# nuclear weapons journal

## Los Alamos restores U.S. ability to make nuclear weapons

*LOS ALAMOS, N.M., April 22, 2003* – Los Alamos National Laboratory has successfully made the first nuclear weapons pit in 14 years that meets specifications for use in the U.S. stockpile

The six-year effort at Los Alamos' plutonium processing facility restores the nation's ability to make nuclear weapons, a capability the United States lost when the Rocky Flats Plant near Boulder, Colo., shut down in June 1989.

On hand to mark the milestone and to celebrate the 60th anniversary of the Laboratory's founding were U.S. Sen. Pete Domenici, R-NM, Ambassador Linton Brooks, administrator of the National Nuclear Security Administration, University of California President Richard Atkinson and Ralph Erickson, manager of NNSA's Los Alamos Site Office.

"The Laboratory has delivered on a major commitment to the Department [illegible]

A pit is the fissile core of a nuclear weapon's physics package. The newly made pit, called Qual-1 because it was built with fully qualified processes, is for the W88 warhead, which is carried on the Trident II D5 Submarine-Launched Ballistic Missile, a cornerstone of the U.S. nuclear deterrent.

"Our next challenge is to carry out the required [illegible] analyses and computer [illegible] so we can certify that this [illegible] manufactured pit will perform reliably in the stockpile, without [illegible] underground nucl[illegible] [illegible] said.

Los Alam[illegible] work includes [illegible] experiments, [illegible] at the Nevada [illegible] hydrodynamic [illegible]

Los Alamos will make roughly half a dozen pits a year from now until 2007 to ensure certification is completed successfully and to put into place the capacity to begin making 10 stockpile pits a year by 2007.

The Department of Energy identified the Laboratory as the site to recapture the nation's capability to manufacture nuclear weapon pits through the 1996 Stockpile Stewardship and Management Environmental Impact Statement. The DOE selected Los Alamos in part because the Laboratory has the nation's only full-capability plutonium facility, and has made pits since the 1940s.

Without the fabrication capability Los Alamos has regained, the nation could not replace stockpile pits in the future. New pits will be needed to replace those in the current stock[illegible]

equipment. The Plutonium Facility at Technical Area 55 was modified, new equipment acquired and new technologies, materials and processes developed.

More than 700 Laboratory staff and contractors have been involved in the effort that culminated in Qual-1, many working overtime.

The Laboratory has made 18 pits in the current program to recapture the capability to manufacture pits. The first pit, called Early Development Unit-1, was completed in February 1998.

In August 2002, the Laboratory made the first pit that exercised all 42 processes required to make a certifiable pit, one that could be certified for placement in the active nuclear weapons stockpile. In December 2002, all 42 processes were qualified.

Qual-1 is the first pit manufactured [illegible]

stockpile if needed, once all the required engineering and physics tests have been completed. All these processes went through step-by-step design, engineering and production reviews to confirm that the processes result in pits that meet specifications.

"All of these manufacturing processes meet today's health, safety, and environmental regulations, so some materials and processes differ from those used at Rocky Flats," Nanos said.

Los Alamos cleans pits with environmentally responsible cleaners instead of solvents that are prohibited today. Rocky Flats used a wrought process to make the initial shape while Los Alamos casts the part. Rocky Flats used machine oil for all the manufacturing steps, while Los Alamos dry machines its pits and adds lubricants only for the final pass. Los Alamos pits are welded with lasers instead of older electron beam [illegible]

**May/June 2003**

**QUAL-1**

**Plutonium Thermodynamics**

**Certified Plutonium**

**Resonant Ultrasound**

**Lujan Center**

Weapons Science and Engineering at Los Alamos National Laboratory

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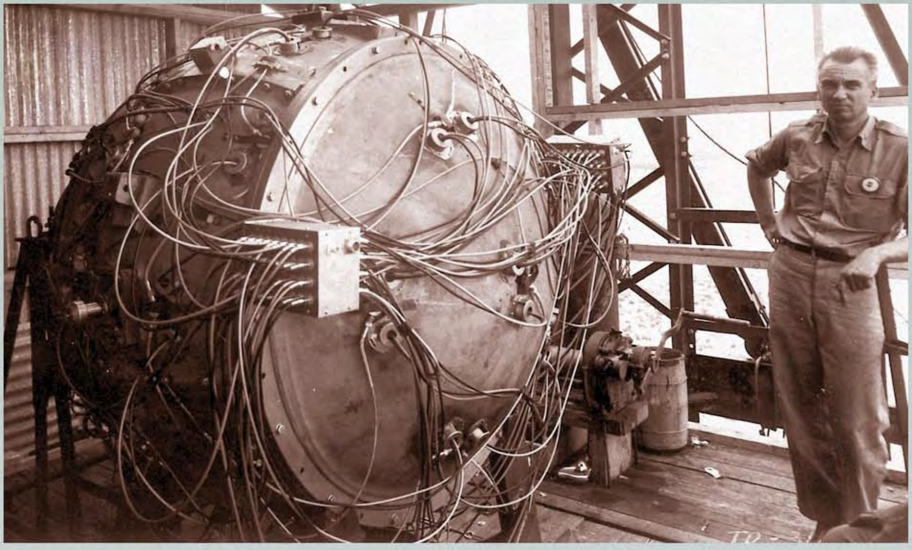

About the cover: In April 2003, Los Alamos National Laboratory restored the nation's capability to manufacture nuclear weapons with delivery of the QUAL-1 pit. The Laboratory announced this achievement during its anniversary celebration to commemorate 60 years of service to the nation and ideas that change the world.

For the record: In the March/April issue, the Point of View article was based on a talk given by John C. Browne, Laboratory Director (1997-2003), at the *High Altitude Thinking: The International Informatics Summit,* October 27–30, 2002, in Santa Fe, and should have been attributed accordingly.

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# Point of View

*John D. Immele*
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## Los Alamos and the New Triad

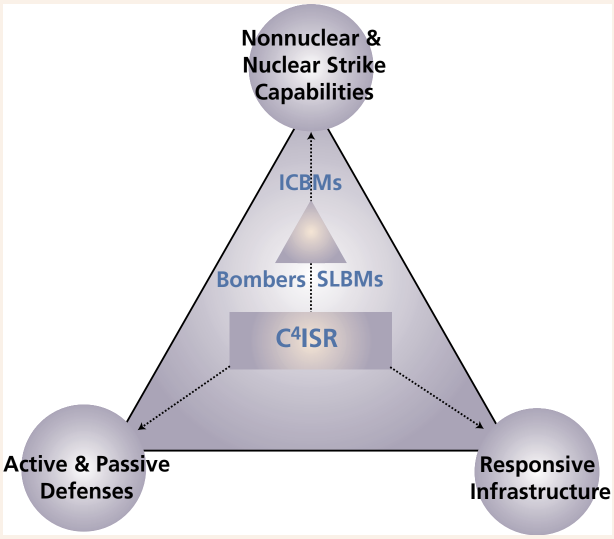
Since the beginning of the Laboratory, defense policy has worked hand-in-hand with science to support the military in the defense of the United States. Over time, this partnership has successfully met and countered evolving threats. As we celebrate our 60th anniversary, the partnership has matured to the point that Los Alamos' scientific contributions support conventional and nuclear defense as well as reducing the threats of proliferation, weapons of mass destruction (WMD), and terrorism against the homeland.

The Nuclear Posture Review (NPR) and the Nation's Quadrennial Defense Review (QDR) indicate sweeping changes in the nation's military posture and corresponding capabilities—some of which were illustrated in Operation Enduring Freedom. The NPR calls for DoD and DOE to work toward a smaller nuclear weapons stockpile* with a flexible and responsive infrastructure that is able to address an uncertain future. As the government implements NPR, Los Alamos National Laboratory continues to evaluate its evolving responsibilities.

> **The New Triad provides an intellectual architecture for most of our national security missions**

### New Triad Conference

On April 28–May 1, Los Alamos hosted a conference on *Nuclear and Conventional Forces: Issues for National Security, Science, and Technology*. Over four days, panel discussions and presentations looked at emerging future technologies and strategies to integrate nuclear and conventional forces and related capabilities into a New Triad to meet the four key US goals of assurance, dissuasion, deterrence, and defeat.



*The centerpiece of the NPR is the New Triad of flexible response capabilities: nonnuclear and nuclear strike capabilities, active and passive defenses, and responsive infrastructure. These elements are integrated into an effective defense posture through effective C$^4$ISR (Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance).*

*In addition to the enduring Los Alamos mission in stewardship of the nuclear deterrent and related infrastructure, the Laboratory will support active and passive defenses through our nonproliferation and homeland security programs. Our work in advanced sensors and automated target detection will contribute to C$^4$ISR.*

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*Strategic Offensive Reductions Treaty, May 24, 2002 (http://www.whitehouse.gov/news/releases/2002/05/20020524-3.html)

*Continued on page 30*

# QUAL-1 2003

On April 22, 2003, Los Alamos National Laboratory delivered to NNSA the first nuclear weapon pit that meets specifications for use in the US stockpile since production ceased at the Rocky Flats Plant in 1989. In delivering QUAL-1, the first pit in the qualification series, Los Alamos restored the nation's pit-manufacturing capability.

Many reports on pit manufacturing at Los Alamos have summarized the equipment installations, the acquisition of a manufacturing and quality infrastructure, the process qualification, the development of work instructions, and the disciplined operator qualification. Considerable attention has been given to the technical challenges that were encountered, mitigated, and resolved, including cast product grain size, standards for measuring contact between materials, resolution of radiographic anomalies, characteristics of welds and brazes, and challenges associated with surface morphology. All of this is well documented. However, as project director for pit manufacturing, I thought it might be useful to provide my perspective on the project management aspect of this accomplishment—what worked and what did not.

## Forming a project

We took a pit manufacturing effort that was under way as a loosely connected set of programmatic activities and formed a project. We did this because focusing effort against a set of objectives dramatically increases the likelihood of delivering the product on schedule, a premise that has been consistently proven in many industries. But how do you know when you have a project? The

following are key indicators:

- A project is unique and finite. You know when you are done.
- The project team comprises a focused group of people.
- The team and the customer have documented a baseline agreement that incorporates scope, schedule, and budget.
- The baseline is not vague.
- The scope explains clearly where the team is headed.
- The milestones are measurable, and there is no ducking the intent.

> Simply put, the essential components were the "3 P's"—people, plant, and paper

I have found project execution at Los Alamos, where the culture is one of scientific exploration and autonomous decision centers, to be especially challenging. Most people concur that the challenge is necessary and agree that the Los Alamos National Laboratory culture will be well served by a push toward increased accountability and balancing science with delivering to commitments.

## Lessons learned

We learned a few lessons along the way to QUAL-1.

**Set a firm baseline, and get it approved.** My predecessor strategized a well-thought-out baseline that we successfully executed. We submitted the baseline to NNSA on October 1, 2000, and it was approved in April 2001—after six months of rewrites, regroups, and tough budget discussions. During this time, we encountered significant stakeholder skepticism. When we finally gained baseline approval, we kept our commitment to the original funding and milestones. The consistent response to the many questions and scenarios about funding was, "Refer to the baseline plan."

An important element of the baseline plan was the written definition of key concepts—like the QUAL-1 pit. When we delivered QUAL-1 to NNSA, the cover letter contained verbatim language from the baseline plan. No one could question that we did what we agreed to do.

**Teamwork is essential.** All other shortcomings can be mitigated. Teamwork is talked about and studied and characterized ad nauseam. Everyone wants it, but how do you achieve it? It is elusive, tough to build, and absolutely essential. It is dynamic and never complete. But you can tell when you have achieved the teamwork threshold to push the project to success. In our case, we reached that point around June 2002, at what was probably the lowest point in the project. We had flunked a quality assurance (QA) assessment and were three months behind schedule in process qualification. We had focused on the interesting technical issues and on making pits, while procrastinating on the tedious work of building a QA infrastructure. There was every opportunity to resort to finger-pointing across divisions or groups. Instead the team pulled together, focused on executing experimental plans, developed recovery plans, hired good contractors, took their advice, and worked hard. Once we got through that pinch, the team was unstoppable. There were weekly problems—the Sheffield gauge and its calibration and software; the Bostomatic mill; and the resolution of radiography, eddy current, weld concerns, and failed brazes. But the team was galvanized and committed. It is that incredible team—people from NMT, ESA, MST, and C Divisions located in Building PF-4, Sigma, the main shops, TA-8, and CMR—who took on the problems and recovered this nation's pit manufacturing capability. They are proud of the accomplishment and are ready for their next stockpile challenge.

Trust the people who know. Several times I wanted to push back on the team. The assembly team wanted more pits. Since the development pits were off-normal, the team wanted to build standard pits. The baseline did not call for standard pits, and I was concerned about scope drift. They convinced me, and standard pits saved the process qualification schedule variance. I insisted that standard pits were not commitments that were subject to performance measurement by NNSA, and we incorporated the builds into our budget on a *pro bono* basis without sacrificing external commitments.

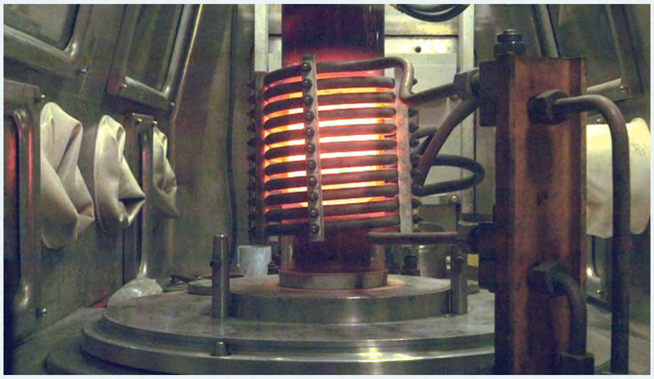
Later, I tried to accelerate a build before the 2002 winter break. I thought we needed the gain before the break because I expected a slowdown after the holiday. The process owners pulled me into a meeting and said, “It’s the wrong time. Our people are tired and edgy. This build is ill-timed. We’ll come back from the break refreshed, not slowed, and will meet the schedule.” We put off that build, and it went smoothly. It is important to do a “gut check” with the people on the floor and act on their intelligence.

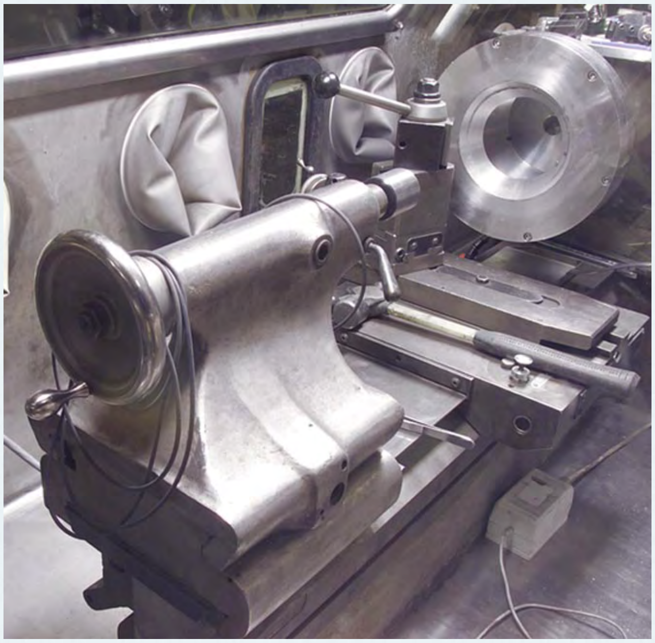
**Find some way to schedule science.** A schedule sets your best understanding of where you expect to go. It is subject to change, but not without cause or new information. Early in the project, around December 2000, the ESA eddy current team briefed us on a technology that was going to be fielded for the nondestructive check of weld penetration. It was a fascinating briefing in which they clearly had a full grasp of the technology, and they could derive the technical basis from first principles. I was sure we were dead. Technology development was on the critical path, and they did not have a delivery schedule. I asked if the next briefing could be half-technical and half-schedule; maybe in three months, they could present cost. It had not occurred to the team to develop a schedule. They hit it hard and developed a detailed schedule that showed process qualification in November 2002. I was incredulous that it could take that long and responded, “You’re building a Cadillac, but we need a VW. Can’t some of this automation and computer simulation be manual?” I called for an independent review from industry. Three days later, the reviewer told me, “These guys are the best. I learned a lot.” The eddy current team delivered, dead on the original schedule, a very powerful tool for on-line resolution of weld penetration to allow for weld repair. This lesson reinforces the importance of trusting the team.

**Teamwork is elusive, tough to build, and absolutely essential**

**Having “priority” is both a benefit and burden.** The benefit part is obvious. We had top management engagement and were the top Los Alamos priority. The ADWEM office chaired the weekly Integrated Product Team meetings, and we could bring muscle, resources, and personnel to bear. However, the burden was the limelight—reporting, briefings, audits, and constant oversight. There are hard-working, credible people with key expertise who have an aversion to the limelight. They seek reassignment. The limelight factor and associated distraction of key personnel needs to be factored into the schedule and managed as a risk.

**Under-commit and over-deliver.** To establish a credible track record with the client, we were careful with our commitments, and we built pits early and often. We managed to an aggressive internal schedule and reported to the client according to a more conservative baseline. The baseline incorporated adjusted durations based on a probabilistic risk assessment that incorporated equipment downtime; scrap; personnel unavailability; and supply, storage, and movement logistics.





There were many other lessons, bumps, regroups, false starts, and disappointments. Then there was QUAL-1. We delivered the submittal package to NNSA-LASO at 7:30 A.M. on April 22, 2003. On April 24, Yevgenia Borisova's article in the *Moscow Times* was headlined "U.S. Restarts Its Nuclear Machine."

## What's next?

So now what? The only way to retain a pit manufacturing capability is to build pits. The project is funded to build pits at a rate that supports certification testing: the commitment is to deliver six pits in FY04 and to scale up to ten pits per year by FY07. The near-term focus will be on gaining more robust, predictable, and improved processes. The vision is for Los Alamos to serve as a small-scale interim producer until a Modern Pit Facility becomes available. I hope that Los Alamos will be viewed as a highly flexible and viable pilot facility for systems beyond the W88 and that the Laboratory's mission will be aimed at the capture and transfer of technologies, demonstration of new processes, and fielding new concepts. ✹

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# Plutonium Thermodynamics from Neutron Scattering

The Plutonium Fundamentals Team at the Manual Lujan Jr. Center at LANSCE has been applying the tool of neutron scattering to the problem of understanding the highly unusual properties of plutonium metal. Further understanding at both empirical and theoretical levels is required because the physical properties of the actinides are known to be complex, and we lack the predictive capability required for applications.

One of the unusual properties of plutonium is its low melting point. Figure 1 shows the melting point of every element in the periodic system, and it is clear that plutonium doesn't fit in: its melting point is too low. Although there is not yet a generally accepted theory of melting, we do have an empirical rule for melting known as the Lindemann criterion: a material melts when the amplitude of the thermal vibration of the atoms exceeds about 10% of the interatomic distance. If we use the accepted values of the elastic constants to estimate the thermal vibration amplitude, we find that plutonium does not obey the Lindemann criterion; from the elastic point of view, it is too stiff for its melting point.

It is possible to use neutron diffraction to measure the thermal vibration amplitude directly, and we

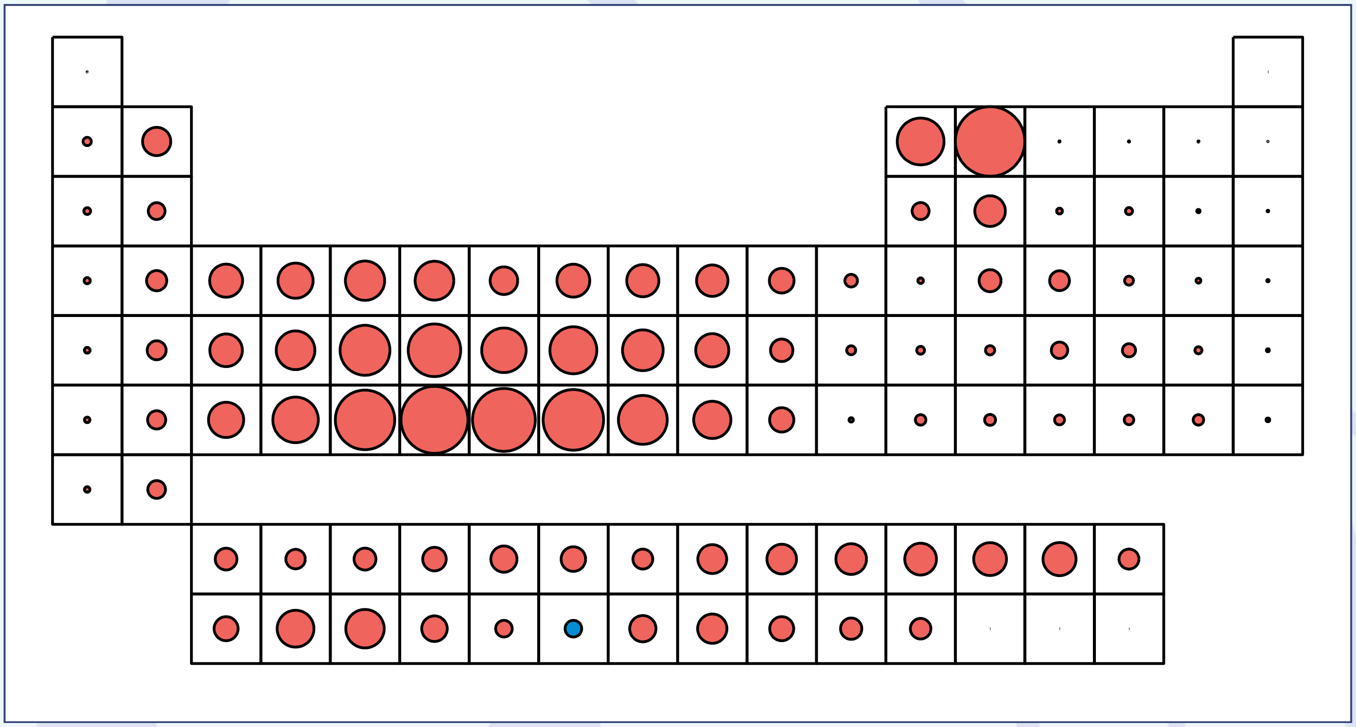
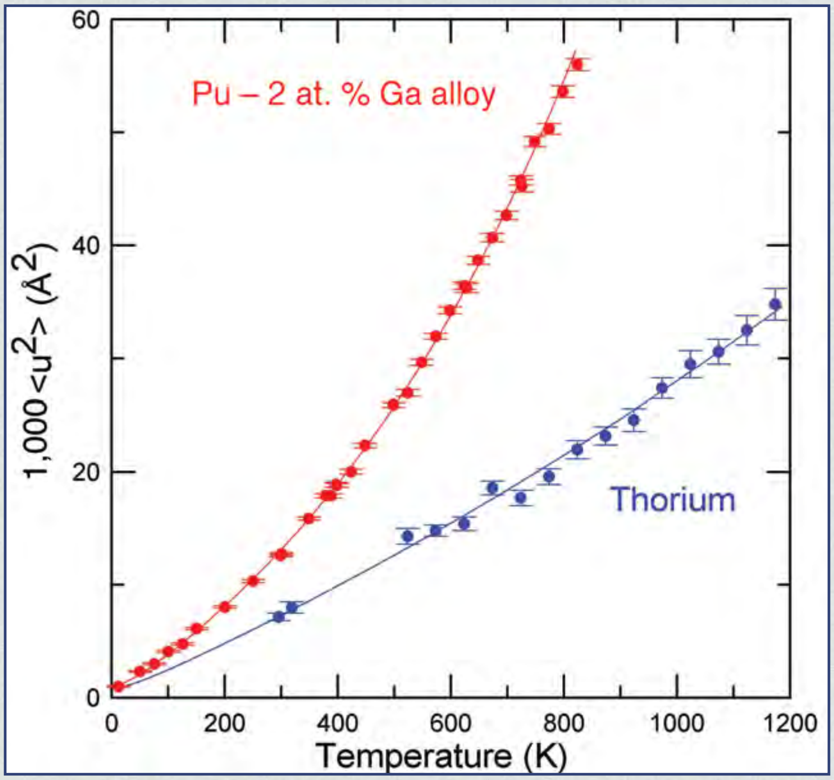


*Figure 1. Melting points of the elements displayed as a periodic table. The diameter of each circle is proportional to the melting point. Plutonium, shown in blue in the bottom row, has an anomalously low melting point compared to the rest of the elements, shown in red.*

*Figure 2. Mean-square atomic vibrational amplitude plotted versus temperature for Pu – 2 at.% Ga and for thorium. Thorium shows a normal linear behavior with temperature, while the plutonium alloy curves strongly upward, indicating an elastic softening of plutonium at higher temperatures. This elastic softening is believed to be responsible for the low melting point.*



have done this. The results are shown in Figure 2, where we have plotted the mean-square thermal vibration amplitude <u$^2$> versus temperature for thorium and Pu – 2 at.% Ga. (The purpose of the gallium in the plutonium alloy is to stabilize the cubic close-packed delta-phase that is used for applications.) An ordinary metal, like thorium, shows a linear dependence of <u$^2$> on temperature. In contrast, <u$^2$> for the plutonium alloy shows a strong upward curvature. This means that plutonium is becoming elastically softer as it is heated—more than any other material. By the time the melting point is reached, plutonium is soft enough to satisfy the Lindemann melting criterion. This behavior shows that the strong elastic softening that is one of plutonium's unique properties causes the low melting point of plutonium.

Another unusual property of delta-phase plutonium alloys is the thermal expansion. For unalloyed plutonium, the delta-phase is stable only at high temperatures and has a negative coefficient of thermal expansion. As gallium is added, the phase becomes stable at lower temperature and the thermal expansion gradually becomes positive, as is observed in most normal metals. This phenomenon has been known for a long time.

Recently we were able to explain this highly unusual behavior by assuming that plutonium atoms exist in two different electronic energy states: a low-energy state that has a larger diameter and a higher-energy state that has a smaller diameter, as shown in Figure 3. (A very similar model is used to explain the thermal expansion behavior of magnetic iron-nickel, the so-called invar alloys.)

This model can be used to fit the thermal expansion data of

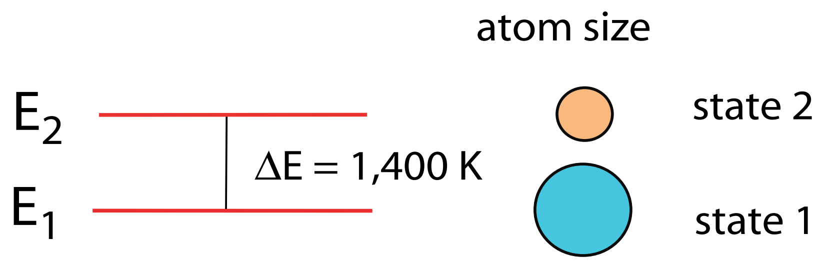


***Figure 3. Energy-level scheme responsible for the anomalous thermal expansion of plutonium. Plutonium is believed to be a mixture of two types of atoms that are distinguished by different electronic states and different sizes. The larger atoms are lower in energy than the smaller atoms by 1,400 K.***

Figure 4 that were measured by neutron diffraction. We find that the energy separation of the two plutonium electronic states is tiny, equivalent to 1,400 K in temperature units. As the temperature changes, so does the relative fraction of large and small plutonium atoms, and this determines the thermal expansion. We do not yet know why the occurrence of two types of plutonium atoms is energetically favorable; this question is the subject of ongoing research.

Since the lattice properties of delta-phase plutonium are so unusual, we decided to determine the vibrational spectrum of plutonium. These measurements could be much more complete if a large single crystal were available; sadly this is not the case. But measurements on polycrystalline Pu – 5 at.% Al proved to be quite interesting. We determined the density of vibrational modes (phonons) as a function of energy at several different temperatures by using the Pharos spectrometer at the Lujan Center. Our results are shown in Figure 5, where we have plotted the phonon density of states, g(E), divided by the square of the energy, versus energy. The reason for dividing by $E^2$ is that a simple standard model for vibrational modes, the Debye model, gives the result that the density of states is proportional to the square of the energy, so that the plot of $g(E)/E^2$ should be just constant at low energies. Instead, for delta-plutonium we get a peak at low energies, and there is considerable temperature dependence to this peak. These data suggest that the vibrational frequencies of plutonium are temperature dependent, a notion that is supported by Figure 2.

We have made substantial progress in understanding the thermodynamic properties of plutonium metal in the past few years. Much work remains to be done because a sound theoretical understanding of the properties presented here is still lacking. Neutron scattering experiments on single-crystal delta-phase plutonium remain highly desirable. ✹

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*Figure 4. Lattice constants for plutonium-gallium alloys versus temperature. The points are measurements made by neutron diffraction; the lines are derived from a model based on the energy-level scheme of Figure 3*

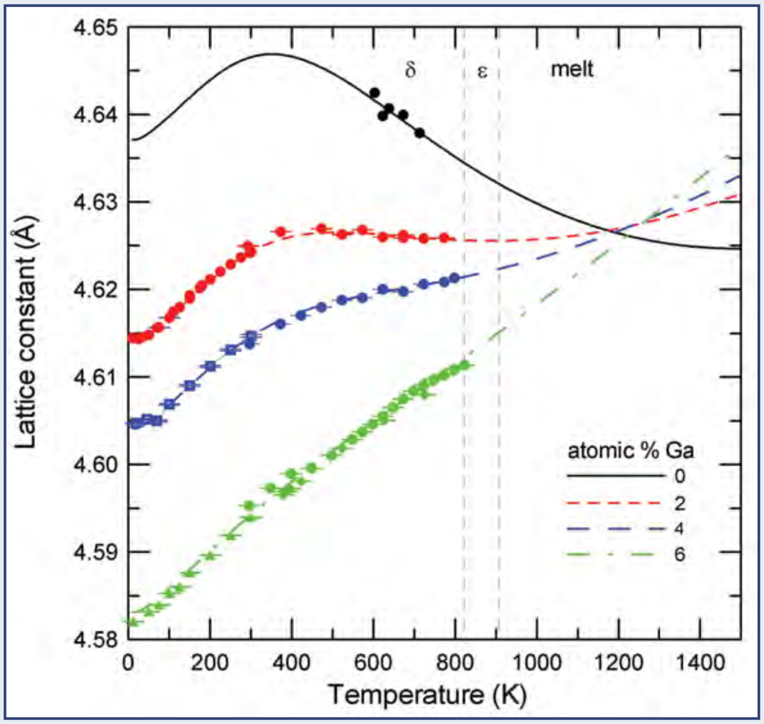
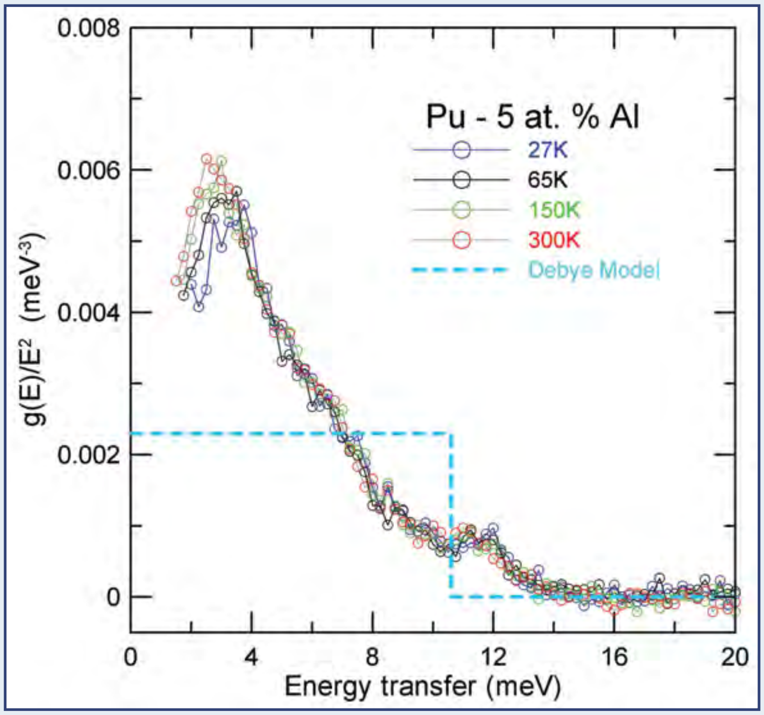


*Figure 5. Phonon density of state divided by $E^2$ plotted versus phonon energy E. This quantity would be a simple step function for the ideal Debye model. The dotted line describes the Debye standard model for vibrational modes, in which the plot is constant at low energies. Instead, in delta-phase plutonium we observe a peak at low temperature that is significantly temperature dependent.*



# Plutonium Metal Certified Reference Material

The Plutonium Standards Project is a partnership between the Actinide Analytical Chemistry Group (C-AAC) at Los Alamos and the New Brunswick Laboratory (NBL), a technical extension of the DOE Office of Nonprolif- eration and National Security located at Argonne National Laboratory, to develop plutonium standards. The 1-g, high-purity plutonium metal samples will be certified as Plutonium Metal Certified Reference Material; these standards are needed by the Pit Manufacturing and Certification Project (PMCP) at Los Alamos to certify the plutonium product in newly manufactured pits and for plutonium assay at other facilities. We expect the 1,100 standards that we prepared to serve these needs for the next 10 years.

## New extrusion process

NMT Division agreed to fabricate the standards, with C-AAC and NBL conducting the analytical chemistry measurements necessary to certify the plutonium metal. The process to fabricate the standards consisted of double electrorefining about 3 kg of high-purity plutonium metal (NMT-2), casting the metal into rods (NMT-5), machining away the surface of the rods (NMT-5), extruding the rods into plutonium wire (NMT-11), breaking the wire into 1-g pieces (NMT-11), and hermetically sealing the pieces in glass ampoules (C-AAC). The plutonium metal pieces will be thoroughly characterized at Los Alamos. NBL will analyze for total plutonium and americium, followed by a statistical evaluation of all the analytical data. NBL will then issue the metal samples for sale to the nuclear community.

*Evacuated glass ampoule containing a 1-g piece of high-purity $^{239}$Pu metal that will eventually be certified by the NBL as Plutonium Metal Certified Reference Material.*

A considerable amount of work was required before the high-purity plutonium could be extruded into wire and fabricated into standards. The work was divided into three parallel efforts: (1) design, fabrication, and testing of extrusion equipment; (2) preparation and commissioning of the glovebox in which the extrusion was to be conducted; and (3) preparation of the hermetic glass-sealing equipment. All three efforts required numerous engineering reviews and formal safety analysis reviews before they were approved for use with plutonium, including reviews of electrical hazards, criticality hazards, high-pressure hazards, industrial hazards, and high-temperature material handling. The safety reviews led to the preparation of detailed procedures (work instructions) for the extrusion, cutting, and sealing operations not covered by existing procedures.

The biggest difference in this process over the previous processes, circa 1986, is that the plutonium is extruded into wire. Previously, the standards were fabricated by casting the plutonium into a plate and using a cutting shear to "nibble" small pieces from the plate. For the current set, we chose to extrude the high-purity plutonium into 5/32-in.-diameter wire and then cut (more correctly, break) the wire into the required number of 1-g standards. After hermetic sealing in individually evacuated glass ampoules, the samples were placed in storage for about six months. We performed periodic surveillance for the presence of oxidation on the surface of the standards to check for atmospheric breach in any of the ampoules.

About 100 of the ampoules leaked, resulting in 1,100 standards that are available for certification.

## Mitigating sample contamination

We recognize that the extrusion process could be a source of iron contamination because the extrusion die is made of tool steel. To mitigate this possibility, we coated the extrusion die with titanium nitride (TiN), a very tough, high-temperature ceramic. The TiN serves as a lubricant for the plutonium during the wire-extrusion process, as well as a barrier to the iron in the tool steel die. Also, the extrusion temperature (430 °C) is sufficiently high that the forces required to extrude the plutonium metal are significantly lower than the forces required to nibble (shear) the plutonium at room temperature. In fact, the plutonium extrusion from the die is very similar to how toothpaste extrudes when the tube is squeezed. Iron contamination of the surface of the plutonium cylinders from the earlier machining step was not considered a serious source of contamination because the extrusion process creates new surface from the interior of the cylinder that is being extruded. The first and last inches of the plutonium wire were discarded to eliminate the possibility of end effects.

Additionally, we took many special measures to minimize the possibility of contaminating the plutonium during processing. The special measures began with the wire-extrusion step and consisted of processing inside gloveboxes with high-purity atmospheres (the sum of oxygen and moisture in the extrusion glovebox was required to be less than 20 ppm) and handling the post-extrusion plutonium with platinum-tipped forceps and tweezers. The extrusion glovebox was an entirely new glovebox commissioned for this project, thus ensuring that the standards plutonium was not cross-contaminated with other actinides. Methods to transport the samples between work stations without cross-contamination were also developed.

## Analysis and certification

During the storage and surveillance phase, we randomly selected about 50 samples for comprehensive chemical analyses. Thirty of these samples are undergoing chemical analyses by C-AAC; the remaining 20 were sent to NBL for similar analyses. The initial analyses of the starting plutonium metal prior to extrusion and sealing showed that the plutonium was consistent across samples and that the plutonium was about 99.98% pure (e.g., the plutonium metal contains less than 200 ppm total impurities). At the completion of the chemical analyses at both laboratories, NBL will certify the standards as Plutonium Metal Certified Reference Material. ✸

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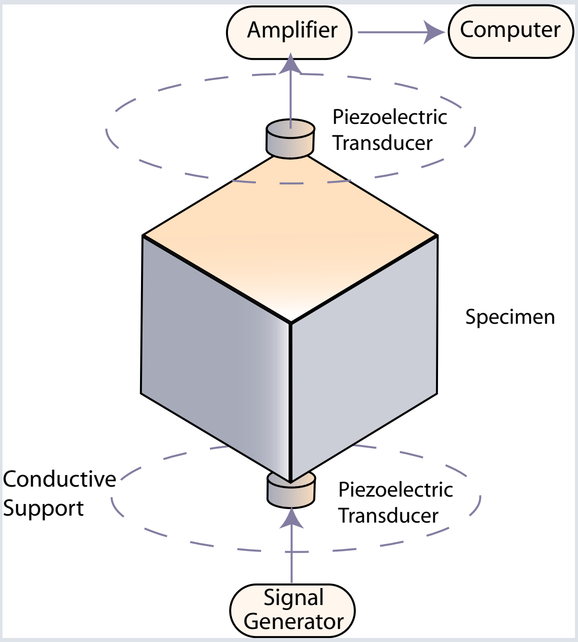
We acknowledge the assistance of those individuals who made this project successful: in fabrication, Vonda Dole and the NMT-2 electrorefining team; casting, Tony Valdez, Mike Martinez, and John Huang; machining, Patrick Rodriguez and the NMT-5 machining team; extrusion, Fidel Vigil, Mary Ann Abeyta, and Adam Montoya; and encapsulation, Terry Hahn, Tom Marshall, and Rick Day. Personnel who helped in ancillary functions included safety reviews, Fred Bolton, Jay Samuels, Ted Karki, Guy Baker, and Mike Larragota; glovebox installation, Ray Olivas and numerous JCNNM crafts workers; glovebox atmosphere purity, Dale Sivils; and imaging, Joe Riedel and Mick Greenbank. Mike Palmer served as project leader. Photo by Jay Samuels.

# Resonant Ultrasound Spectroscopy of Energetic Materials

Since the late 19th century, mechanical engineers and material scientists have known that mechanical resonances provide a distinctly advantageous means for determining the elastic properties of materials. Applications involving isotropic elastic spheres appeared first, due in large measure to the fact that Horace Lamb provided the characteristic equations of sphere resonance in 1882.



***The test configuration developed by the original Los Alamos RUS team employed rectangular parallelepiped specimens with dimensions of a fraction of a millimeter to several millimeters. The specimens were suspended between vertically aligned input and output transducers by contact with diagonally opposite corners.***

However, serious development of the technology we now know as resonant ultrasound spectroscopy (RUS) did not swing into high gear until the 1960s. The availability of analytic solutions for sphere resonance made it relatively easy to determine the material properties of spheres from spectra of their mechanical resonances. Consequently, in 1962, seismologists determined the isotropic elastic constants of the earth from the period of free oscillations after a large earthquake.

Within a decade, the theory of free oscillations of the earth became very sophisticated, and applications in the materials sciences soon followed. Small isotropic spheres, including roughly 40 spheroids from the moon with diameters of about 0.3 mm, were studied extensively, and many characteristics of modern RUS systems were developed in that time frame.

The use of two piezoelectric transducers, one to input vibrations to the specimen and a second to record the specimen's response, became standard. The input transducer was swept over a range of frequencies while the output transducer indicated which frequencies corresponded to resonant vibration modes of the specimen. The vibration response spectrum recorded from the output transducer provided the data from which material properties could be extracted. During the latter part of the 1970s, RUS was successfully extended to nonisotropic crystalline specimens cut to rectangular parallelepiped configurations.

A team at Los Alamos National Laboratory, led by Albert Migliori, began working with RUS in 1987. The Los Alamos team developed improved computational and experimental techniques for determining the elastic properties of non-isotropic materials in simple geometric configurations (spheres, rectangular parallelepipeds, and cylinders). The improved techniques were used to conduct a highly productive study of phase transitions and associated property changes in plutonium, and a seminal text on RUS technology, *Resonant Ultrasound Spectroscopy: Applications to Physics, Materials Measurements, and Nondestructive*

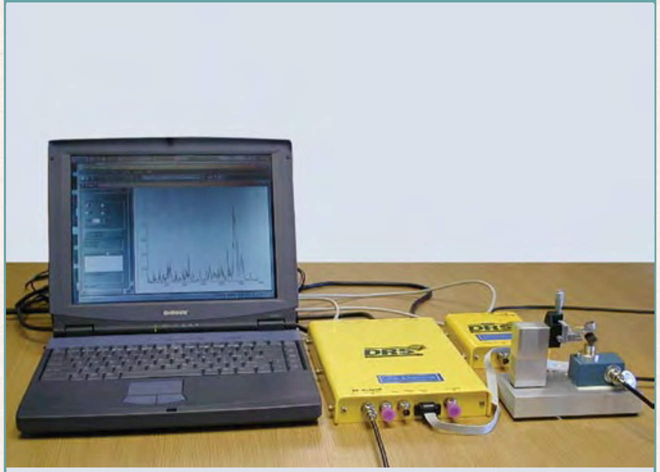
*Evaluation*, was authored by Migliori and John L. Sarrao in 1997.

The goal of the current project is to use RUS to determine the mechanical properties of complex high-explosive materials, including PBX 9501 and its primary constituent, HMX crystals. Several extensions of existing RUS technology are required to accomplish our objectives. HMX is a low-symmetry crystal (monoclinic) having 13 elastic constants. The difficulties involved in working with low-symmetry materials are exacerbated by the fact that HMX is very fragile and cannot readily be machined to precise configurations. The specimens we have to work with are imperfect hexahedra of a few millimeters in extent and have crystal axes that are not necessarily aligned with the specimen edges. Because of their material and geometric complexity, the HMX crystals are not amenable to study by standard RUS techniques.

Achieving a fundamental advance in RUS technology requires that tough problems be overcome

The second material, PBX 9501, is a composite consisting of 95 wt% HMX crystals in a plasticized Estane binder. The solid/solid mixture is viscoelastic and, consequently, highly dissipative due to the rubber-like binder and to interactions between the two constituents. Highly dissipative materials are low Q, meaning that they do not exhibit the sharply defined resonant peaks that are characteristic of elastic materials. Low Q materials are also not amenable to study by standard RUS techniques.

However, we find good reason to believe that by using finite element analysis (FEA) to establish a link between the response spectra of complex specimens and their elastic or viscoelastic properties, we can significantly extend the range of materials that may be investigated by RUS. First, FEA can be applied to specimens of almost arbitrarily complex geometries. Second, material complexities such as anisotropy of any level and viscoelasticity can be readily included in finite element simulations. Computed response spectra are determined by eigenvalue extraction for anisotropic elastic materials and by direct steady-state dynamics for viscoelastic materials.



***The RUS system developed by Migliori's team was commercialized by Dynamic Resonance Systems, Inc. The test jig at the right of the photograph is shown with a cubic graphite specimen mounted between the two transducers. Software to control the system and process the data is provided as part of the package.***

Current efforts on PBX 9501 are directed at improving the repeatability of data associated with the first two resonant maxima that appear in the RUS scans. Our 1.00-cm cubic specimens resonate at much lower frequencies and with much lower amplitudes than the metallic and crystalline specimens for which the original RUS system was designed. Consequently, it has been necessary to undertake several modifications of the test jig and transducer mounts.

- A persistent background signal was found to be the result of transmission through the test jig and was eliminated by vibration isolation.
- The original aluminum transducer mounts were found to exhibit vibration modes that overlap those of our specimens. New mounts were designed and fabricated from Stycast, a highly dissipative, castable, polymeric material. The Stycast mounts have a fundamental mode

frequency that is an order of magnitude below that of the aluminum mounts and do not sustain the higher frequency vibrations that would otherwise interfere with resonant motion of the PBX 9501 specimens. Our signal-to-noise ratio was improved by a factor of three to four by switching to the Stycast mounts.

- Finally, it was determined that the fundamental mode we are trying to detect involves motion that is theoretically parallel to the transducer surface. The transducer is sensitive to motion normal to its surface, so only imperfections in specimen geometry or alignment permit the fundamental mode to be seen at all. (Nonetheless, the fundamental mode is always clearly visible in RUS scans of elastic cubes.) We are therefore investigating lower-symmetry geometries for which motion associated with the fundamental mode is more normal to the transducer surface.

High-quality RUS data have been obtained on available HMX crystals, and current efforts are primarily directed at developing the computational tools needed to extract elastic constants. Simulated spectra will be fit to measured RUS spectra by use of a genetic algorithm (GA), which has been found to be very effective in fitting complex data sets in many different fields. A suitable GA code has been developed and tested on isotropic materials with good results. Work is now under way to develop a specialized finite element code that can be used to run large sets of RUS simulations simultaneously under the control of the GA driver. The software under development will also be used in the analysis of PBX 9501 data.

Achieving a fundamental advance in RUS technology requires that a series of tough experimental and computational problems be addressed and overcome. However, the scientific and programmatic benefits to be derived from such advances make the effort well worthwhile. ✹

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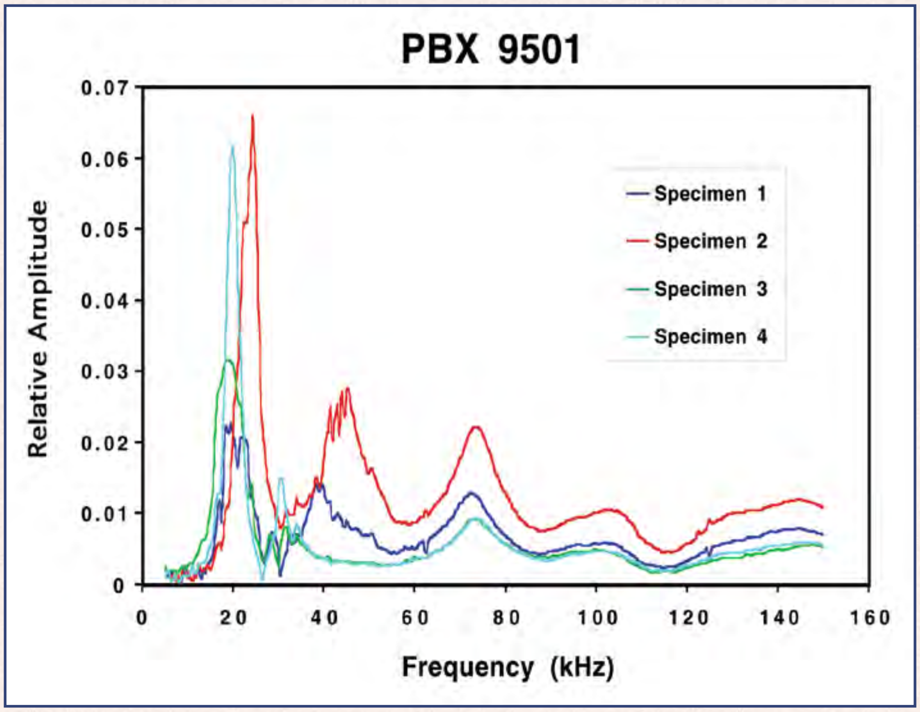
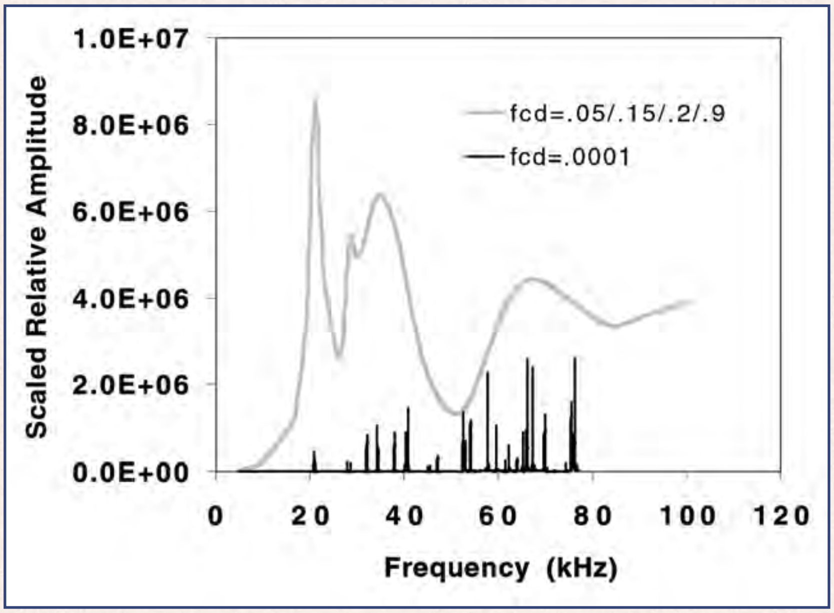
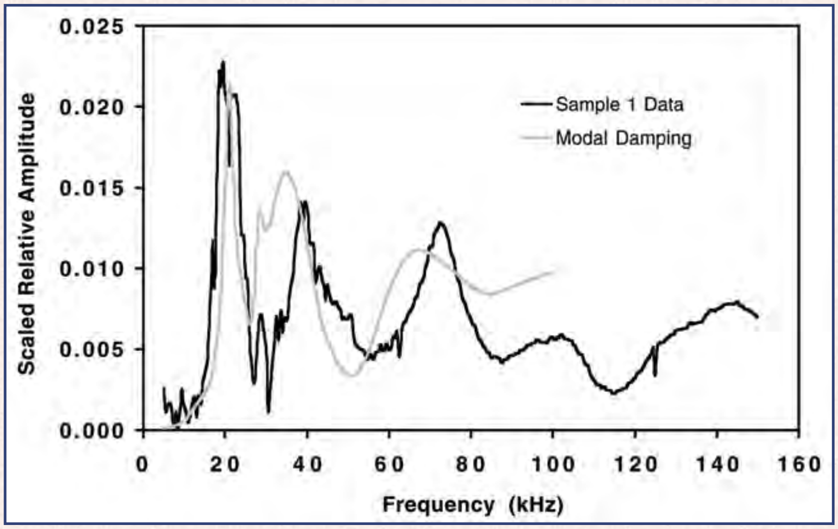


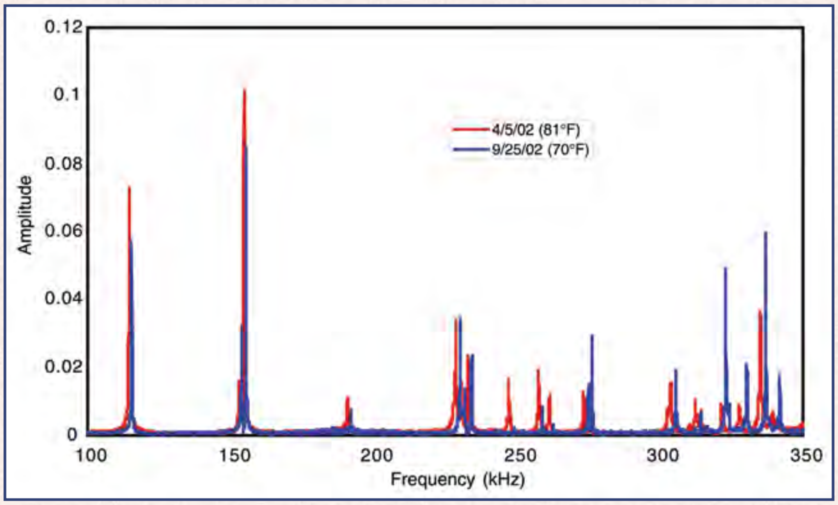
***As part of a preliminary feasibility study, RUS scans were taken on four 1-cm cubes of PBX 9501. All specimens exhibited five broad resonant maxima between 10 kHz and 160 kHz. The mean frequency of the first resonant maximum, 20.8 kHz, coincides almost exactly with the fundamental mode frequency calculated by finite element analysis using the best available data on elastic properties.***



*Finite element simulations of the RUS measurements on PBX 9501 were conducted using modal damping (the simplest possible representation of dissipation) to account for viscous effects. The simulation indicates that the sharp resonant spikes occurring at the nearly elastic fcd (fraction of critical damping) of 0.0001 are widened and eventually coalesce into broad resonant regions as the fcd is increased. The first resonant region is seen to represent the fundamental mode while higher frequency regions are the result of modal coalescence.*



*The modal damping simulation resembles the PBX 9501 RUS scans closely enough to indicate that more sophisticated respresentations of viscoelastic behavior should provide the flexibility needed to fit the data precisely.*



*RUS scans on HMX crystals are of good quality and repeatability. The scans depict the spectral shift associated with an 11 °F change in temperature.*

# The Lujan Center
## and Neutron Scattering

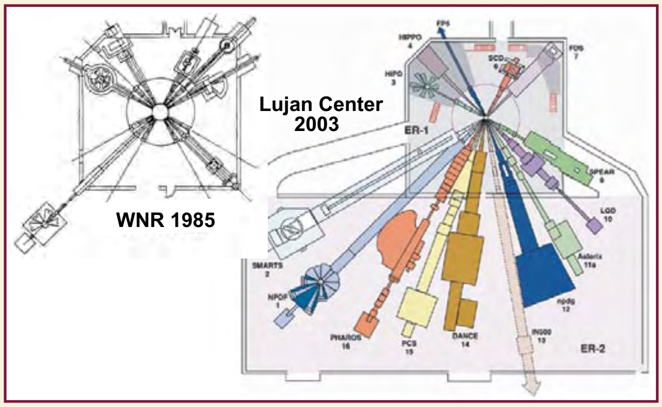
work side by side with national security researchers, and no other facility within the Laboratory exemplifies this Los Alamos style better than the Los Alamos Neutron Science Center (LANSCE) and the Manual Lujan Jr. Neutron Scattering Center. Perched on its own mesa between steep canyons laden with archeological sites, the Lujan Center is at the business end of the LANSCE proton accelerator. The Lujan Center is a pulsed spallation neutron source equipped with time-of-flight spectrometers for neutron scattering studies of condensed matter.

> **After highly successful run cycles . . . the outlook is bouyant**

As a national user facility, the Lujan Center provides instrumentation and support for user-driven research. Hundreds of academic researchers arrive each year from all over the world to do nuclear physics or materials science experiments. The high energy of the Lujan Center derives from melding science and national security: while one researcher may be working on weapons materials and another on industrial materials, they can learn from each other because the science is the same.

Neutron scattering is indispensable in today's condensed matter and materials science studies. Neutrons that have been "moderated," or slowed down, match well the length and energy scales of solid and liquid matter. Because of their high penetration, isotopic selectivity, and magnetic sensitivity, neutrons are uniquely suited to probe materials in special, powerful ways. At the Lujan Center, neutrons are created when energetic protons from the LANSCE accelerator hit a tungsten target, resulting in the copious production of neutrons by spallation through liquid hydrogen or water moderators to slow them down; then they travel down a "flight path" to an instrument, such as a scattering experiment. The neutrons' time of flight can be measured to determine their energy (i.e., wavelength) accurately. In some experiments the energy gained or lost by scattering from a sample is measured, which provides information about excitations in the material. By combining the wavelength with the angle at which neutrons scatter, one can determine the momentum change in the scattering process, hence the spacing of atomic-level structures in the sample.

***Construction of Experimental Room 2 (ER-2) and the Lujan Center office building began in 1986. The facility was occupied in 1988 after a construction project of $18M. The first instrument built in the new ER-2 was the Neutron Powder Diffractometer (NPD)—pieces of which are visible in the photo—which today exists in upgraded form as NPDF. The blue case on the left in the top photo is the NPDF, and the red case in the center is Pharos, which probes lattice and magnetic dynamics of materials.***



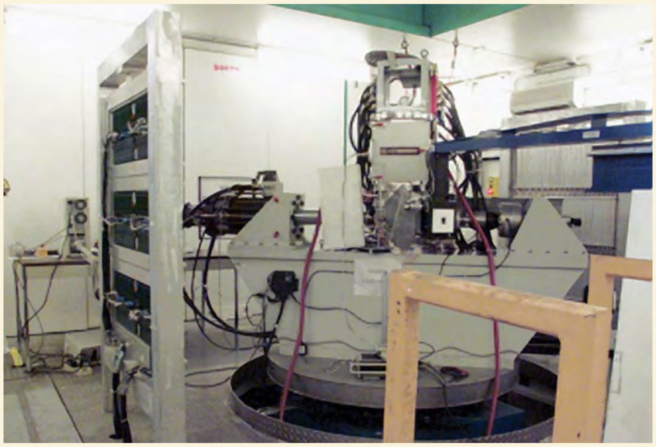
*The Lujan Center's instrument suite in 1985 and 2003. The tungsten spallation target (cylindrical feature in ER-1) accepts proton beam from the PSR aimed vertically down by steering magnets. The instruments view moderated neutrons through 16 penetrations in the bulk shield.*

Generally speaking, a higher neutron flux leads to better and more science, but neutrons are expensive to make. The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory will be the largest single investment in materials science in history, costing $1.4 billion by the time it begins operation in 2006. Much of that money is invested in neutron flux. Although the Lujan Center currently has a competitive peak flux—running at about 100 kW—the SNS will surpass it by a factor of 15 at its design power of 1.4 MW. With this juggernaut coming on-line, what is the future for the Lujan Center?

## History

The Lujan Center grew out of the Weapons Neutron Research (WNR) facility, where pulsed neutron research began in 1977. In those days the facility ran in "long-pulse mode"—750 ms per proton pulse to the target at 120 Hz—and the early experimenters chopped the beam drastically to sharpen the resulting neutron pulse. In this way they could reduce the uncertainty in neutron time-of-flight measurement to determine neutron energy accurately. A typical time-average proton current then was only about 3 mA.

Next, the Proton Storage Ring (PSR) was built for $22M and took first beam in 1985, heralding the birth of the Los Alamos Neutron Scattering Center—the original LANSCE. The PSR compresses proton pulses from 750 ms to a quarter of a microsecond, multiplying the peak flux enormously. Nowadays, the neutron spallation target receives pulses at 20-Hz and 120-mA time-average proton current. A very significant advance in the target-moderator system was the 1998 installation of flux-trap, partially coupled, liquid-hydrogen moderators. This invention has become standard for spallation sources around the world. An expansion in experimental area, office space, and user support facilities was funded at $18M by DOE's Office of Science (Basic Energy Sciences) in FY86 and was completed in 1988. LANSCE then became a true national user facility for neutron scattering. In 1995, the facility was renamed the Los Alamos Neutron Science Center and includes the accelerator and all of its experimental facilities. Named after the Secretary of the Interior at the time, the Lujan Neutron Scattering Center includes the old WNR facility—now known as ER-1—and the new experimental room ER-2. In 2003, the Lujan Center has 13 active instruments, of which 7 are new or recently upgraded. The first neutron scattering instrument at LANSCE, the Filter Difference Spectrometer built in 1981, is still opera- tional and is the oldest operating instrument at a spallation source anywhere.

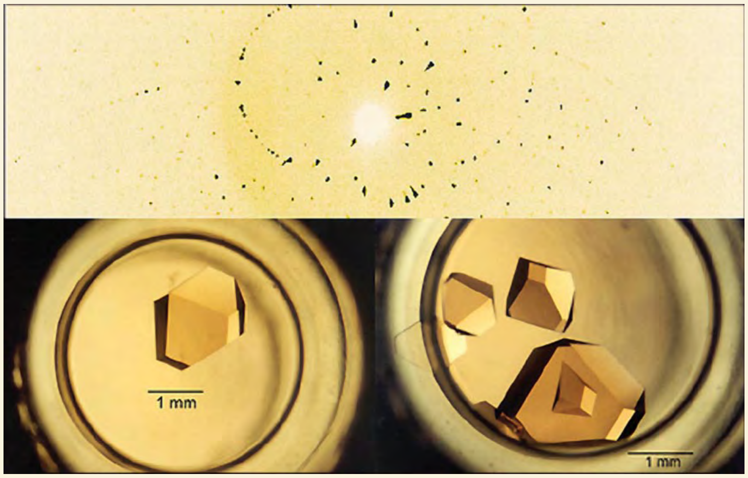


*The SMARTS spectrometer cave and load frame/furnace set. This spacious cave facilitates engineering-size objects for residual strain studies. The load frame and its companion furnace are capable of 250-kN force applied to samples simultaneously heated to 1800 °C.*

## Current instrument suite

The Lujan Center's 16 neutron flight paths view water or liquid-hydrogen moderators that provide beams of thermal and cold neutrons. Seven of Lujan Center's 16 flight paths are equipped with new or upgraded instruments for determining the atomic, molecular, and magnetic structures of materials as well as their vibrational and magnetic excitations. Three flight paths are devoted to fundamental nuclear physics using neutrons.

The core of the instrumentation at Lujan is diffraction, which plays to the strength of pulsed neutron sources. The new Spectrometer for Materials Research at temperature and stress (SMARTS) is optimized for studies of engineering problems in materials, such as residual strain or polycrystalline deformation. The High-Pressure Preferred Orientation diffractometer (HIPPO) allows researchers and students to conduct real-time structural and textural studies *in situ* at low to high temperatures, at pressures up to ~30 GPa, or under uniaxial stress. The Neutrons for Pair Distribution Functions diffractometer (NPDF) was upgraded from the venerable Neutron Powder Diffractometer (NPD). The NPDF specializes in total scattering studies useful for unraveling how modern materials work on an atomic level. Another new instrument is the Protein Crystallography Station (PCS). It is the only neutron instrument in North America devoted to structural biology. The Single Crystal Diffractometer (SCD) and the High-Intensity Powder Diffractometer (HIPD) round out the diffraction suite.



***The protein D-xylose isomerase is an enzyme that catalyzes the conversion of D-xylose to D-xylolose and glucose to fructose by hydrogen-atom transfer. Scientists need to locate the hydrogen atoms within the enzyme, not just the heavier atoms found by x-ray diffraction. Neutrons are an excellent tool for structural determination of biological materials because unlike x-rays they scatter strongly from hydrogen and they do not damage the delicate structures. Also, the scattered intensity does not diminish with scattering angle as much as x-rays (the "form factor" is constant).***

A notable change in the neutron scattering landscape at LANSCE since 1985 is the advent of cold (long wavelength) neutrons from cold moderators. The science enabled by those flight paths with liquid hydrogen moderators is suited for polymers, biological systems, thin films, nanoscience in general, and nuclear physics. Those instruments using long-wavelength, cold neutrons are known collectively as large-scale structure instruments. The Surface Profile Analysis Reflectometer (SPEAR) is a top-flight instrument used for reflectivity measurements from liquid surfaces and thin layers. Asterix is a new instrument that provides a polarized neutron beam for studies of magnetic materials and spin polarization, using reflectometry, diffraction, and high magnetic fields. The Low-Q Diffractometer (LQD) is designed to study long-length-scale structures with dimensions from 10 to 1,000 Å. Examples of problems that LQD can help solve include phase separation, morphology, and critical phenomena in hard and soft matter and in magnetic structures; colloid and polymer structures; biomolecular organization; and bubble formation in metals.

Cold neutrons are also needed for the nuclear physics beamlines, NPDGamma and DANCE. The former is used for studying the reaction (n,p)→(d,g) and will begin testing parity-symmetry breaking in the weak interaction in 2003. DANCE is a new instrument in which short-lived nuclei are observed and characterized following neutron capture reactions that are relevant to nuclear weapons and astrophysics.

The next wave of new instruments at the Lujan Center will add to the inelastic scattering suite. The current inelastic instruments are the Filter Difference Spectrometer (FDS) and Pharos. FDS is still used for molecular vibrational spectroscopy by using inelastic neutron scattering; it is most useful for measurements requiring high sensitivity, such as very dilute systems or molecules adsorbed on catalyst surfaces. Pharos, a newly rebuilt chopper spectrometer, measures phonon and spin-wave dispersions, phonon densities of states, magnetic excitations, momentum distributions, spin-orbit and crystal-field levels, chemical spectroscopy, and dynamic structure factor in disordered systems.

Currently under development, the IN500 instrument will employ novel techniques to enhance the performance of inelastic neutron scattering at pulsed neutron sources such as the SNS at Oak Ridge. Three IN500 innovations are the partially coupled moderator, repetition-rate multiplication, and ballistic neutron guide technology.

- The partially coupled moderator has a high degree of neutronic coupling with the reflectors in the target system, giving rise to greater flux for instruments. Recent measurements of its performance match well our design calculations.
- Repetition-rate multiplication is a technique in which the pulsed neutron beam is chopped (by massive rotating machinery) into precisely timed short segments that are later reassembled in the scattering experiment. By reassembling segments from different pulses in a known way, counting time by the detectors can be used more efficiently.
- Finally, the ballistic neutron guide is a new technology for transmitting a neutron beam over a large distance with acceptable losses. Our neutron guide is a square “pipe” with highly polished inside surfaces. Through a guide, neutrons can propagate by complete internal reflection from the guide’s surfaces, and the attenuation is determined by the number of reflections. A ballistic neutron guide has tapered ends that collimate the flights of neutrons—leading to fewer reflections, hence more efficient transmission.

***During the 2002 run cycle at the Lujan Center, the newly commissioned 11-T superconducting magnet provided users with the first results of an intensity image (reflection) of neutron data collected from an antiferromagnetic material on the new Asterix instrument.***

All three of the innovations are “firsts” for the IN500 prototype instrument. IN500 will be used for nanoscale dynamic correlations in a variety of non- crystalline materials. After proving the principles of the new approaches in 2003, a vacuum detector chamber with a 15-$m^2$ detector area will complete IN500 by early 2006, funding permitting.

## Lujan Center in the SNS Era

There is little doubt that the Spallation Neutron Source will surpass the LANSCE accelerator in power soon after 2006. The number of SNS neutron scattering instruments will gradually reach 18 over the first few years of operations, and the power level will similarly increase gradually to 1.4 MW.

The strategy for LANSCE and the Lujan Center is to remain scientifically competitive worldwide in the SNS era. To do so when flux is not a distinguishing advantage requires choices of instru- mentation and staffing that will keep the Lujan Center on the cutting edge. The strategy has five parts.

- First, the SNS alone cannot provide the necessary neutron scattering capability, and ways must be found to enhance the effectiveness of other sources as well. The recent Report on the Status and Needs of Major Neutron Scattering

Facilities and Instruments in the United States by the Office of Science and Technology Policy Interagency Working Group on Neutron Science (June 2002) points out that Europe has 4,500 users—in contrast to fewer than 2,000 in the US—and twice the number of instruments in operation. The European user community was progressively built up after the start of the Institut Laue-Langevin 35 years ago. The US has a strong latent user community that is driven by research across the physical and biological sciences. This latent user demand can be attracted to and served by the Lujan Center. In the last two years, LANSCE and the Lujan Center have proved to be the country's best neutron sources, both in reliability and in flux for today's research. By 2006, the Lujan Center could offer 12 instruments in the national user program if funding permits. Starting in 2003, neutron scattering users will enjoy 20% more beam time after the installation of a kicker magnet that allows effective sharing of beam with proton radiography.

- Second, the Lujan Center must grow the science that is important regionally and to Los Alamos. Examples are nanoscience, with the building of the Center for Integrated Nanotechnologies at Sandia and Los Alamos, high-pressure materials research, engineering and geosciences, and condensed matter of correlated electron materials. The foremost needs in these areas are inelastic scattering capability, improved sample environments, and constant refurbishment and upgrade of existing instruments.
- Third, there is no other facility that can meet the needs of the national security community, from the standpoint of doing classified research and studying special materials such as plutonium. Since the science is the same, focusing on national security areas takes nothing away from—in fact, enhances—the academic research areas that bring in outside users.
- Fourth, the Lujan Center is in a competitive position for materials science with cold, pulsed neutrons and will remain so with the SNS.

***DANCE is a new gamma-ray detector at the Lujan Center. It consists of 160 $BaF_2$ scintillation detectors mounted as a sphere to detect as much gamma radiation as possible from a central target sample (some is lost through beam entrance and exit holes). The large photo shows the outside of the DANCE flight path; the detector is inside the large white area. The inset shows the DANCE array, split open for access. The individual $BaF_2$ crystals are visible, each covered with black light-tight shielding.***

Although raw power is not a differentiating strength for the Lujan Center, its low pulse repetition rate at 20 Hz is unique relative to SNS (60 Hz) and the ISIS UK pulsed neutron source (at the Rutherford Appleton Laboratory near Oxford) (50 Hz). Only the European Spallation Source at 16 Hz will be similar and then only in 2010 or later. (The longer time between pulses allows greater access to long-wavelength neutrons.) In addition, since no instrumentation technology will be put into the SNS without first having been tried somewhere, the Lujan Center can serve as the test bed for new, innovative neutron techniques. History supports this role as evinced by Lujan's innovations in partially coupled moderators, flux-trap targets, IN500's repetition-rate multiplication and ballistic guides, and the long-pulse concept. A great advantage at Los Alamos is the availability of institutional funding to explore innovations.

- Fifth, a critical role for the Lujan Center and for the entire LANSCE complex is that of portal to the scientific world. Recruitment of top scientists from all over the world to Los Alamos is essential to its vitality and effectiveness in national security. Arguably, deterrence by capability is just as important in today's world as nuclear deterrence. This national role solidifies the Lujan Center's position in the SNS era and beyond.

There is superb optimism among Lujan Center users, staff, and sponsors. After highly successful run cycles in 2001 and 2002, the outlook is buoyant. There have already been many exciting results from the new instruments. New developments, such as the kicker magnet that will give us at least 20% more beam time and the 11-T superconducting magnet, are all aimed at greater service to users. Through the Lujan Center window, the future looks bright and exciting.

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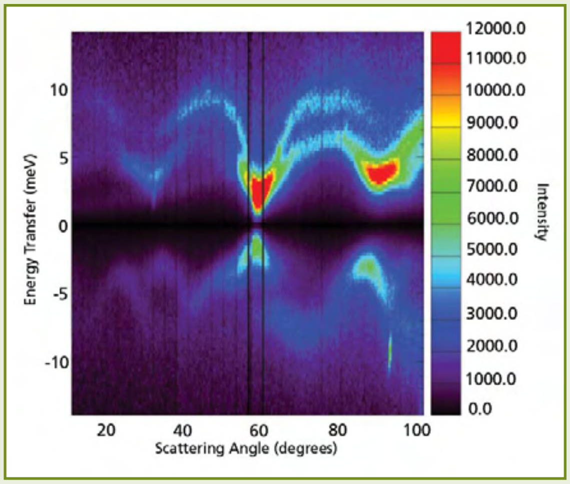

***Excitations in single-crystal lead resolved two acoustic phonons after 2 h on the Pharos instrument. Pharos, a newly rebuilt chopper spectrometer, probes lattice and magnetic dynamics of materials such as strongly coordinated electron systems, disordered systems, and molecular magnets.***

# Nuclear Weapons Integrated Baseline

The Laboratory's Program Integration Board (PIB) has developed a comprehensive, multiyear program plan for its Nuclear Weapons Program—the *Nuclear Weapons Integrated Baseline*—to enhance project management and encourage accountability. This plan's hierarchy consists of *Five-Year Program Element Plans*, *Five-Year Project Plans*, and activity worksheets. These commitments mesh into the overall *Nuclear Weapons Integrated Baseline,* which in turn rolls up to the Laboratory-wide baseline.

The program element plans include scope, schedule, and cost commitments for the period of the Future Years Nuclear Security Plan (FYNSP). Thus, the integrated baseline includes information ranging from a specific staff member who is working on an activity of a project all the way up to division-wide baselines. Through the Planning and Integration Office, managers can access the integrated baseline to track progress, labor needs, materials and supplies, major procurement and contract items, capital equipment, and facility needs.

## Annual Planning Cycle

The program manager and division leader prepare the *Five-Year Program Element Plan*, and the program director and PIB approve it. The program manager and division leader use *Five-Year Program Element Plans* to guide the management of the program element; to communicate the scope, schedule, and cost of the program element to others; and to evaluate and review actual work progress against the baseline plan. The plan covers five years—the budget year plus four years. Thus, in May 2003, the FY05–09 plans will be reviewed and approved by the boards. In May 2004, an additional year will be added (2010) and revised plans for FY06–10 will be submitted by program managers and division leaders for approval.

All *Five-Year Program Element Plans* contain details of their requirements, milestones, and deliverables; scope, schedule, and costs; people and facilities requirements; interdependencies and risks; and previous baseline approvals. *Five-Year Program Element Plans* are built from the *Five-Year Product* and *Project Plans* that compose the program element.

- *Five-Year Program Element Plans* are revised and reviewed once each year, during the Spring Program Review.
- The PIB and the program directors provide guidance and requirements to program managers (October), review proposed changes to the previous year's five-year baseline (April), and then approve the next year's FYNSP proposal to NNSA (May).
- Program directors, along with their coordination boards, conduct quarterly reviews of program elements to ensure they are on track and to review change proposals during the year of execution.

## Budget

There is a clearly identified and finite amount of money available to the nuclear weapons program through FYNSP; therefore, before resources can be added to one program element, they must be taken away from another element. Only DOE, the Congress, or the President can increase FYNSP allocations.

## Commitments

Milestones are the formal commitments to complete work, and they are a central feature of the *Five-Year Program Element Plans* and *Five-Year Project Plans.* Details of commitments are maintained in the integrated baseline. The program directors, along with their advisory coordination boards, review progress in these areas quarterly.

- Level 1 Milestones are commitments between NNSA and the Laboratory Director and between the Laboratory Director and the PIB.
- Level 2 Milestones are commitments between NNSA and the Laboratory Director and between the PIB and the program directors.
- Level 3 Milestones are commitments between the program directors and program managers.
- Level 4 Milestones are commitments between program managers and product leaders.
- Level 5 Milestones are commitments between program managers and projects.

## Change Control

Because the budget, scope, and schedules must always “add up,” no changes can be made to the integrated baseline without approval from the program director or the PIB—although program managers do have some flexibility within their program elements to move resources. ✸

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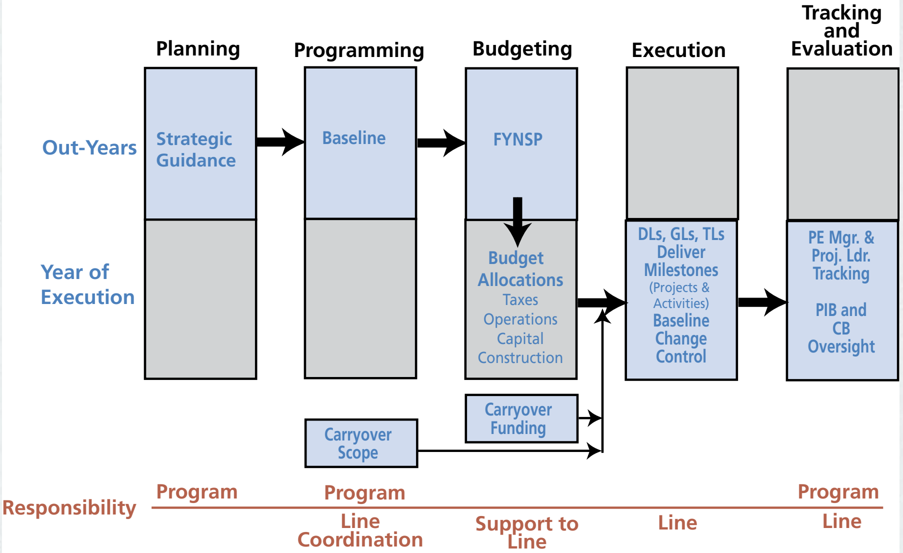
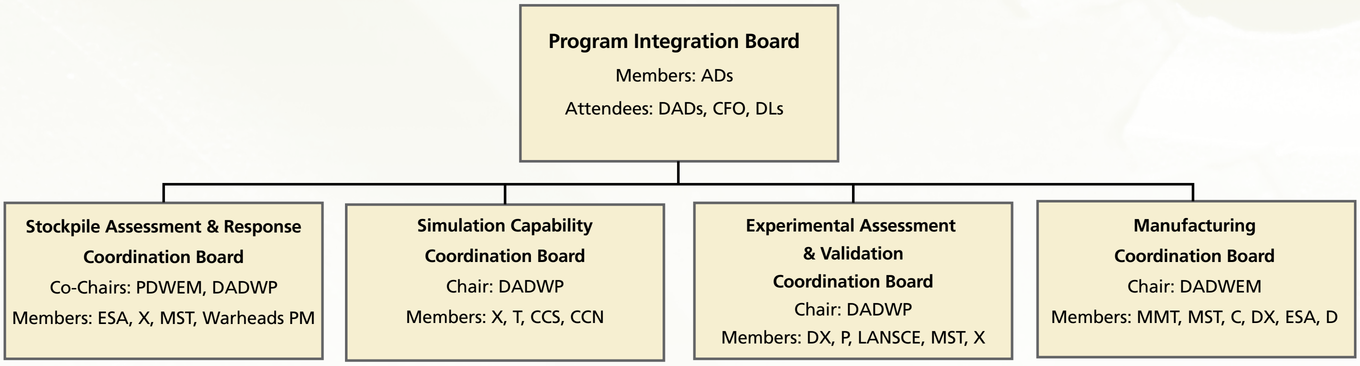


***The transition from planning to execution. Note that during a year of execution, there will be carryover work scope and carryover funding from the previous year.***

| Heirarchy | Responsibility | Programmatic Responsibilities | Program Execution | # of milestones | Commitments |
|---|---|---|---|---|---|
| Integration | PIB (Associate Directors) | Los Alamos *Nuclear Weapons Integrated Baseline.* | Level 1 (strategy) | 8–10 | • LANL and NNSA<br>• LANL and Director and PIB |
| Programs | Program Directors (Deputy Associate Directors) | 5 program sectors: stockpile assessment and response, simulation capability, experimental assessment and validation, manufacturing, and operations. Program directors advised by coordination boards. | Level 2 (objectives) | 30–50 | • LANL and NNSA<br>• PIB and Program Director |
| Program element | Division Leader (Appoints Program Manager) | 30 program elements described in *Five-Year Program Element Plans* roll up to become the NWIB. | Level 3 (requirements) | 200–400 | • Program Director and Division Leader |
| Product | Product Leader | Occur when there is a large and complex set of projects and the span of control is too great for the Program Manager to have direct oversight of all projects. | Level 4 | as needed | • Program Manager and Product Leader |
| Project | Project Leader | Described in *Five-Year Project Plans,* which roll up to become *Program Element Plans.* | Level 5 (deliverables) | Approx. 2000 | • Program Manager and Project Leader |
| Activities | Group Leader/ Team Leader | Execute the work described in activity worksheets, which roll up to become *Five-Year Project Plans.* | | | • Project Leader and Group Leader |

# Manufacturing Coordination Board

The Manufacturing Coordination Board (MCB) coordinates and integrates the complex fabrication and production activities within the Los Alamos weapons program, including the manufacture of all major components that support elements of the nuclear weapons stockpile within the Laboratory's responsibility.



The Laboratory Director and the Senior Executive Team expect the MCB to strengthen Los Alamos manufacturing and to contribute to the overall integration of the weapons program by improving planning and programming, clearly defining priorities, and developing requirements-based work plans and deliverables. The MCB is subordinate to the Program Integration Board (PIB) and, like the three other coordination boards, is expected to provide integrated requirements and plans, review the *Five-Year Program Element Plans*, monitor program element progress, and manage program element change control. Each coordination board supports the PIB by implementing *Weapons Program Guidance* through detailed program element requirements, implementing *PIB Fiscal Guidance* by issuing *Coordination Board Fiscal Guidance*, providing input into the PIB on requirements and fiscal issues, and resolving integration issues at the coordination board level.

The MCB met for the first time in October 2002 to discuss its responsibilities as outlined in the *Integrated Management of the Weapons Program: Implementing the Recommendations of the Thirty-Day Study,* draft a charter, and organize program elements. The approved charter states, "The Manufacturing Coordination Board is accountable for the manufacture of all major components supporting those elements of the stockpile for which Los Alamos has responsibility. This includes pits, detonators, other major manufactured components, and components for experimental programs." The MCB is organized around seven program elements: pit manufacturing, beryllium manufacturing, detonator manufacturing, experimental component fabrication, neutron tube target loading, technology development, and surveillance.

D Division, ESA-Manufacturing Program Office (MPO), Weapons Quality Assurance Office (WQAO), and Facilities (ADO-IFC) provide analysis, administrative support, and subject matter expertise.

The MCB's responsibilities include
- overseeing the development and execution of *Five-Year Program Element Plans;*
- overseeing and coordinating the management of those program elements;
- managing changes to scope, schedule, and budget as delegated by the PIB;
- offering options and recommendations to the PIB when baseline changes affect the broader program;
- defining and prioritizing RTBF facilities and projects within MCB program elements; and
- ensuring that the *Weapons Program Plan* accurately captures detailed manufacturing plans for work, facility, and resource requirements in the technical divisions.

The MCB communicates regularly with NNSA points of contact to convey status and changes within the program, to enhance quality oversight and integration by NNSA, and to enable the most effective management and responsiveness at Los Alamos.

The MCB meets monthly to discuss issues and respond to tasks from the PIB. As the primary advocate to the PIB for the manufacturing program elements, the MCB is addressing the mid- FY03 budget, beginning preparations for the FY04 budget, and examining significant out-year program element issues.

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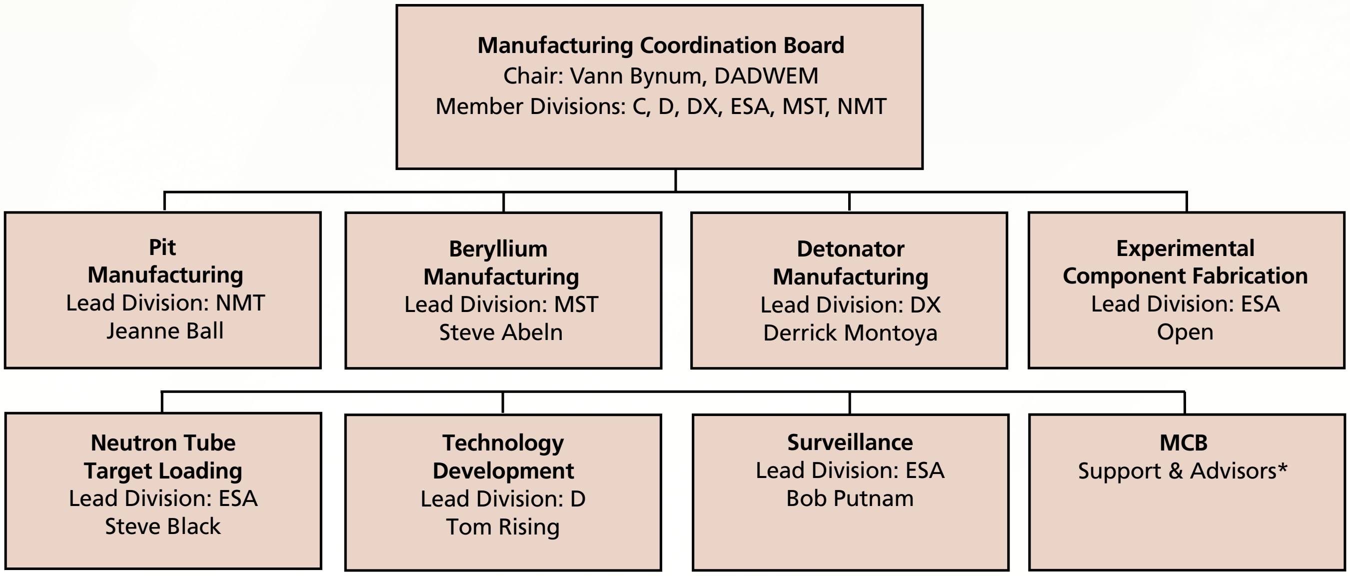


*D Division, ESA-Manufacturing Program Office (MPO), Weapons Quality Assurance Office (WQAO), and Facilities (ADO-IFC) provide analysis, administrative support, and subject matter expertise.

# Do Work Safely: The Five-Step Process

In January 2003, Director Pete Nanos expressed his concern over the upward trend developing in the Laboratory's injury and illness rates and established the Director's Safety Initiative. Using nested safety committees, employees provided input to specific questions from the Director.

When asked what can be done—and what can you do—to reduce workplace injuries, many workers focused on the five-step process:

- What ever happened to the five- step process?
- Are we still using the five-step process?
- If we are using nested committees, do we still have to do the five-step process?
- Does the five-step process apply to my project?

*The Integrated Safety Management (ISM) Description Document,* LA-UR-98-2837, Rev. 4 (Feb- ruary 2003), contains a description of the five-step process and states that it "applies to all work at Los Alamos, from office activities to designing experiments, to assembling and detonating explosives."

The five-step process, as established under ISM, is as follows:

- Define the scope of the work.
- Identify and analyze hazards.
- Develop and implement controls.
- Perform the work safely.
- Ensure performance and continuous improvement.

The level of effort and formality needed to implement the five-step process can be tailored to any activity. For example, office workers and supervisors consider the hazards associated with their work and how to control hazards for individual safety and the safety of others. On the other hand, when planning a more complex laboratory experiment or project, workers and supervisors must consider broader issues. Safe Work Practices, LIR300-00-01 provides details on the Laboratory requirements for implementing the ISM five-step process.

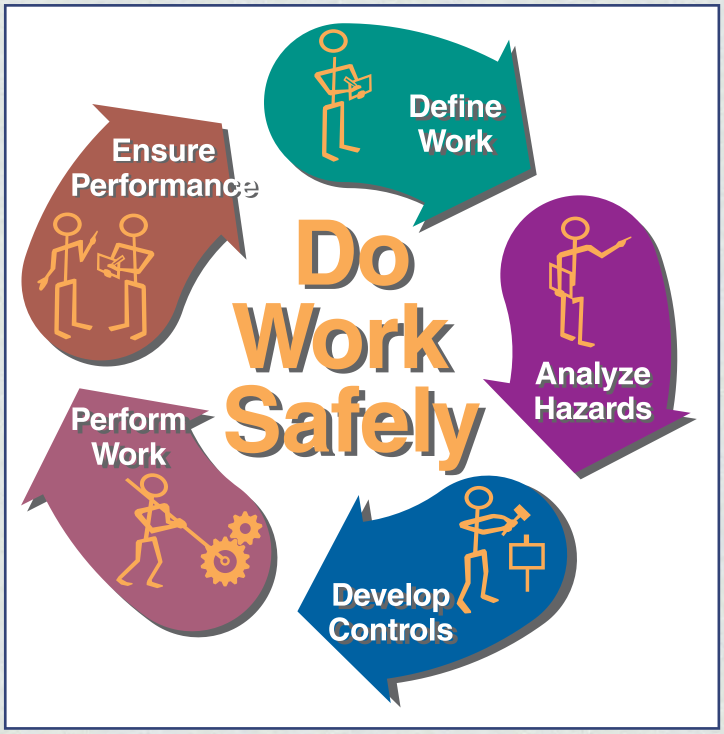
**Define the Scope of the Work.** In this first step, workers and supervisors must define the specific activities, sequence, and duration of the work; the materials to be used in the work; the configuration of equipment to be used in performing the work; and the facility or location where the work will be performed. The workers involved in the work and those in the vicinity who may be affected by the work also must be identified.

**Identify and Analyze Hazards.** Using their knowledge of the defined work activities, workers and supervisors must then identify the hazards associated with the work and the circumstances in which they could cause injury or harm to workers, the public, or the environment, or cause damage to or loss of property. Then they must evaluate the hazards and determine their likelihood and severity, that is, the level of risk of occurrence—minimal, low, medium, or high. (Note: A risk determination matrix is provided in LIR300-00-01.)

**Develop and Implement Controls.** Based on the hazard evaluation, workers and supervisors then must develop and implement controls with a rigor appropriate to reduce the initial risk to an acceptable level. If hazardous materials or processes cannot be eliminated or substituted, then engineering controls, administrative controls, and/or personal protective equipment must be used. Depending on the level of initial risk, the hazard control system developed must be reviewed by an ES&H subject-matter expert and/or an independent peer who is familiar with and knowledgeable about the specific work but is not directly involved in or does not benefit by the work.

The hazard control system must be documented in a hazard control plan, or other approved work procedure documents, before the work can be authorized. The level of residual risk, that is, the risk remaining after the controls are put in place, determines the management-level approval required to authorize the work. For example, minimal-risk work can be authorized by a supervisor, low-risk work by a group leader, and medium-risk work by a division leader. (Note: High-residual-risk work will not be authorized at the Laboratory).

Just as the work must be authorized so to must each worker be authorized to perform the work. Part of the hazard control system for the work is the identification of the knowledge, skills, and abilities needed by the workers and the training required to understand the hazards, effectively use the controls, and perform the work safely. As with authorization of work, the level of residual risk determines the management-level approval required to authorize the workers. For example, to perform minimal-risk work a supervisor can grant authorization, to perform low- or medium-risk work a line manager must grant authorization in writing.



**Perform the Work Safely.** Before beginning work, each worker must perform a self-readiness check to confirm that the work conditions have not changed, that the controls and equipment specified in the hazard control document(s) are in place and functional, and that authorizations are current. If all is as it should be, the worker can then perform the work safely, using the established controls. If any aspect of the scope of work has changed, the work must be redefined to determine whether new hazards exist and whether new controls are needed.

**Ensure Performance and Continuous Improvement.** Periodically or whenever changes in the scope of work are identified, workers and supervisors must review the work, re-evaluate the effectiveness of the controls, and incorporate lessons learned into the hazard-control system. Such changes must be communicated to the workers, and to others as needed, using an established change-control process.

The five-step process is not a one-time excercise to be used only at the onset of new work; rather, it is an ongoing process to be used every day for every work activity. Recognizing changes in the work—changes that could introduce new hazards and require new controls—is key to preventing accidents.

A video on the five-step process was produced by the Tritium Science and Engineering Group (ESA-TSE) in collaboration with the Industrial Hygiene and Safety Group (HSR-5) following a welding accident that occurred in April 1999. In this video, technicians and man-agers frankly discuss the events that occurred before, during, and after the accident and provide lessons learned within the broader context of ISM and the five-step process. The filmmakers of this video, *The Work. . . and What We Learned: A Daily Approach to Integrated Safety Management,* were the 2001 recipients of the DOE Ægis Award for Training and Direction. This video, now being used throughout the DOE complex, is available from HSR-5, 665-5505. ✹

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# Behind the Weapons Program: The Silent Security Envelope

A front door opens just a crack and two black canisters the size of hand grenades come tumbling into the entryway. In an instant, they explode in a brilliant flash as a breath-taking blast shakes the building and reverberate through its foundation. A heartbeat later shouted commands and the tips of M-4 assault rifles cut through the smoke of the flash-bang grenades, sometimes called diversionary devices, as a team of heavily armed assailants in full combat gear storm through the front door. This is an exercise that some observers might guess is designed for military training; in reality, this is training for the Laboratory's contract guard force.

The image usually associated with contract security guards is one of an unarmed, uniformed guard patrolling shopping malls or parking lots on watch for "dangerous acts" like shoplifting or parking in fire lanes. While the events of 9/11 have helped improve the capability of security services around the globe, the DOE has maintained high standards for its contract armed protective forces for decades. In fact, over the years, the DOE has required protective forces to maintain physical fitness and firearms qualifications that closely model armed forces requirements.

Providing a high level of protection for nuclear weapons research and the staff responsible for stockpile stewardship has been a primary focus for the Senior Executive Team at Los Alamos National Laboratory since the early days of the Manhattan Project. Initially provided by the US Army, security for our nation's premier weapons research and development laboratory eventually evolved to a contract civilian force.

In the training scenario depicted above, the combatants are an elite team with Protection Technology Los Alamos (PTLA), the protective force for Los Alamos National Laboratory.  For this particular scenario, the Special Response Team (SRT) was tasked with neutralizing a fictitious band of terrorists who had infiltrated a mock-up of a lab facility containing nuclear material.

Before this year, such an exercise at Los Alamos National Laboratory would have been impossible because it didn't have the facilities to run such live-fire simulations. Thanks to DOE funding and five years of mutual effort by the Laboratory's security staff and contractor management, PTLA now has a top-notch "Live Fire Shoot House" at Technical Area 72. The facility opened for operations in March and was tagged as the foremost live-fire training facility in the DOE.

The Live-Fire Shoot House complements a rigorous training regime; the 352 security police officers (some armed, some Special Response Team

members), 42 security officers (unarmed), and 71 uniformed supervisors are required to complete more than three months of intense training that rivals the instruction that combat troops receive. Armed with Glock .40 handguns, M-16 and M-4 rifles, 12-gauge shotguns, M-60 machine guns, and M-79 grenade launchers, the protective force maintains a quiet but effective security envelop for the national security mission of Los Alamos.

The 600 hundred people, including administrative and technical staff, who make up the protective force are charged with guarding 6 metric tons of nuclear material and several million classified documents across Los Alamos's 43 square miles. Hardly fitting the conventional notion of a contract guard company, PTLA provides realistic, military-type training and effective leadership to allow the critical science of our nation to prosper.

Recently, a PTLA team from Los Alamos competed in the Security Police Officer Training Competition (SPOTC) at the DOE's Central Training Academy in Albuquerque. The Los Alamos team competed against 21 other teams from other DOE sites; police officers from the United Kingdom, Albuquerque, and the State of New Mexico; and military teams from the US Air Force and Marines. The competition included events such as marksmanship (handgun and rifle), physical agility, and critical thinking. ✹

*Michael Wismer, 665-6362, mwismer@lanl.gov*

### *The Los Alamos SPOTC Team*

*Tim Casias*
*Will Clayton*
*Joe Nieto*
*Felix Valdez*
*David Zufelt*

*Team Captain*
*David Miranda*
*Team Coaches*
*Steve Rivera*
*Dominic Browning*

*Continued from page 1*

This conference made it clear that Los Alamos has an important role in this New Triad to provide mature, sustainable, and agile support for current and future requirements of the nuclear stockpile; responsive infrastructure elements; and nonnuclear defense technologies for global surveillance, ballistic missile defense, and advanced conventional strike missions.

Los Alamos missions support the New Triad.
- Stockpile stewardship—the most important mission at Los Alamos—supports nuclear strike capabilities.
- Nonproliferation and homeland security technologies are critical for supporting the active and passive defenses important to our homeland, our armed forces, and our allies.
- Advanced sensors, target detection, and data processing algorithms underlie command, control, communications, computer systems, intelligence, surveillance, and reconnaissance ($C^4$ISR).
- Responsive infrastructure relies on sustainable weapon certification and manufacturing capabilities and on the ability to explore new design/advanced concepts. It is the responsive infrastructure that makes the national labora-tories and plants, in and of themselves, part of the New Triad. By guaranteeing the US capability to respond rapidly to new threats, the laboratories and plants help dissuade potential adversaries and assure our allies.

The New Triad provides an intellectual architecture for most of our national security missions, and the Laboratory has an important suite of mission responsibilities and new opportunities within this shifting paradigm.

## Stockpile Stewardship

In the context of this core mission, Los Alamos is committed to meeting its current responsibilities for nuclear weapons stockpile stewardship. This commitment includes support for required stockpile life extensions, for the certification of newly manufactured pits, for establishing a technically sound basis for certification science, and for the experimental campaigns necessary to meet stewardship requirements.

### Los Alamos responsibilities and opportunities in the New Triad

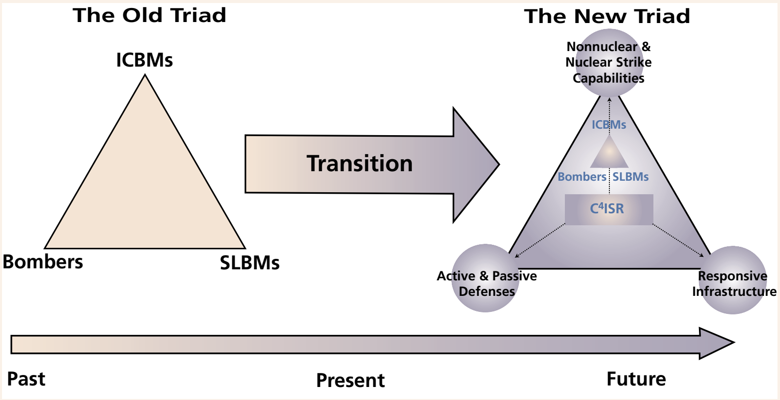
**Stockpile Stewardship**
- Certification
- Advanced concepts
- Flexible manufacturing infrastructure

**Threat Reduction**
- Nonproliferation and counterproliferation
- Homeland security

**Defense Transformation**
- Global situational awareness and sensors
- Advanced conventional munitions

**Broad Scientific Underpinnings**
- Energy and environmental security
- Nuclear fuel cycle
- Nanotechnology
- Superconductivity
- Carbon sequestration

Such experiments make vital contributions to the nuclear weapons science for which we are responsible and involve several key Los Alamos facilities. With the second axis of DARHT coming online, we will be acquiring two-view, time-resolved, 3-D radiographic implosion data on simulated weapon primaries. We will continue to utilize the U1a complex at the Nevada Test Site to conduct subcritical experiments that are directly relevant to nuclear weapons hydrodynamics. Proton radiography at LANSCE has given us a new tool to study dynamic materials behavior at high spatial and temporal resolution. Los Alamos is also working closely with Livermore and will be conducting experiments at the National Ignition Facility (NIF) as that user facility comes online. Experimental campaigns using these and other facilities are challenging our understanding of and providing important data against which to calibrate our nuclear weapons simulations. Code development and validation, and their application to high-speed, high-capacity computing, are key elements of science-based stockpile stewardship in the New Triad. Furthermore, Los Alamos is working with NNSA to evolve stockpile stewardship into the mature, sustainable, and agile program necessary to meet evolving nuclear requirements. Through this more mature program, the Laboratory will establish itself as a fully capable element of the nation's responsive infrastructure. Goals for this evolving program include ensuring a sustainable weapon certification capability, providing limited but flexible manufacturing capability in support of NNSA needs, and establishing and demonstrating the capability to respond to force evolution through advanced weapons concepts.



*The old triad was based on bombers, ICBMs (intercontinental ballistic missiles), and SLBMs (submarine-launched ballistic missiles).*

The Advanced Concepts Initiative (ACI) is a specific component of the NNSA's efforts in this direction: to revitalize the nuclear weapons complex's capability to support DoD requirements for flexibility. The ACI program will conduct new weapon studies and will explore concepts for new warhead designs and modifications to meet DoD needs that are not met by the current stockpile. The ACI is a program for developing and exercising capability and for applying that capability to examine options. Any actual warhead development would be decided and pursued only through the established Nuclear Weapons Council process with Congressional approval of the necessary funding.

## Defense Transformation

Transformation is a common theme in recent US pronouncements about defense strategy. Undersecretary of Defense Steve Cambone spoke about it in his keynote address at our conference. Also, the President's *National Security Strategy* states, "Innovation within the armed forces will rest on experimentation with new approaches to warfare, strengthening joint operations, exploiting US intelligence advantages, and taking full advantage of science and technology."

The Laboratory is well suited to contribute science and technology for defense transformation, including efforts to develop and demonstrate new, more sophisticated threat-detection and early warning systems and directed energy systems.

- We are building on our success over the past four decades in developing satellite sensor and monitoring systems—most recently, the completion of two successful flight campaigns of the novel remote ultra low-light imaging (RULLI) sensor designed for single-photon imaging under lighting conditions in which other techniques cannot function.
- We offer key capabilities in real-time active and passive sensors, detectors, and network-centric systems looking at the full range of WMD threats from both rogue states and transnational actors.
- We are uniquely positioned to design and implement the next generation of speed-of-light, directed-energy laser systems. In response to US Navy interest, the Laboratory proposed designs for a free-electron laser (FEL) that can demonstrate pulsed lethality and high-power atmospheric propagation.

## Nonproliferation and Homeland Security

Nonproliferation and homeland security technologies have become cornerstones in reducing the WMD threat.

- Many advances are being made in nuclear materials security in a complex international environment: international safeguards; technologies to track, locate, and secure nuclear materials; support for materials disposition; arms control monitoring and verification; export monitoring, assessment, and control; and integrated assessment of national and subnational activity.
- Technical support to homeland security includes new bioagent and chemical sensors and networks of distributed nuclear and physical detectors for border and transportation security. These systems are part of the architecture to limit proliferation and protect the homeland.
- Infrastructure modeling and emergency response enable us to analyze vulnerabilities and better prepare for the threat of terrorism against the US.

## Broad Scientific Underpinnings

Complex systems design, engineering, testing, and evaluation, as well as theoretical and computational physics and materials science, are core capabilities in our science and technology base. We have begun to refer to the integrated application of these disciplines as "predictive science." All of what we do at Los Alamos can be viewed as being in support of predictive science.

This robust science and technology base has always served as the foundation for our national security mission; this scientific approach to addressing national problems has not changed in 60 years. For example, our scientific and technical contributions toward developing a secure and adequate energy supply demonstrate the strategic thinking necessary in the New Triad. We can apply technology from our national security mission to solve important problems in such areas as advanced fuel cycles, space nuclear power, fuel cell technology, and waste management and disposition—all of which are important contributions to the broader national security and economic well being of our country.

## Ideas That Change the World

At the conference, an impressive array of national and international experts provided insights on the future national security landscape. They affirmed and congratulated our remarkable contributions to this nation's well being and commented on the inspiration of driving up the same "Hill" that once hosted Oppenheimer and Fermi.

The directions laid out in the New Triad envision a closer and more coordinated relationship between nuclear and conventional forces and new and different roles for nuclear weapons. The implementation and integration of these ideas will rely on many of the core scientific capabilities and resources of the Laboratory. Los Alamos welcomes the opportunity to demonstrate our continuing technical leadership to the world. ✸

### Organizational Acronyms and Abbreviations

| | |
|---|---|
| C | Chemistry Division |
| CMR | Chemistry and Metallurgy Research (building) |
| DO | Division Office |
| DOE | Department of Energy |
| DoD | Department of Defense |
| ESA | Engineering and Sciences Applications Division |
| LANSCE | Los Alamos Neutron Science Center |
| LASO | (DOE) Los Alamos Site Office |
| MST | Materials Science and Technology Division |
| NMT | Nuclear Materials Technology |
| NMT-2 | Actinide Process Chemistry |
| NMT-5 | Weapons Component Technology |
| NMT-11 | Actinide and Fuels Cycle Technologies |
| NNSA | National Nuclear Security Administration |
| PIO | Planning and Integration Office |
| WEM | Weapons Engineering and Manufacturing (Directorate) |

# A BACKWARD GLANCE

## Implosion on the 4th of July

In the spring of 1943, Seth Neddermeyer introduced to Los Alamos the original concept of using high explosives as a method of producing a critical mass of fissile material in a very short time. Neddermeyer's idea was to surround a hollow cylinder of active material—whose dimensions were incapable of sustaining a fast neutron chain reaction—with enough TNT to blow it into a solid mass in which a fast chain reaction would take place.

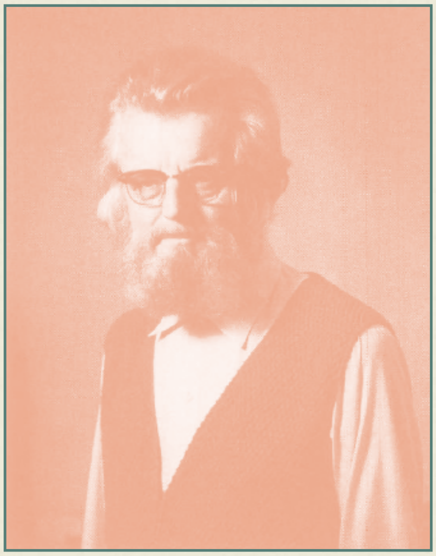
*Result of implosion test*

By July 4, 1943, Neddermeyer had acquired enough TNT and primacord to conduct his experiment. On that Independence Day, Neddermeyer gathered his boss, Navy Captain William (Deak) Parsons, and Ed McMillan, Hugh Bradner, John Streib, and Charles Critchfield at a site on South Mesa, near the current-day Otowi Building, to witness his test.

After wrapping the explosives around a sewer pipe, the group helped place that pipe inside a sleeve made from an ordinary kitchen stovepipe. Then they took cover and detonated the apparatus. By coincidence, the experiment proved to be just the correct combination to blow the iron pipe into a solid mass and keep it that way.

Parsons left shortly after the detonation to buy a saddle horse for his wife. The remaining five waited until he was out of earshot, then they loaded a duplicate piece of stovepipe with the remaining TNT and set off the biggest-ever 4th of July fire cracker in the history of Los Alamos.

Parsons was not enthusiastic about implosion and disapproved of Neddermeyer's continued work on the method. It wasn't until John von Neumann visited Los Alamos and blessed implosion that the Laboratory took this method seriously.



*Seth Neddermeyer*

Roger Meade, LANL historian, extracted this story from an article by Charles Critchfield, a mathematical physicist and Ordnance Group Leader who was at South Mesa that day. For more information on Neddermeyer's work, his report *The Collapse of Hollow Steel Cylinders by High Explosives* (U) (LA-18, Los Alamos Scientific Laboratory, August 1943) is available online from the Laboratory's Research Library collection at http://lib-www.lanl.gov/documents/g/00349600.pdf or search the library catalog for LA-18 at http://lib-www.lanl.gov.