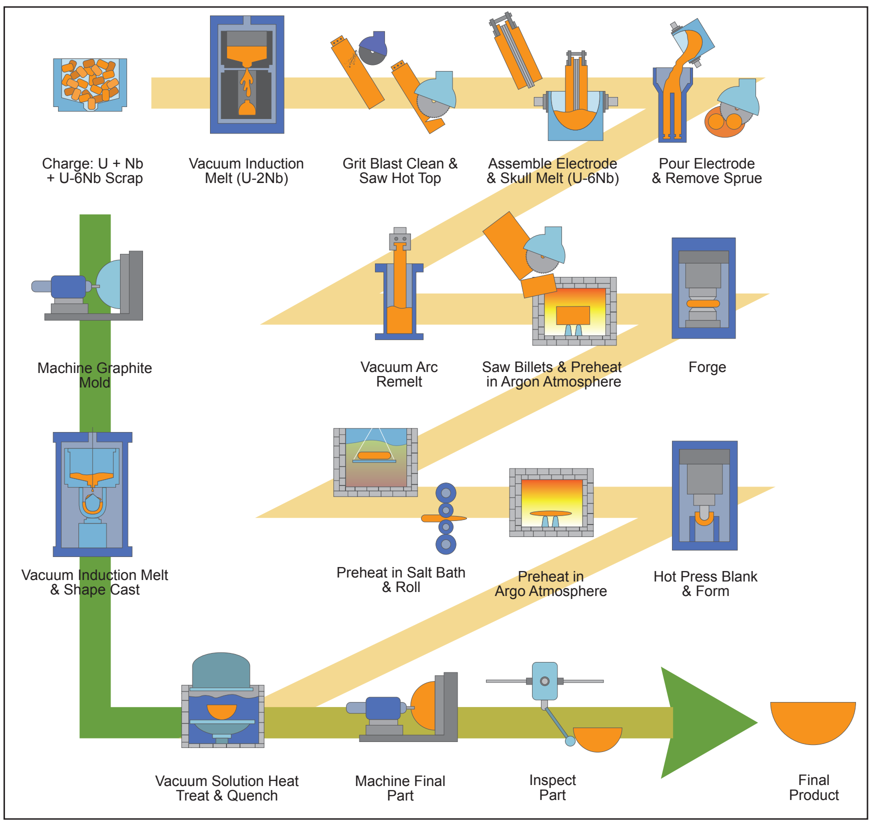
Prolonged immersion studies have also been conducted with the currently used and potential replacement density medium. This immersion study was conducted in similar fashion to that of the potential coolants. Conclusions from the analysis of these coupons to date are comparable with those from analysis of the coupons immersed in the potential coolants. Here also work is in progress to characterize the surface layer.

What is the miracle cleaning fluid?

There have been many efforts at Los Alamos to develop alternative plutonium cleaning techniques, including supercritical carbon dioxide, radio-frequency plasma, and aqueous cleaning. All have proven to be difficult to implement from a safety basis and design standpoint. The ideal replacement candidate should be able to drop into existing glovebox infrastructure, be resistant to radiation degradation, have similar solvency to trichloroethylene, be compatible for use with plutonium, be safe for workers, be commercially available, and have minimal regulatory compliance requirements. After reviewing alternative cleaning fluids, the 3M™ engineered fluids within the Novec™ product range show great potential for success. At Los Alamos, a proposal has been funded to begin addressing concerns regarding the mixed waste resulting from the use of trichloroethylene. A "cold" cleaning study is being carried out to down-select those hydrofluoroether azeotropes that will adequately remove the machining oil and vacuum grease from aluminum coupons. If successful, those solvents will be tested for cleaning effectiveness on actual plutonium substrates. Additional funding will be needed to complete plutonium-corrosion and glovebox-fixture compatibility studies. Conducting headspace gas analysis and ion chromotography tests with irradiated fluids will search for any corrosive breakdown products.

Los Alamos continues the investigation of for qualifying new "green" machining, density, and cleaning fluids. The Universal Fluid Initiative provides a venue for a life of buy/build, which will allow for a streamlined assessment process and standardization.

Direct Casting is the Future of Manufacturing Uranium Components



This article was contributed by Deniece Korzekwa, group leader of the Los Alamos Nuclear Materials Science Group and team leader of the uranium casting project. Korzekwa's career has focused on the field of casting, fluid flow, solidification modeling of actinide metals, and the impact of that research on national security.

Processing flow diagrams show the existing nineteen-step (entire illustration) wrought production stream (low efficiency, no recycle) and the new five-step direct-cast processing (in green).

Direct casting is the future of manufacturing uranium components

Replacing wrought casting of uranium with direct casting of uranium components has been the successful outcome of a complex project. Using a wealth of information derived from previous work, paired with new technology, material scientists from Los Alamos National Laboratory entered the 21st century. The team had a goal of concurrent engineering to facilitate design, engineering, and manufacturing activities in a parallel rather than serial manner. They realized cost savings while budgets for research and development were declining.

Differences between wrought and direct-cast processing

The existing wrought processing production stream uses nineteen individual processing steps to fabricate a finished component. These processing steps result in a processing stream that is only three-percent efficient (for example, one hundred kilograms of material go in and result in a three-kilogram finished part). The waste from the wrought processing is not recyclable and must be disposed of as radioactive waste.

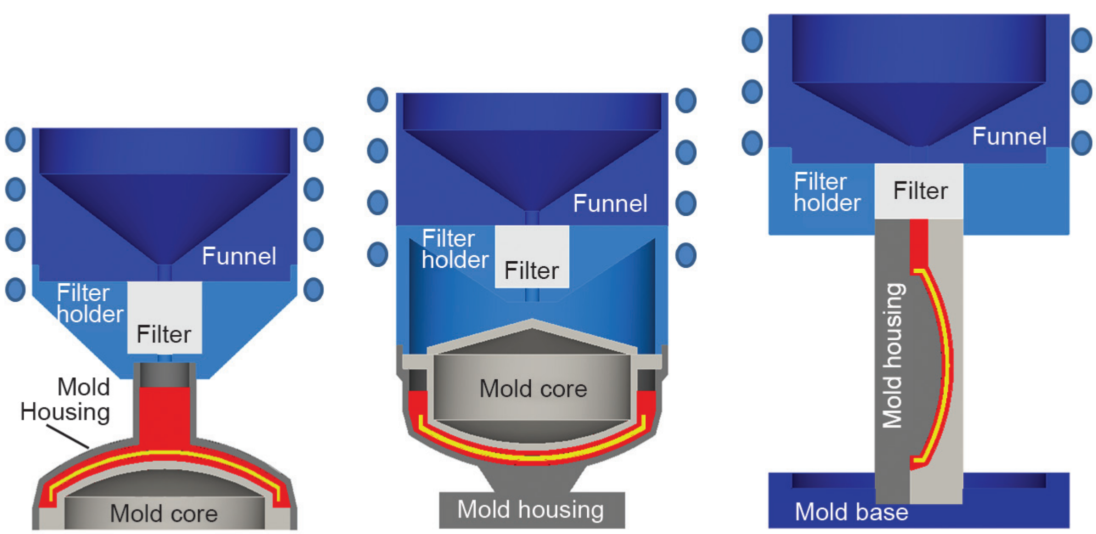
In contrast, the direct-cast processing stream requires only five processing steps and allows for the recycle of existing components as well as any waste from the wrought processing line. The smaller number of processing steps results in less waste and increased efficiency. In addition, fewer processing steps saves factory footprint and reduces the number of workers exposed to radioactivity.

Advances in casting technology

Designing a new casting process is not simple. It is not enough to cast a part with the correct shape; the material must also have the desired microstructure and properties. In contrast to traditional trial-and-error design, this project used a coupled computer modeling/experiment approach for the casting design.

Computer models help the casting design process in several ways. To begin, the time from concept to part is greatly shortened. With modeling, many computer experiments investigating mold designs and processing parameters can be analyzed in a short period of time. From this, greater understanding of the casting process is gained. The casting model can pinpoint the processing parameters that control various key phases of the process such as filling and

The geometry of the three casting scenarios investigated in this study. The final part is shown in yellow and is the casting volume for each scenario.



Case 1: Pole up
Casting volume = 387 cm^3
Riser volume = 43 cm^3

Case 2: Pole down
Casting volume = 466 cm^3
Riser volume = 122 cm^3

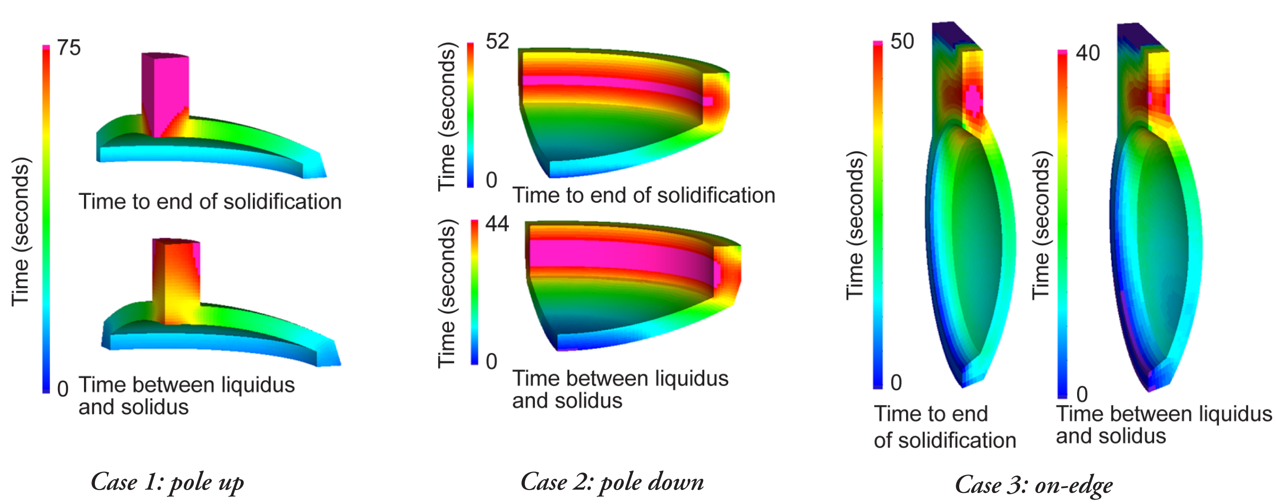
Case 3: On Edge
Casting volume = 487 cm^3
Riser volume = 143 cm^3

solidification. This understanding helps guide the casting design and also aids in process control and problem solving during the production phase. Furthermore, fewer materials and resources are needed and less waste is produced, which has obvious benefits for all manufacturing processes. Most important, when working with radioactive or hazardous materials, there is less exposure to personnel due to fewer experiments being required.

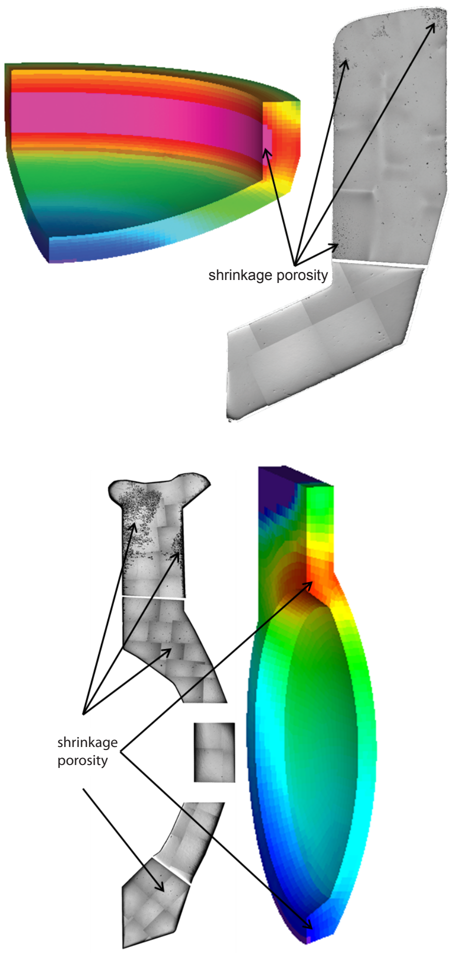
Three casting scenarios were investigated. Traditionally, uranium shells have been cast in a pole-up configuration, which requires only a small amount of material for a riser and naturally promotes directional solidification. But while the pole-up method works well for nonalloyed uranium, studies have shown shrinkage porosity in the pole area and areas of high solute concentration around the pole due to a stagnation of the solidification front when casting alloyed uranium. Therefore, two additional configurations, a pole-down design and an on-edge design, were considered. All the scenarios included a funnel to direct the metal from the crucible into the mold cavity and a zirconia filter held within a graphite holder. The filter was used to remove oxides from the molten metal.

The team used computer modeling to focus on mold design and process parameter selection questions: will the potential mold achieve the desired process temperature profile during induction heating, will the mold properly fill during pouring, and will the metal cool at a rate to produce the desired solidification? Although these questions can be answered separately and in any order, they ultimately are tied together. For example, while solidification modeling may indicate the need for a steep temperature gradient within the mold for good solidification, can that required gradient be achieved with the induction heating?

Two types of modeling outputs were used for comparison of various casting scenarios. The first was the time to the end of solidification. This gives an indication of the last place to solidify and indicates if molten metal will be available to feed solidification shrinkage. The second was local solidification time or the time



Solidification results for each casting scenario. Case 1: The solidification front proceeds nicely until the riser is reached, when solidification is dramatically slowed. Case 2: The solidification front appears to be almost parallel rather than perpendicular to the mold wall. It has good directional solidification and much shorter solidification times than Case 1. Case 3: It shows very nonsymmetric solidification both vertically and horizontally. There are several areas where liquid metal feeding may be blocked during solidification.



Comparison of simulation predictions to macroscopic cross sections of castings for Cases 2 and 3. The simulations show good, although not exact, indications of porosity due to shrinkage.

spent between the liquidus and the solidus. The local solidification time gives an indication of how much segregation may occur in the metal during solidification. The goal was to find the correct parameters so that the last place to solidify would be in the riser and require the shortest local solidification time possible.

The solidification results for Case 1 exhibit the same behavior as previous pole-up configurations. The solidification front proceeds nicely until the riser is reached. At this point solidification is dramatically slowed; leaving an area at the pole that is cut off from any liquid metal feeding and an area around the pole that has a long solidification time and potential segregation band. Case 2 shows good directional solidification and has much shorter solidification times than Case 1. The solidification front appears to be almost parallel rather than perpendicular to the mold wall, indicating an area of potential porosity along the inner wall of the casting. Case 3 shows very nonsymmetric solidification both vertically and horizontally. Solidification occurs relatively early in the riser and liquid metal will not be available to feed the upper portion of the casting.

Experiments and comparison

Experimental castings were made for both Cases 2 and 3. Molds for both cases were machined from graphite and optimum process parameters chosen from the simulations. Thirty-two thermocouples were placed in the mold and the mold cavity. The resulting castings were sectioned and analyzed using macrometallography for porosity and micrometallography for segregation and grain size.

Simulation results from Cases 2 and 3 were compared with the macroscopic cross sections of the castings and the simulations showed good—although not exact—indications of porosity due to shrinkage.

The temperature profiles from the Case 2 experiment were compared with the temperatures predicted by the model. The temperature profiles of the experiment and the simulation are generally the same, but the area near the pole region experiences significant undercooling prior to the start of solidification, which affected both the time and temperature at which solidification began. Undercooling is difficult to model and is not currently part of the modeling codes used.

Casting furnace.

Fabrication of uranium castings

The Case 2 pole-down design was chosen and additional computer modeling was performed to optimize the final mold design and process parameters to be used to fabricate the castings. These steps included the fabrication of the castings, mold and crucible preparation, casting setup, and postcasting cleanup. As a culmination of this sixteen-month project, the Los Alamos Materials Technology: Metallurgy Group made four uranium castings that demonstrated the potential of this new approach.


Rocky Flats, still operational in 1995 (left), showing the industrial area and the surrounding open space, totaling more than six thousand acres; Rocky Flats in 2005 (right), after closure, with buildings and pavements removed. (Photos courtesy of David L. Clark.)

A Look Back at the W88 Days

Recapture of a U.S. Manufacturing Capability

This article was contributed by Robert L. Putnam, who was the director of the Los Alamos Plutonium Sustainment and Pit Manufacturing Program. Putnam is currently on assignment in Washington, D.C., as the senior advisor for nuclear defense in the office of the Assistant Secretary of Defense for Global Strategic Affairs.

During the height of the Cold War and even into its waning years, the bulk of the United States' plutonium manufacturing capability was located at the Rocky Flats Plant, in the foothills of Colorado's Rocky Mountains. Being a Colorado native, I was surprised some years later to learn that "Rocky," as insiders generally referred to it, had been just north and west of the Denver-area neighborhood where I grew up and went to school. On June 6, 1989, the Federal Bureau of Investigation and the Environmental Protection Agency raided Rocky for alleged violations of environmental law; it would never reopen as a manufacturing plant.

Today, Rocky has been razed, and the remediated grounds, known as the Rocky Flats National Wildlife Refuge, are under the stewardship of the U.S. Fish and Wildlife Service. While the grounds remain closed to the public because of a lack of funds to manage refuge operations, the site is an important habitat for native wildlife. But in its heyday Rocky was a major element of the nation's nuclear weapons production complex. Plutonium-239 is a key nuclear material required for the pits, or nuclear triggers, for modern nuclear weapons.

Pits were fabricated at Rocky and its closure left the nation without a pit manufacturing capability midway through fabrication of the W88 warhead for the then-new D-5 Trident submarine-launched ballistic missile.

Little did I know, as a kid living in Rocky's shadow, that nearly two decades later, in 2007, I would help restore to the United States the capability to manufacture those vital components for the nuclear weapons stockpile. The manufacturing was not in my native Colorado but in neighboring New Mexico and would take nearly a decade to accomplish. And unbeknownst to many, the effort would require the assistance of an untold and often forgotten cadre of retired "Rocky" workers to accomplish.

Structuring the work

The history of the U.S. nuclear weapons research and development program is intimately linked with Los Alamos and has been since the Manhattan Project. During the Manhattan Project, Los Alamos coordinated the development, design, testing, and manufacture of nuclear weapons components. What grew out of those years came to be known as the Nuclear Weapons Complex (NWC) with various materials and weapons components being manufactured and assembled throughout the United States. In 1978 Los Alamos, in support of the NWC, commissioned a new plutonium research facility after nearly a decade of design and construction. The Plutonium Facility Building 4 (PF-4) became the heart of Los Alamos Technical Area 55 (TA-55). Inside the 1978 state-of-the-art building, scientists and engineers could work with multikilogram-sized plutonium shapes and chemical forms. Work performed at PF-4 supported initial pit design and materials testing as Los Alamos physicists conceived newer or more efficient weapons before transferring those designs to the Rocky Flats Plant for final development and production. Pits designed by both national laboratories were manufactured at Rocky Flats and not at the design laboratories' plutonium research facilities.

Aerial view of LANL TA-55 in 2012.

PF-4 was also home to research on the frontiers of materials science, including the characterization of actinide materials and the purification of plutonium metal for use in the Rocky pit manufacturing lines. Other PF-4 missions involved special isotopes and forms of plutonium other than the abundant plutonium-239. A similarly tasked facility—Superblock—was operational at Livermore National Laboratory, the sister laboratory to Los Alamos.

When Rocky was unexpectedly closed in 1989, the United States was left without a pit manufacturing capability and without facilities designed or laid out for production. After a few years of unsuccessful attempts to restart production at the Rocky Flats Plant, the Department of Energy tasked LANL with the mission to recapture the capability to manufacture pits for the stockpile. PF-4 was the only modern and operable facility within the NWC that the Department of Energy knew it could retool for a pit manufacturing capability. Manufacturing lessons learned from the former Rocky workers became vital. And so began a decade and a half of collaboration within the NWC culminating in the 2007 restoration of U.S. war-reserve pit manufacturing capability at PF-4.

Over the ensuing years, Los Alamos' mandate would change from capture the capability to establish a capacity and more recently, increase the capacity. With each quantum step, the challenges of retooling PF-4 increased, and the need for industrial level manufacturing experience increased proportionately.

Focusing the effort

Almost immediately upon receiving the assignment to recapture the pit manufacturing capability, Los Alamos began a series of personnel searches among the existing NWC workforce. The searches were designed to give Los Alamos an industrial level understanding of the manufacturing processes, layouts, and lessons learned from a facility such as the former Rocky Flats for pit manufacturing. The knowledge acquired would help Los Alamos retool PF-4 for a pit manufacturing mission.

Initially, a series of long-term, in-residence advisors were sought from the ranks of the now diffused Rocky workforce. Many came to Los Alamos for months and years at a time, helping Los Alamos assess the aging research and development (R&D) equipment and the plant layout for W88 pit manufacturing. These advisors gave way for a second wave of experts where issues of in situ equipment maintenance; glove box design, installation, removal, and decommissioning; process sustainability; and nuclear facility engineering became the urgent need.

In 1996*, when the pit manufacturing objective started in earnest within the United States, Los Alamos was behind. Equipment was twenty years old and inadequately maintained, manufacturing capability contained glaring holes, and work was slowed by inadequate budgets. Los Alamos also was faced with an R&D culture that did not understand the rigor required for quality manufacturing metrics. Through a process of knowledge capture combining peer review within the NWC, joint development, and determination; a manufacturing team began to materialize at Los Alamos.

The plan at the time envisioned construction of a future facility—a modern pit facility—that would capture the Rocky-like capacity then required by the nation. PF-4 was to be only a capability bridge to that new facility. But the plan

***Installation of this Deckel Maho DMU-35 milling machine at PF-4 was one of the interim-capacity projects designed to help bridge the gap in the pit-manufacturing program as the United States transitioned from* capability *to* capacity.**

*Federal Register DOE Record of Decision December 26, 1996.

Closeup of DMU-35 milling machine.

changed. The U.S. decided against construction of a new Rocky-like pit facility and instead gave Los Alamos an enduring pit production mission for PF-4.

This assignment augmentation came with budget augmentation, and as a result, it was possible to plug some of the holes in capability and capacity that the now Los Alamos-based team of former Rocky Flats experts had identified relative to the Rocky Flats plant. This was accomplished by focusing on specialized manufacturing using similar processes that were available to the Los Alamos facility. Los Alamos began to increase, educate, and train its new manufacturing workforce and establish a pit manufacturing capability at PF-4. The United States had rethought and rescoped pit manufacturing concepts, and the future course for pit capability was established. The next generation of pit engineers, technicians, welders, and machinists was being trained.

To fill the significant gaps in U.S. manufacturing capability during the transition to ten-pits-per-year capacity, Interim Capacity projects were started within the pit manufacturing endeavor. Pit capability as a program ramped up to meet long-term capacity goals while the interim capacity projects had the short-term mission of augmenting and improving the robustness of Los Alamos' manufacturing. Former Rocky experts became peer reviewers for major technology development and equipment installation projects within the pit-related programs.

Pit capability projects included installation of the tilt-pour furnace (for plutonium oxide conversion to metal and subsequent purification of the product), a modern production foundry (led by Livermore), and a modern machining platform (led by Los Alamos). The projects also included improvements to materials transportation (trolley systems) and design and modeling of gloveboxes. Specific capacity projects drove immediate upgrades to laser welding and inspection of shapes.

Many of the Interim Capacity projects are now complete or are nearing completion. These projects include upgrade of the hot coordinate measuring machine; installation of the Deckel Maho DMU-35 milling machine, the second T-base plutonium lathe, and the continuous-wave laser; and replacement of the electrorefining line. The 3rd Turning Center is also completed.

Addressing maintenance

New equipment installations were not the only avenue being pursued to bridge the production capacity gap. In early 2004, as the pit manufacturing program initiated a cost, schedule, and capability maintenance program for specific pieces of production equipment, Los Alamos began retrofitting and improving the maintenance of the installed base of programmatic production equipment at PF-4. Los Alamos researchers learned maintenance execution in a production environment.

Los Alamos sought out expertise on how to plan, schedule, evaluate, and perform preventive and corrective maintenance on its production systems and gloveboxes. Before this, a "use it to failure" approach to maintenance had been the norm in the Los Alamos research and development facilities. Such an approach focuses on using equipment as long as possible and then discarding the husk when repairs are no longer possible. Often this results in equipment being abandoned in place because it is too expensive to decommission and discard, or because well-intended repair plans are derailed by changes to budgets or program space within PF-4.

Today the plutonium sustainment program (the successor to the pit manufacturing and pit capability programs) has plans for recovering and using space abandoned by previous programs. The recovered space would support any future increases in capacity. Over the past few decades, the U.S. program has become quite adept at in situ glovebox removal and decommissioning. Recently, the United States has collaborated within the NWC on the first of many in situ plant glovebox modifications occurring in other operational nuclear facilities. With the implementation of a maintenance program modeled on the best practice industrial processes, Los Alamos pit manufacturing is producing quality product on vintage machines. With this collaboration, the pit manufacturing program has come full circle.

More areas of challenge to come

In addition to production facilities and equipment, manufacturing and production processes are fertile areas for improvement. The NWC nuclear materials teams are participants and peer reviewers of data in a round-robin analysis of analytical chemistry processes. Participants include Lawrence Livermore, Savannah River Site, Argonne, and Pacific Northwest, along with international partners such as the International Atomic Energy Agency. Pit manufacturing has led the plutonium standards metal exchange that is used to establish the quality metrics and pedigree for U.S. plutonium chemistry and analysis within the NWC and other U.S. Government agencies, including the Department of Homeland Security and the Federal Bureau of Investigation. This information is leveraged to the benefit of other programs, for example, the National Technical Nuclear Forensics, supporting counterproliferation and counterterrorism efforts within the United States and beyond.

The U.S. pit manufacturing enterprise will essentially make the same end product in the future. There are key differences in many of the traditional manufacturing process steps and sequences between the various pit types. Differences and changes in regulatory environments challenge current LANL plutonium manufacturing techniques when compared with those used by Rocky. It falls to the current LANL manufacturing team to improve and reduce the consequences of its manufacturing processes on the environment and on worker safety. Improvements in machining, cleaning of machined components, characterization of finished component shape, transportation and handling, production environmental corrosion, and storage were realized by the LANL program through interactive collaboration and process knowledge exchange within the NWC. Many of these process areas provide unique and viable investigation

Production capacity and robustness improved with the installation of the second T-base lathe. Installation was completed in 2011.

Coordinate measurement machine (CMM) technology is advancing rapidly and provides one mechanism for cooperative influence on replacement of sunset technology such as rotary contour machines like the Sheffield. Additionally, CMM inspection of production components can aid in product-based rather than process-based quality metrics.

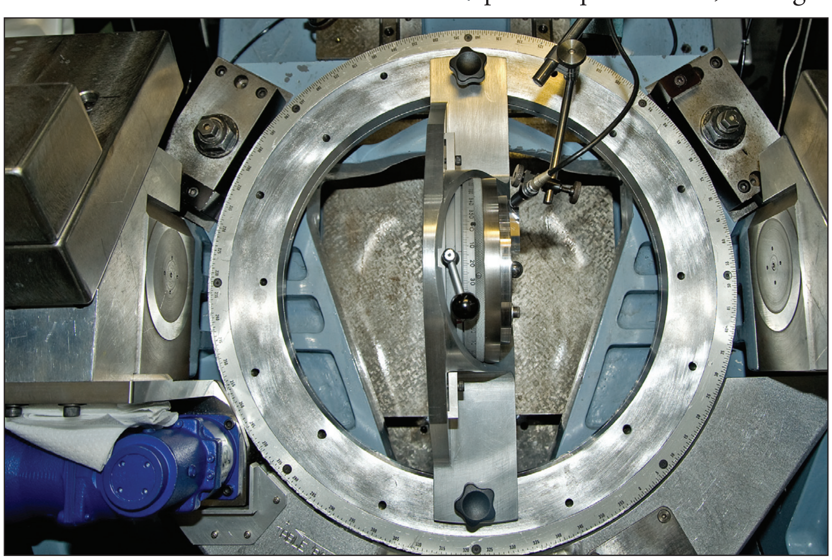
Transferred from the Rocky Flats Production plant, the plutonium Sheffield inspection gage at TA-55 is the only one left in production use. Spare parts must be handcrafted at great expense to keep this nearly sixty-year-old equipment operational. Advances in coordinate measurement machine and computing technology provide viable alternatives to its use.

topics for the future as budgetary, environmental, and regulatory conditions shape the development of processes in future production campaigns.

Future potential and collaboration

The recent LANL success in developing near-net-shape casting of components has garnered significant interest from other partners within the NWC, where cost savings can potentially reach hundreds of thousands of dollars per production unit. Near-net-shape casting is a manufacturing method in which the initial casting is close to the final shape required, which reduces the amount of final machining and shaping necessary. It is a significant advance in technology over that used at the Rocky Flats plant. With a greater than 30 percent reduction in the total amount of plutonium required to produce a finished pit component, this pending production improvement will significantly reduce future requirements on U.S. Pu metal purification and waste disposal requirements for the next pit production series. Other, as yet untapped, efficiencies have potential for even greater improvements. Because of potential changes in a future regulatory environment, development of dry machining, which has potential for direct recycling of plutonium swarf (machine turnings and chips) could greatly reduce process waste streams and save the U.S. program millions of dollars a year.

Los Alamos requires a nearer-term replacement of technologies for welding or joining plutonium components, including rotary contour gauging for the acceptance of manufactured parts. We continue to collaborate with other fabricators on this endeavor. LANL is considering modern lasers, coordinate measuring machines, and engineering software for use in developing and qualifying tool paths and machining processes. Terms like active tooling, continuous-wave laser welding, Sheffield equivalency, and product-versus-process qualification, among others, will pepper the collaborative environment for the near future.



In my years of experience with the pit manufacturing program and collaborations with a previous generation of manufacturing colleagues, I have found that it makes good business sense to have history on your side. Just as I found my formative years to be in the shadow of the closure of the Rocky Flats Plant, I now find my professional years to be in the dawn of a new era of U.S. pit manufacturing capability. I only hope that future challenges can be met as we have met those of the past, with a wealth of experience and support to draw upon as we travel this road to the future of the Nuclear Weapons Complex.

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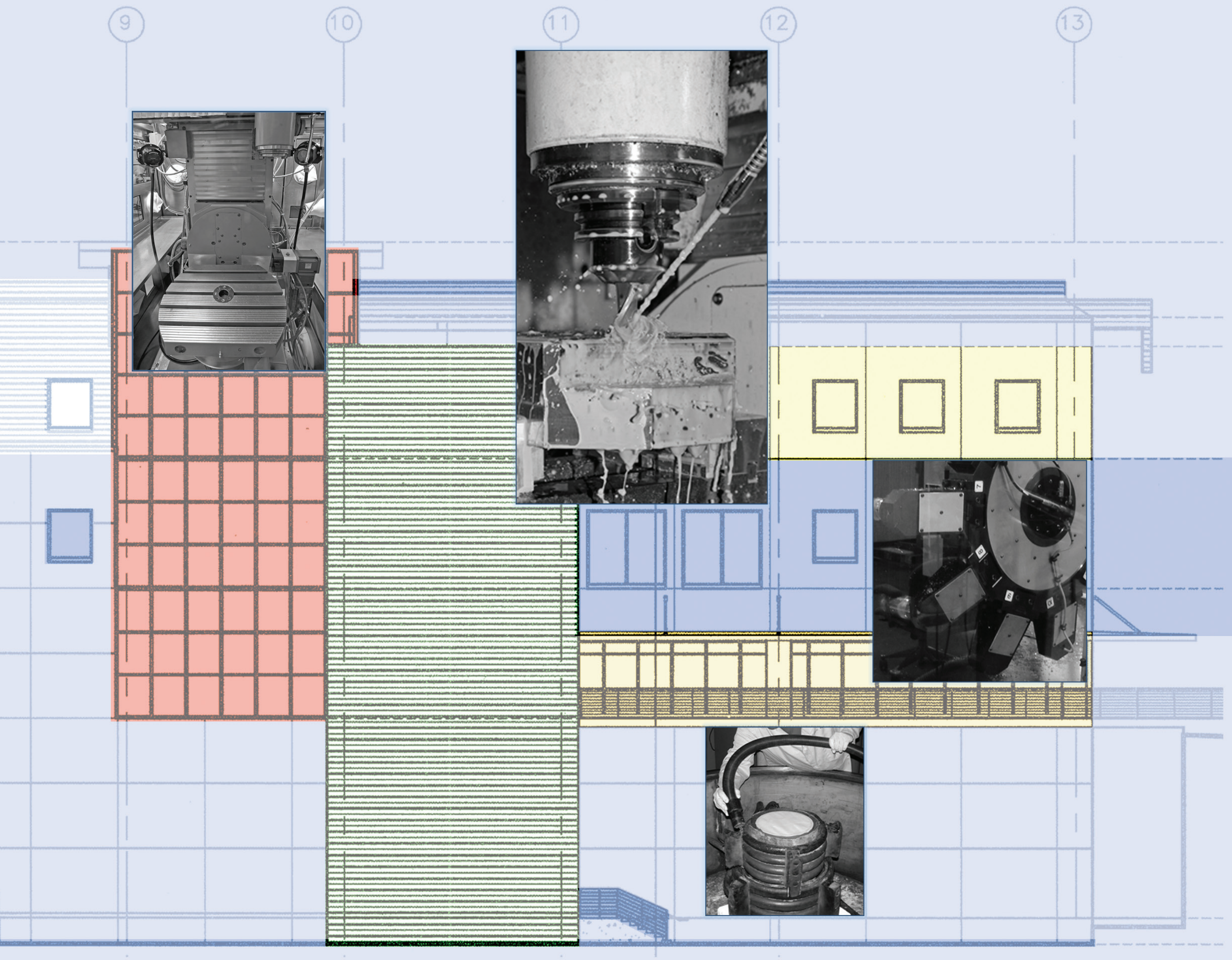

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