the Pulse
LANSCE Los Alamos Neutron Science Center
June 2016
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INSIDE

Los Alamos NATIONAL LABORATORY EST. 1943

Successful run cycle showcases neutron science in all its diversity

Five major experimental facilities operate simultaneously at LANSCE, contributing to the nation's nuclear weapons program and research in nuclear medicine, materials science and nanotechnology, biomedicine, electronics testing, fundamental physics, and many other areas. The U.S. Department of Energy, National Nuclear Security Administration, Office of Science and Office of Nuclear Energy, Science and Technology–the principal sponsors of LANSCE–have synergistic long-term needs for the linear accelerator and neutron science that is the heart of LANSCE.

Accelerator investments enable extended beam production

The Los Alamos Neutron Science Center (LANSCE) recently completed a productive and—with DOE investments in the accelerator—an extended run cycle, operating at full production from October 2015 to February of this year, three weeks beyond the scheduled end date. LANSCE is the Laboratory's accelerator complex providing intense sources of neutrons and protons for experiments supporting civilian and national security research.

Upon this year's planned completion of the Linac Risk Mitigation Strategy, a DOE investment in the reliability and sustainability of the accelerator, LANSCE is scheduled to operate from September to February 2017.

The LANSCE linac is an essential element of MaRIE, the Laboratory's proposed experimental facility for time-dependent materials science at the mesoscale. Leveraging LANSCE's existing 1-MW, 0.8-GeV proton accelerator, MaRIE will bring together the world's highest energy free-electron laser with gigahertz repetition ability, a Multi-Probe Diagnostic Hall, and a Making, Measuring, and Modeling facility. The roadmap to MaRIE leverages government investments at LANSCE to efficiently provide future capability.

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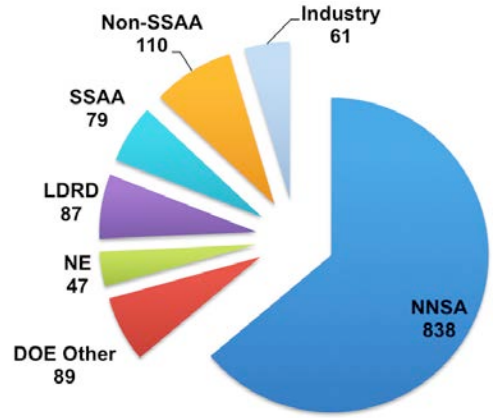
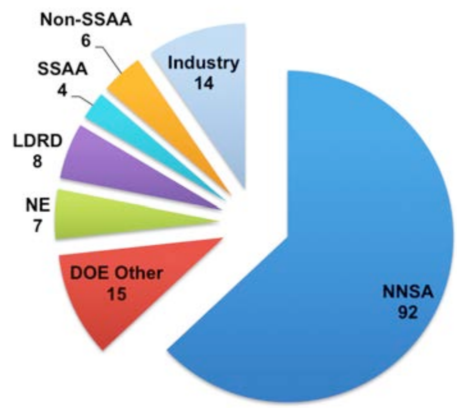
> *“A clear demonstration of the high-level support we are receiving is the support for replacing the current 1L target in the Lujan Center.”*

From Gus’s desk . . .

I am honored and excited to be named the new LANSCE User Facility director. LANSCE is an amazing facility that continues to provide state-of-the-art measurements for the nation. The last run cycle was a productive one. The accelerator delivered beam for about 100 days and had an uptime of ~82%. At the Isotope Production Facility, we produced enough strontium-82 for ~120,000 cardiac images and continue to develop alternate means to produce actinium-225, an alpha emitter that is being investigated for cancer therapy. Proton Radiography executed 32 dynamic experiments, 6 of which supported the B-61 Life Extension Program. We ran 119 experiments at the Lujan Center and Weapons Neutron Research facility, advancing our knowledge of the total fission cross section of uranium-235 and the neutron energy spectrum from the fission of plutonium-239. The materials science program at the Lujan Center executed experiments to further our understanding of the properties of additively manufactured material, the characteristics of insensitive high explosives, and the affect of a simple heat treatment to the properties of U6Nb. At the Ultracold Neutron facility, we made significant progress in our ability to accurately measure the neutron lifetime and understanding how to increase the flux of ultracold neutrons (UCN), which will benefit all UCN experiments. We also made critical contributions to the basic research program at the Large Hadron Collider (LHC) at CERN. The U.S. members of the LHC used the Blue Room to develop the radiation-hard electronics they will need for planned upgrades at the LHC. In all, we hosted more than 400 visitors at LANSCE during the run cycle. The schedule was extended for two weeks to enable two high-priority experiments at the Proton Radiography facility, but everyone was able to take advantage of the additional beam time. We are now in a maintenance outage where we are replacing the final high-power amplifier (module 3) of the RF system. Work is progressing and we are on schedule to resume accelerator operations in September.



Number of beam days provided per program during the most recent LANSCE run cycle.



Number of proposals run during the most recent LANSCE run cycle; data from NNSA-designated national user facilities.

I am optimistic as we look to the future. Less than two years ago we faced the incredible challenge of the loss of Basic Energy Sciences funding for the materials science program at the Lujan Center. This presented an enormous challenge to the scientists and the mesa. In a short period of time we had to demonstrate to the NNSA that we could make important measurements in support of its programs. The response from the scientists has been truly amazing—in just a single run cycle they were able to demonstrate not only that we can make needed measurements here at LANSCE, but also that neutron scattering has an important role to play in the Stockpile Stewardship

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From Mary's desk . . .

Three near misses in two months at TA-53 is a clear indication we all need to commit to pausing, reflecting, and taking action to ensure the safety and well being of ourselves and our coworkers. While the motivation for us to get our job done is a good thing, no job is so important that someone gets hurt.

These near misses—unplanned events that did not result in injury or fatality, but had the potential to do so—involved a cut electrical conduit, a 480-volt extension cord, and a forklift-auto collision.

Each near miss had in common a "fortunate" break in the chain of events that prevented a calamitous outcome: the electrical safety officer flipped the circuit breaker, "just because;" the worker held the extension cord by the cable instead of the metal connector box; the driver of the vehicle drove slowly and braked quickly.

In these events, assumptions—not thinking that anyone would cut a conduit containing electrical wires, that anyone would incorrectly wire an extension cord, or that cars would come through a non-barricaded work area with an obstructed view—played a key role.

We make risk calculations on a daily basis—so how do we get the risk assessment right? Our assumptions tend to be that everything will work as planned—yet conditions change and human error happens all the time. We need to include this in our thinking.

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Our decisions tend to depend on assessments of time and money. In these events, we *could have* expedited air gapping, *would have* bought a cord rated for the job, *should have* taken a minute to lower the forklift tines.

Humans are human, and we need to plan for it with robust systems that take into account the inevitable. Integrating human performance initiative principles into how we plan and perform our work is essential. We need to think about consequences and how to mitigate them; an error-tolerant system that lowers the consequences is where we need to go.

These recent near misses—the facts and the lessons—were the focus of a discussion between TA-53 residents and its leadership team. Following a plenary session with all attendees, participants divided up into breakout sessions to discuss assessing risk, pausing work, recognizing changing work conditions, and asking for help.

From our breakout sessions we received several concrete actions that we can undertake, and we plan to give more careful consideration to the ideas presented briefly from the other sessions. The notes from the breakout sessions and the presentation are available on the ADEPS web site.

The TA-53 management team remains committed to being present in the workplace—being aware of what is taking place, being available for questions, and assuring that operational concerns are addressed in a timely manner.

And we hope each of you during the meeting realized things that you can do to help us all be safer in the workplace, or if you have ideas later that you share them with co-workers, because the gathering was not just about the day, it was about tomorrow, and all the days after tomorrow and how we prepare for and minimize the consequences of inevitable human error.

Mary

Experimental Physical Sciences Associate Director Mary Hockaday

LANSCE scientists in the news

Andy Saunders among newest APS Fellows

Andy Saunders was recently named an American Physical Society Fellow, Division of Nuclear Physics. Saunders (Subatomic Physics, P-25) was cited for contributions in developing proton radiography and the Los Alamos National Laboratory ultracold neutron source, enabling new applications of nuclear science and an improved understanding of the decay of the free neutron.

Saunders, who received a PhD in physics from the University of Colorado, joined the Laboratory in 1998 as a postdoctoral researcher. He has participated in the development of proton radiography (pRad) since the early demonstration experiments conducted at Brookhaven National Laboratory in 1997; has led the Los Alamos pRad imaging capability since 2013; and served as the radiographer in charge of executing more than 150 explosively driven dynamic experiments at the Los Alamos Neutron Science Center (LANSCE) for the weapons program, for which he is developing new techniques in charged particle radiography. Saunders also participated in the design and construction of the Laboratory's Ultracold Neutron Facility and is co-spokesperson of a project measuring the average lifetime of the free neutron. Saunders has received nine Defense Program Awards of Excellence and five Los Alamos Distinguished Performance Awards.

Technical contact: Andy Saunders

Bruce Carlsten named IEEE Fellow

The Institute of Electrical and Electronics Engineers (IEEE) has honored Bruce Carlsten (Accelerator Operations and Technology, AOT-DO) with the title of Fellow. IEEE cited him "for contributions to high-brightness electron beams and vacuum electron devices."

Carlsten is a pioneer in the production and use of high-brightness electron beams. His discovery of techniques enabling unprecedented beam brightness has led to a new generation of intense free-electron lasers, including the Lab's Navy Free Electron Laser (FEL) and MaRIE (Matter-Radiation Interactions in Extremes), a proposed premier x-ray FEL facility. These ideas are of such fundamental importance that virtually every free-electron laser in the world uses them.

Carlsten received a PhD in electrical engineering from Stanford University and joined the Laboratory in 1982. He is a member-at-large of the IEEE Particle Accelerator Science and Technology Technical Committee and the American Physical Society's Executive Committee of the Division of Physics of Beams, and a Fellow of the American Physical Society and Los Alamos National Laboratory. Carlsten has received a U.S. Particle Accelerator School Prize for Achievement in Accelerator Physics and Technology, three Los Alamos Distinguished Performance Awards, and six patents on novel accelerator and RF source technologies. He has more than 100 referred publications and serves on the editorial board of *Physical Review Special Topics – Accelerators and Beams*.

Technical contact: Bruce Carlsten

Jonathan Engle receives DOE Early Career Research Award

Jonathan Ward Engle (Inorganic Isotope and Actinide Chemistry, C-IIAC) received a 2016 Early Career Research Program Award from the Department of Energy. Engle is one of 49 recipients of the award, which recognizes outstanding researchers in universities and DOE national laboratories. The award also supports the development of individual research programs of scientists early in their careers and stimulates research careers in the disciplines supported by the DOE Office of Science.

Engle's winning proposal, "Nuclear Data for Spallation Neutron Radioisotope Production," will establish valuable international collaborative relationships with the potential to create a sustained fast-neutron cross-section measurement program, characterizing new medium-energy neutron-induced reactions relevant to radioisotope production and facility design, plus the ongoing effort to improve the predictive power of nuclear codes on supercomputers. The project also will enable evaluation of achievable yields of radioisotopes and consideration of radioisotopic impurities likely formed in reactions of current interest to DOE's Isotope Program.

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LANSCE scientists cont.

Sven Vogel named to European Spallation Source's Scientific and Technical Advisory Panel for Engineering and Imaging

Sven Vogel (Materials Science in Radiation and Dynamics Extremes, MST-8) has appointed to the Scientific and Technical Advisory Panel (STAP) for Engineering and Imaging for the European Spallation Source (ESS) by Ken Andersen, head of the Neutron Instruments Division of the European Spallation Source. The ESS is under construction in Lund, Sweden, and once operating at full power will be the most powerful neutron source in the world. Vogel will advise on the design of the ODIN imaging beamline as well as the engineering diffractometer BEER.

He was selected for this position by Markus Strobl, deputy head of the Instrument Division of ESS due to his combination of expertise in both engineering neutron diffraction as well as advanced neutron imaging techniques. Vogel's appointment is for two to four years. A member of the MST-8 scattering team, Vogel is the instrument scientist for the HIPPO (high pressure/preferred orientation) neutron diffractometer and the energy-resolved neutron imaging beam line at the Los Alamos Neutron Science Center.

Technical contact: Sven Vogel

Los Alamos Northern New Mexico IEEE Section wins two excellence awards

The Los Alamos Northern New Mexico (LANNM) Institute of Electrical and Electronics Engineers (IEEE) Section has received 2015 Outstanding Small IEEE Section awards for excellence in local activities, which are mostly run by volunteers from Los Alamos National Laboratory. LANNM section activities include technical talks open to the public (about 6–10 per year), professional development training, students and high school events promoting science and engineering, and recruiting gatherings.

After winning the award in the Southwest area of Region 6, the LANNM section advanced to the Region 6 competition, where it was again a winner, competing with other small sections with up to 500 members. The IEEE consists of 10 regions worldwide, of which Region 6 in the United States is the largest, covering western states where high-tech companies abound.

IEEE professional interests have expanded, covering practically all science and technology, including nuclear, photonic, power, software engineering, and biotechnology. IEEE serves as an umbrella organization for many professional societies of a more precisely defined scope of interest, the largest of which is the Computer Society. The LANNM section includes some of these local chapters.

From Los Alamos National Laboratory, LANNM volunteers include Section Chair Hanna Makaruk (Applied Modern Physics, P-21), Section Vice-chair Bruce Carlsten (Accelerator and Operations Technology, AOT-DO), Signal Processing Society Chapter Chair David Izraelevitz (Space Data Systems, ISR-3), Computer Society Chapter Chair Michael Ham (P-21), Nuclear & Plasma Sciences Society Chapter Chair Nathan Moody (Accelerators and Electrodynamics, AOT-AE), Women in Science and Engineering Affinity Group Chair Heather Quinn (ISR-3), Young Professional Affinity Group Chair Charles Weaver (Space Electronics and Signal Processing, ISR-4), and Section Historian and former longtime Chair Teri Roberts (Data and IT Quality Management, SAE-1). Tom Tierney (Intelligence & Systems Analysis, A-2) is a longtime volunteer and past section chair, currently serving with IEEE-USA board of directors as vice president for government relations.

Technical contact: Hanna Makaruk

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LANNM section volunteers celebrate the Outstanding Small Section Award at a social gathering in Los Alamos on IEEE Day. From left: Robert Owczarek (University of New Mexico), Bruce Carlsten (Los Alamos National Laboratory), Gregg Giesler (COMPA Industries), Peter Clout (Vista Control Systems Inc.), Heather Quinn, David Izraelevitz, Christopher Brislawn, Hanna Makaruk, Zack Backer, Michael Ham, Randy Roberts, and Teri Roberts (all Los Alamos).

LANSCE scientists cont.

Los Alamos Distinguished Performance Awards recognize Laboratory staff

Los Alamos National Laboratory Distinguished Performance Awards are presented in recognition of outstanding contributions in support the Laboratory's programmatic efforts. The following LANSCE-based teams were recognized with awards.

Chi-Nu DAQ Team, Small Team Award
The Chi-Nu project is a multi-laboratory, multi-year, and multi-million-dollar Campaign 1 experimental nuclear physics project with the goal to accurately measure the emission spectrum from neutron-induced fission on plutonium-239 and uranium-235. In January 2014, the existing Chi-Nu data acquisition (DAQ) system was unable to keep up with the data rate for the studies. In just six months, Shea Mosby and John O'Donnell (LANSCE Weapons Physics, P-27) (photo, above) designed, procured, coded, validated, and implemented a new highly capable, versatile DAQ scheme that positions the Chi-Nu project to meet its deliverables and provide required data.

Legacy Lead Bricks Team, Large Team Award
Mark Peters (Applied Modern Physics, P-21), Julian Lopez (Subatomic Physics, P-25), Steve Glick (Physics Division Office, P-DO) and Jeanette Gray (formerly P-DO), and Keith Rielage and Mitzi Boswell (Neutron Science and Technology, P-23) were part of a team that repurposed 50 tons of legacy lead bricks. When Physics Division staff realized the bricks contained a type of lead useful for shielding in particle-physics counting experiments, the team safely moved the bricks—valued up to $3 million—and shrink-wrapped them, thereby saving a valuable resource for future scientific research and eliminating an environmental hazard.

LANSCE WNR Facility Recovery Team, Large Team Award
Milestones for two NNSA Defense Program campaigns were at stake when damage from a water leak and a fire threatened to interrupt the Weapons Neutron Research facility run cycle. Pete Aguino, Greg Chaparro, Tim Medina, and Bill Waganaar (P-27) were among more than 40 employees who redesigned the WNR water system, built a replacement for the affected target, and replaced a 20,000-pound magnet, which had damaged coils, with two magnets. Beam was once again delivered on October 18.

Mini-CAPTAIN snags first ionization track

Los Alamos detector paves way for international neutrino experiment

Mini-CAPTAIN, the prototype for the Cryogenic Apparatus for Precision Tests of Argon Interactions with Neutrinos (CAPTAIN), recently demonstrated its first ionization track. The Mini-CAPTAIN detector is a liquid argon time projection chamber (TPC), a device capable of imaging charged particles through the trail of ionization electrons (ionization tracks) left behind when they interact with the argon nuclei. Its success makes it one of only a handful of liquid argon detectors now operating in the world. Liquid argon is increasingly being used as a detection medium by the worldwide neutrino community.

Under commission at Los Alamos, the 1,000-channel liquid argon TPC with 400-kg instrumented mass will use the Los Alamos Neutron Science Center's high-energy neutron beam, which is uniquely suited to aid understanding of how to reconstruct few-GeV neutrino interactions. The data are crucial to enabling larger and more complex neutrino experiments aimed at solving scientific grand challenges

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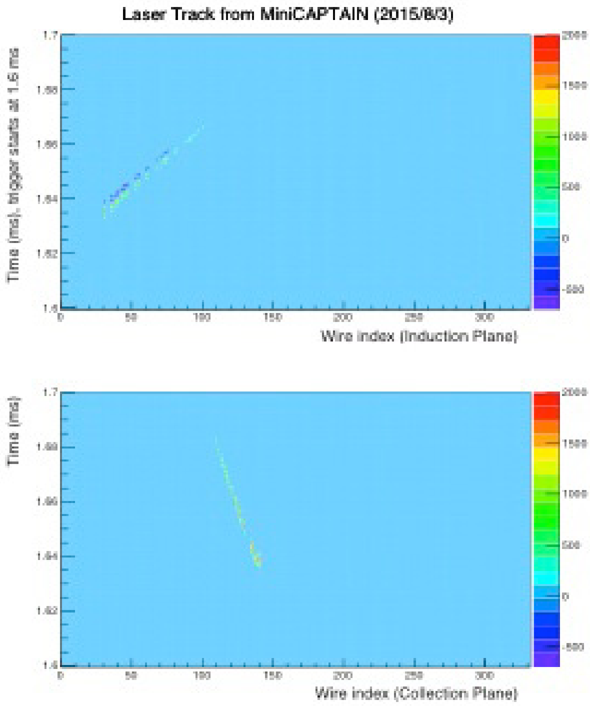
Mini-CAPTAIN snags cont.



First demonstration of an ionization track from a laser calibration system in the Mini-CAPTAIN detector. Data were created with a high-intensity ultraviolet laser pulse traversing the time projection chamber. The color of the track represents the amplitude of the signal. Mini-CAPTAIN is currently running with one collection plane and one induction plane.

such as explaining the universe's matter-antimatter asymmetry.

Los Alamos researchers working on Mini-CAPTAIN include Christopher Mauger, Elena Guardincerri, Gerald Garvey, David Lee, Qiuguang Liu, William Louis, Jacqueline Mirabal-Martinez, Jason Medina, Geoffrey Mills, John Ramsey, Walter Sondheim, Charles Taylor, and Richard Van de Water (all Subatomic Physics, P-25); Keith Rielage (Neutron Science and Technology, P-23); and Gus Sinnis (LANSCE Weapons Physics, P-27).

In addition, the CAPTAIN detector, a 5-ton instrumented mass liquid argon TPC with 2,000 channels, is under construction at Los Alamos and will eventually run at the Fermi National Accelerator Laboratory.

The CAPTAIN program addresses important scientific questions associated with the long-baseline, atmospheric, and supernova neutrino science of DUNE. Dune (for Deep Underground Neutrino Experiment) is an international long-baseline neutrino program designed to aid neutrino science and proton decay studies. Los Alamos is developing and managing the DUNE detector systems.

The CAPTAIN program began as a Los Alamos Directed Research and Development (LDRD) program project with scientists in P-25, P-23, and Nuclear and Particle Physics, Astrophysics and Cosmology, T-2) performing work relevant to the long-baseline program. The development of the detector at Los Alamos led to the formation of a broad collaboration from institutes across the United States. Many external collaborators, especially graduate students and postdoctoral researchers, have spent significant time at Los Alamos National Laboratory working on the project. The CAPTAIN program continues to involve Los Alamos researchers from Physics and Theoretical groups.

External CAPTAIN collaborators include the University of Alabama; Argonne National Laboratory; Lawrence Berkeley National Laboratory; Brookhaven National Laboratory; University of California, Davis; University of California, Irvine; University of California, Los Angeles; University of California, San Diego; Fermi National Accelerator Laboratory; University of Hawaii; University of Houston; Indiana University; Louisiana State University; University of Minnesota; University of New Mexico; University of South Dakota; South Dakota State University; and Stony Brook University. This work is supported by the Department of Energy through the Los Alamos LDRD program and the Office of Science High Energy Physics, and the University of California Institute for Nuclear/Particle, Astrophysics and Cosmology. The work contributes to DOE Office of Science missions and supports the Laboratory's Nuclear and Particle Futures science pillar.

Technical contacts: Christopher Mauger, Elena Guardincerri

Redesigned LANSCE target to provide higher energy neutrons for nuclear science

Nuclear science requires a higher intensity (or higher flux) in the epithermal and medium neutron energy ranges than materials science. In support of defense program applications such as nuclear science, the Lujan Center at the Los Alamos Neutron Science Center is redesigning the current Mark-III Target-Moderator-Reflector-Shield to provide a higher intensity in the epithermal (100 eV–10 keV) and medium (10 keV–1 MeV) neutron energy ranges. Suzanne Nowicki and Michael Mocko (LANSCE Weapons Physics, P-27) conducted Monte Carlo Neutral Particle-eXtended (MCNPX) simulations that compared neutron intensity in the lower and upper tiers of five preliminary models and narrowed the field to one promising design.

Currently, Mark-III flight paths are distributed over two tiers. The lower tier consists of three chilled H_2O and one liquid hydrogen (LH_2) + chilled H_2O moderators to deliver cold and thermal neutrons to 12 flight paths. The upper tier consists of one LH_2 and one chilled H_2O moderator to deliver cold and thermal neutrons to four flight paths. Materials science projects are conducted on the lower tier flight paths. Because the upper tier and the lower tier are intrinsically coupled, any changes on the upper tier will affect the lower tier.

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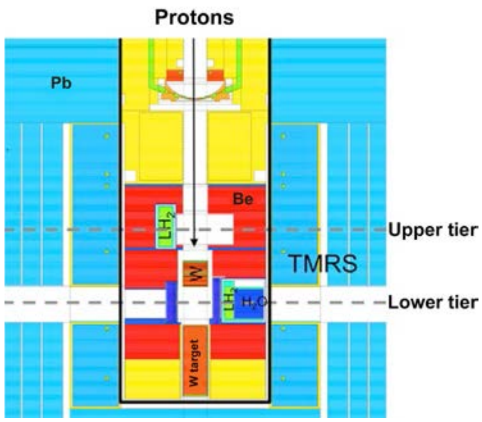
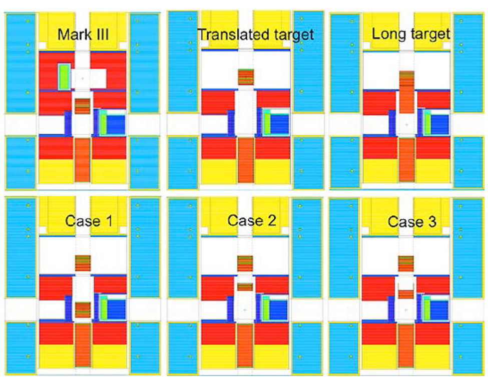
Redesigned LANSCE target cont.

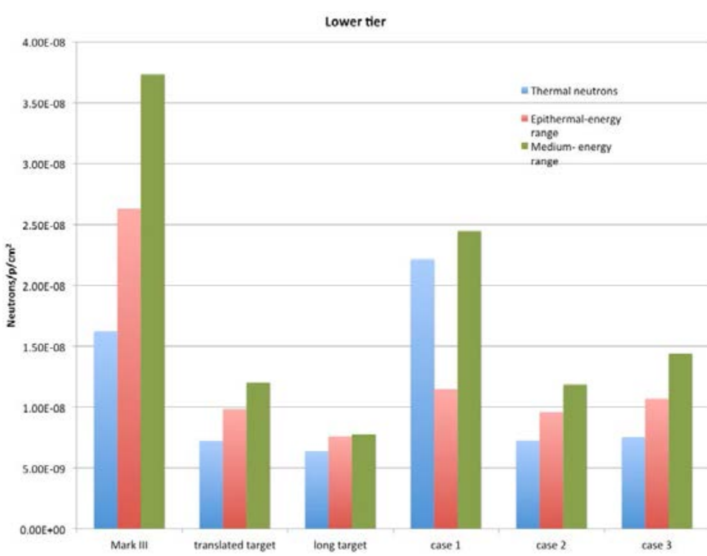
The researchers conducted simulations to monitor the changes on both tiers when the target is redesigned for nuclear science. The upper tier results revealed a significant improvement in the ranges of interest when the target in translated in the upper tier field of view (improvement by a factor of 10 in the medium energy range). The lower tier results show that, for all examples except case 1, the intensity of thermal neutrons decreases. In case 1, the thermal neutron intensity increased. This design looks promising because it also shows that the ratio of neutrons more than 0.4 eV to thermal neutrons is lower than for the other designs.





Top: Schematic of the Mark-III geometry in the Y-Z plane. Labels: target moderator reflector shield (TMRS), tungsten target (W), LH_2 moderator (LH_2), H_2O moderator (H_2O) beryllium reflector (Be), lead-reflector shield (Pb).

Bottom: Comparison schematic of Mark III and preliminary models.



Simulated neutron intensity results for Mark III and five preliminary models on the lower tier flight path. Case 1 is the most promising model.

The team is conducting optimization studies of the physics design to further develop the case 1 design. The researchers will simulate time emission spectra both in the lower and upper tiers, and the scientists will correlate the characteristics of the spectra (full width at half maximum, tail, and background) to the size of the moderators, the target, and the proton pulse.

The NNSA Readiness in Technical Base and Facilities (RTBF) program funded the work in support of LANSCE, a national user facility where a variety of science is performed.

Technical contact: Suzanne Nowicki

^{63}Ni (n,γ) cross sections measured with DANCE

Recent LANSCE measurements on a radioactive isotope of nickel with the Detector for Advanced Neutron Capture Experiments (DANCE) at the Lujan Center have shed new light on how copper and zinc are made in stars. A team of scientists from P-27, C-NR, Goethe Univ. of Frankfurt, and Univ. of Vienna have published their results in a recent article in *Physical Review C.* This work was part of the PhD thesis of Mario Weigand, an experimental nuclear physicist from the Goethe Univ. of Frankfurt.

The DANCE instrument, located at flight path 14 in the Lujan Center, is a 160-element barium fluoride scintillator array designed to perform measurements on small samples of rare isotopes. It is illustrated in Figure 1. The high segmentation combined with the high efficiency of the instrument has allowed measurements on a wide range of isotopes for programs ranging across national security, nuclear forensics, nuclear energy, nuclear structure, and nuclear astrophysics.

In this study, a sample of ~350 mg of isotopically enriched nickel-62 was irradiated at a reactor, converting 11% of the stable nickel-62 into unstable nickel-63. Nickel-63 is a radioisotope with a 101-year half-life, decaying via emission of a 67-keV electron. The inherent sample activity was 80 GBq, or 2.2 Ci.

After the sample was produced, it was brought to the Los Alamos Neutron Science Center (LANSCE), where the DANCE experiment was completed.

The elements heavier than iron are primarily produced through neutron capture processes in late stellar evolution of stars somewhat and significantly more massive than the sun. Both a *slow* and *rapid* neutron capture process

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Cross sections measured with DANCE cont.

Figure 1: A schematic model of part of the DANCE array is illustrated above. Different crystal shapes are indicated in different colors. Gamma rays are shown coming from the sample position. The sphere at the center represents the ^{6}LiH sphere placed at the center of DANCE to absorb scattered neutrons.

can contribute to their production. The slow, or *s* process, evolves along the line of beta stability, with neutrons being sequentially captured until an unstable isotope is created. If it is short-lived (<1 year), it will decay before another neutron capture can take place. If it is long-lived (>1000 years), it will capture another neutron. Isotopes with lifetimes between these extremes are called "branch-point" isotopes, as they split the reaction flow, including both neutron capture and beta decay. Nickel-63 is one such isotope.

Precise knowledge of the neutron capture cross section on branch points allows them to be used to determine stellar conditions at the *s*-process site. Before this work, there was only one measurement of the neutron capture cross section on nickel-63, which differed from theoretical estimates by almost a factor of 2.

The differential measured cross section is shown in Figure 2a and extends up to 500 keV. For stellar nucleosynthesis calculations, a Maxwellian-averaged cross section (MACS) is needed at 8, 25, and 90 keV. The measured MACS together is shown in Figure 2b, together with the previous evaluation and the measurement from neutron time of flight (nTOF).

The excellent agreement between the DANCE and nTOF results lends confidence to adopting the increased cross section relative to the theoretical estimate. This is particularly important as the nickel-63 branching controls the production of both copper-63, which is primarily made in the *s* process, and zinc-64, which is exclusively made in the *s* process. Because nickel-63 will capture more neutrons than previously expected, the reaction flow will bypass the production of both copper-63 and zinc-64 in these environments, leading to a roughly 30% reduction in the expected yield of these isotopes in massive stars.

This work supports the Laboratory's Nuclear and Particle Futures (NPAC) science pillar, with particular impact on the NPAC goals of "Cosmic Explosions: Origins to Ashes and the Origin, Evolution, and Properties of Atomic Nuclei." This work directly answered questions of the nucleosynthesis of copper and zinc. DOE/SC Nuclear Physics and the Laboratory's Los Alamos Directed Research and Development program provided support for the Los Alamos investigators.

Los Alamos personnel are T. A. Bredeweg (Nuclear and Radiochemistry, C-NR), A. Couture (LANSCE Weapons Physics, P-27), M. Jandel (C-NR), J. M. O'Donnell (P-27), J. L. Ullmann (P-27).

Reference: "^{63}Ni (n,γ) cross sections measured with DANCE," *Phys. Rev. C* **92** (045810) October 2015.

Technical contact: A. Couture

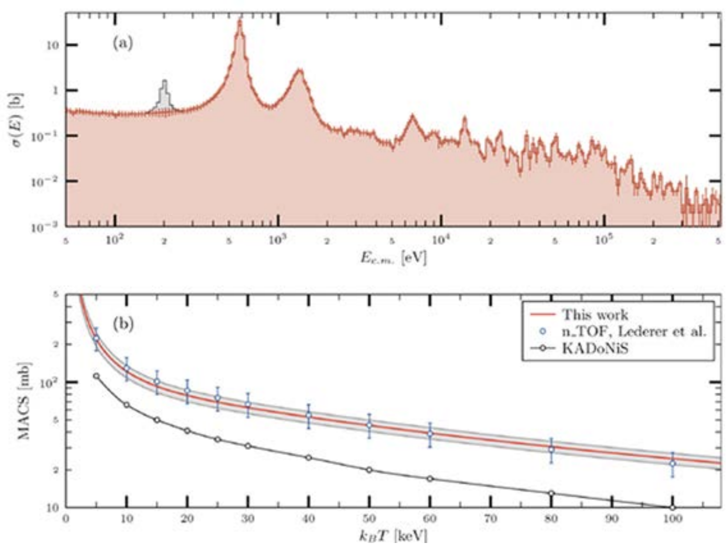

Figure 2: Shown in red in the upper panel (2a) is the measured differential neutron capture cross section on nickel-63. Shown in grey is a resonance from a contaminant. The lower panel (2b) compares the MACS from DANCE and nTOF measurements, which are in excellent agreement.

New surface studying capabilities at Lujan Center

Asterix neutron spectrometer probes chemical evolution of surfaces and thin films in variety of physical and chemical environments

Recent modification to the Lujan Center's polarized neutron reflectometer, Asterix, has created a new set of experimental capabilities. The alterations enable comprehensive characterization of chemical and structural properties of the surfaces of materials of importance and experimental environments to control the investigated surfaces' hydration, oxidation, temperature, and pressure to mimic a wide range of field conditions.

The instrument's conversion into a versatile nano- and meso-scale neutron scattering beamline by Erik Watkins (Materials Synthesis and Integrated Devices, MPA-11), Jarek Majewski (Center for Integrated Nanotechnologies, MPA-CINT), and Mark Taylor (Engineering Services for LANSCE Facility Operations, ES-LFO) allows Asterix to perform horizontal and vertical surface scattering geometries. For example, its horizontal sample geometry allows handling heavy and bulky sample environments required to investigate thin layers and bulk material surfaces in extreme environments. This capability may also be applied to study low-rate kinetics, like surface oxidation or evolution in a corrosive environment.

The modification also provides a possibility to address so called "off-specular" scattering from the samples. Off-specular data provide the neutron intensity distribution as a function of the neutron momentum transfer vector parallel to the sample's surface. This information can provide additional insight into in-plane correlations of the surface and interface structures. For example, such data can address correlations between the roughness of different interfaces, corrosion-induced pitting processes, and the growth or phase separation of in-plane islands.

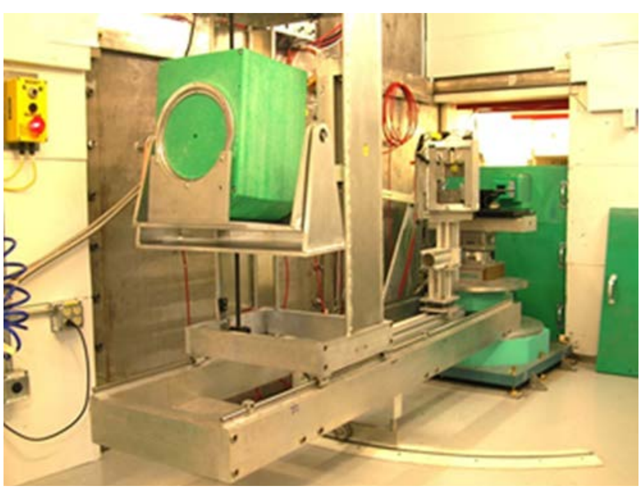

Figure 1. Shown are parts of the completed modifications (a new detector gantry and sample positioning mechanism), which allow vertical scattering geometry.

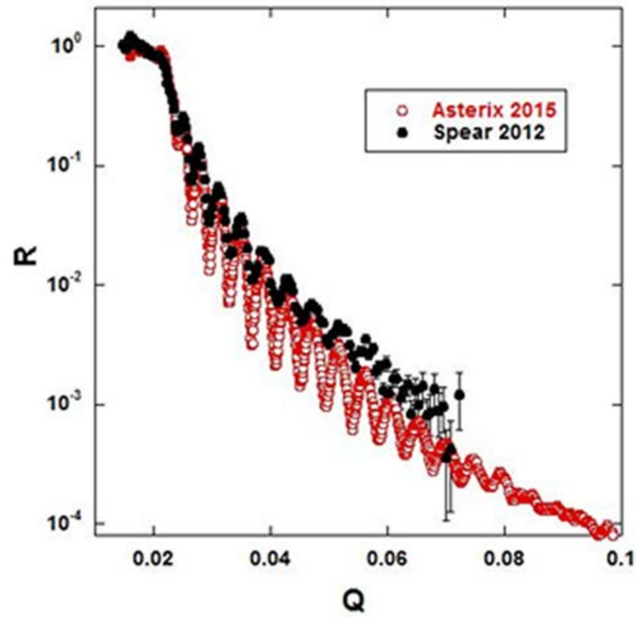

Figure. 2. Comparison of neutron reflectometry from approximately 140 nm of Ni deposited on a quartz substrate obtained from Asterix (red) and previous Lujan Center spectrometer SPEAR (not currently in use). Higher resolution and bigger momentum transfer vectors Q are measured at Asterix.

Surfaces and interfaces play a major role in material properties and frequently determine the behavior of bulk materials and their aging. They are especially important in determining the behavior of soft- and condensed matter nanostructured materials, such as metallic surfaces, polymer composites, multilayer structures, bio-related systems, etc. Experimentally investigating interfaces presents significant challenges. Interfaces are often buried within the material, therefore accessing them frequently requires destructive characterization or extensive sample preparation methods, such as for transmission electron microscopy or atom probe tomography. Despite many recent developments, interface structure and properties remain poorly understood, in part due to a limited experimental toolbox for their characterization.

Neutron scattering offers unique opportunities for studying interfaces due to the high penetration depth of neutrons and the non-monotonic dependence of their scattering cross sections on atomic numbers. For example, interfaces in metals typically have low thickness; indeed, some are atomically sharp. Thus, understanding interfacial phenomena requires high—sometimes ångstrom-level—spatial resolution. Moreover, certain interfaces only exist at high temperatures and pressures or under contact with external media, such as gases or liquids.

Frequently, investigating such interfaces requires special techniques and in situ characterization methods, which are at the core of MaRIE, the Laboratory's proposed

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Asterix neutron spectrometer cont.

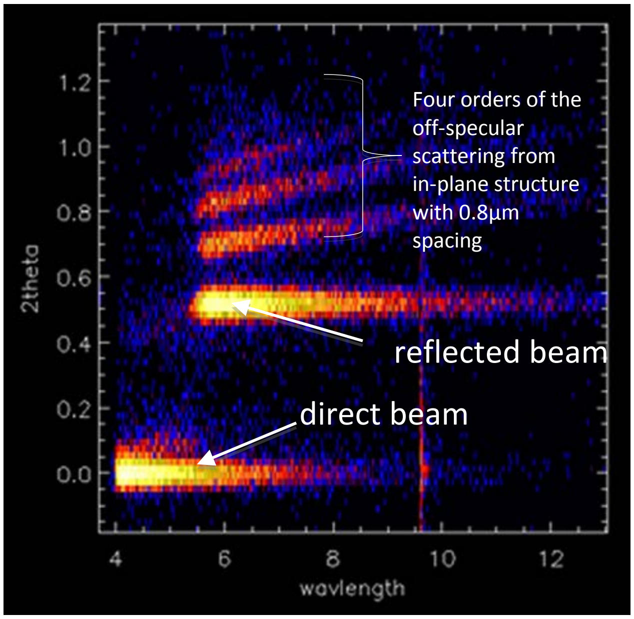


Figure 3. Off-specular neutron scattering measured on Asterix demonstrates the possibilities to address the in-plane structures with ~µm spacings. In this case, the scattering originated from linear grooves with 0.8-µm spacing.

experimental facility for the study of matter-radiation interactions in extremes.

In surface sensitive scattering methods, a neutron beam strikes a flat sample at a small angle of incidence (or a particular value of the momentum transfer vector, Q) and can undergo reflection, transmission, or refraction at various interfaces within the sample. Consequently, the intensity of the outgoing, scattered neutron beam differs from that of the incident beam. This difference—measured as a function of Q—encodes information about the physical structure and composition of the surface or interfaces.

Mechanical and data reduction modification and upgrades are complete and Asterix has been commissioned fully functional (Figures 2 and 3). Future plans call for installation of small angle scattering (SANS) and grazing incidence small angle scattering (GISANS) capabilities.

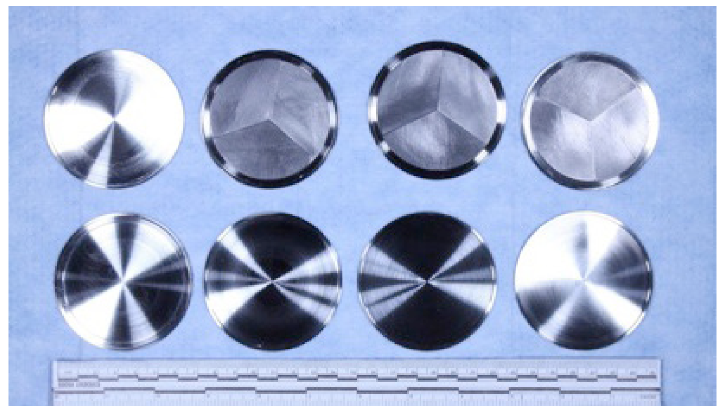
With that completed, Asterix will be one of the most versatile neutron surface scattering spectrometers in the complex, allowing a wide range of scattering—from material surfaces and bulk materials—to be performed.

The capability supports the Laboratory's Stockpile Stewardship mission and will support FY16 scope funded by the Science Campaigns, Program Manager Steve Sterbenz. Additional support was provided by Don Brown, Ellen Cerreta, Rick Martineau, Joseph Martz, Steve Sterbenz, Ross Muenchausen, and Gus Sinnis.

Technical contacts: Erik Watkins and Jarek Majewski

Laboratory metallurgists make thorium targets for production of cancer-fighting isotopes

Together, Los Alamos, Brookhaven, and Oak Ridge national laboratories are developing a large-scale accelerator production capability for actinium-225 (Ac-225), a rare radioactive isotope that attacks cancer cells without damaging nearby healthy cells. Encapsulated thorium target assemblies are being used to produce Ac-225 via irradiation using high-energy proton beams at accelerator facilities located at Brookhaven and Los Alamos labs. Irradiated targets are shipped to Oak Ridge for chemical processing, with distribution of isolated Ac-225 for initial evaluation studies conducted by independent researchers and clinicians worldwide.



From left, weld test specimen and three thorium target assemblies made at the Sigma Facility at Los Alamos National Laboratory to be irradiated at Brookhaven National Laboratory.

This tri-lab effort is driven by the pressing need to provide enough Ac-225 to support clinical trials of medicines based on this isotope. The current supply of Ac-225 available to the research and commercial market is inadequate. The tri-lab team, through the auspices of DOE's National Isotope Program, is developing chemical processing techniques and production-scale targetry to prepare for Ac-225 manufacturing.

None of this would be possible without the capability to manufacture encapsulated thorium capsules for irradiation. The Sigma Complex at Los Alamos is the only place in the United States with the equipment, expertise, and access for melting, forming, and machining thorium, which is radioactive. The Isotope Program has collected a ready supply of thorium at Los Alamos for the effort.

Over the past two years, members of the Metallurgy group (MST-6) have produced 11 thorium targets for the Los Alamos Isotope Production Facility, where researchers test the capsules to ensure their viability during irradiation and measure the Ac-225 yield to address the increasing worldwide clinical demand. The Los Alamos Neutron

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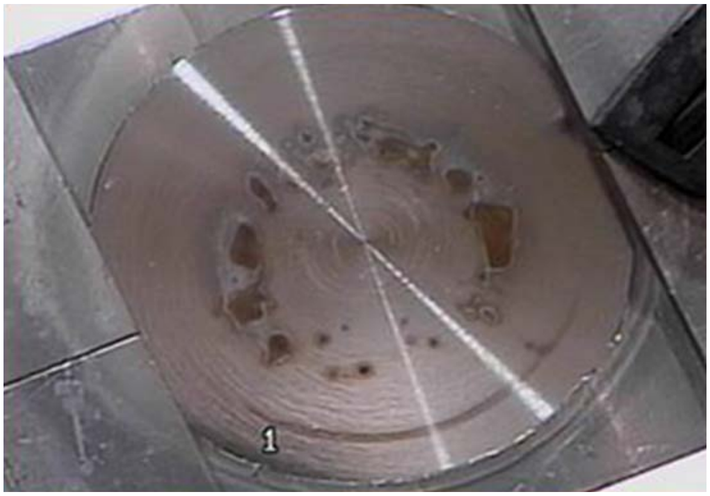
Laboratory metallurgists cont.



A thorium target prepared by the Sigma team after irradiation at the Los Alamos Isotope Production Facility. Scorching pattern is a result of circularly rastered proton beam interactions with the target surface.

Science Center is one of the nation's most powerful proton linear accelerators, providing protons at 100 MeV to the Isotope Production Facility for the purpose of large-scale generation of radionuclides needed by the larger isotope community.

In a recent achievement showing Sigma's growing role in the tri-lab effort, MST-6 machinists, welders, and metallographers manufactured three extremely thin thorium irradiation targets for Brookhaven National Laboratory. The fabrication of these targets required exceptional skill and precision in order to meet Brookhaven's specifications. Brookhaven's specifications for 0.015-inch-thick thorium targets in a capsule with a 0.020-inch-thick window presented new challenges. Jeff Scott rolled existing thorium plate to the 0.015-inch-thick dimension, and machinist Jeff Robison machined the thorium target pieces. Rick Hudson machined the thin Inconel capsule halves, which Matt Dvornak electron beam welded together with the thorium inside. The welding test specimen contained a 0.015-inch-thick stainless steel disk to mimic the thorium target. After welding, a hole was bored into the test specimen's center for helium leak testing. The test confirmed that the target did not leak. These targets will be irradiated at the Brookhaven Linac Isotope Producer in support of ongoing Ac-225 product evaluation studies.

As Los Alamos established a versatile thorium target manufacturing capability, the following MST-6 staff have been instrumental over the past two years: Richard W. Hudson, Andrew N. Duffield (now with MET-2, Pit Integrated Technologies), Matthew J. Dvornak, Jesse N. Martinez, Matthew T. Strandy, Joel D. Montalvo, Bo S. Folks, Jeffrey C. Robison, Tim V. Beard, Victor D. Vargas, Maria I. Pena, Hunter Swenson, Daniel A. Aragon (now with Prototype Fabrication-Weapon Fabrication Services), Jeffrey E. Scott, Kester D. Clarke, Robert T. Forsyth, Daniel A. Javernick, James C. Foley, and Jason C. Cooley. This work was supported by the United States Department of Energy, Office of Science via funding from the Isotope Development and Production for Research and Applications subprogram in the Office of Nuclear Physics. This new capability at Sigma supports the Lab's national security mission and Materials for the Future science pillar.

Technical contact: Jason C. Cooley

Enhanced imaging for dynamic physics research

Prototype 10-frame camera operated in proton radiography dynamic experiment

Members of Neutron Science and Technology (P-23) and Subatomic Physics (P-25) have successfully installed and operated a new and improved high-speed imaging system at Los Alamos's Proton Radiography (pRad) facility at the Los Alamos Neutron Science Center (LANSCE).

A product of collaboration between Los Alamos, Teledyne Imaging Sensors, Fishcamp Engineering, and Sandia National Laboratories, this new system's large-format, 10-frame hybridized focal plane array design offers much improved spatial and charge resolution, higher quantum efficiency, lower noise, and faster repetition rate over the current state of the art, with integration times below 50 ns. These advances significantly enhance pRad's capabilities for users in the materials and shock physics communities.

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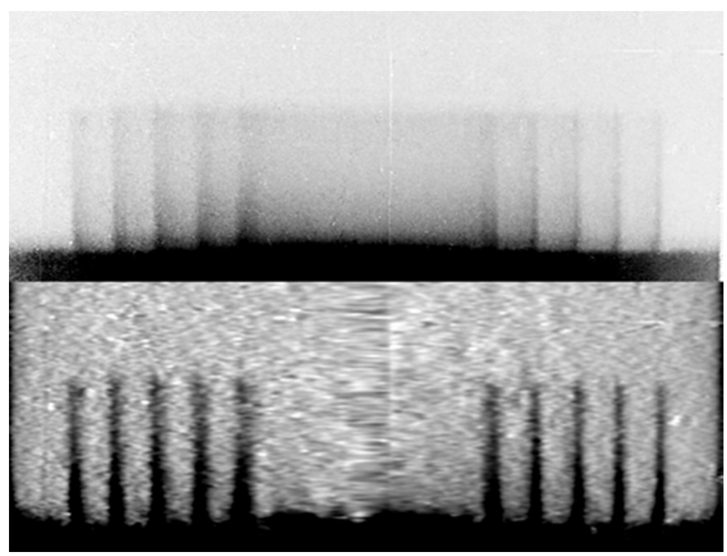


Researchers performed two identical experiments (PI Billy Buttler, P-23) at about 7 atm (atmospheric pressure) of helium. Two shots—one from 0–5.5 us with an interframe time of 275 ns (21 images and a static) and one from 5.8–13.8 μs (21 images)—will be combined. The 10-frame camera, which was fielded on the second (pRad0625), from 5.9–9.5 μs with an interframe time of 400 ns, is a link between the two, to verify repeatability. The image above, taken using the 10-frame camera, shows (top) areal density and (bottom) Abel-inverted.

Prototype 10-frame camera cont.

The new camera design, slated to replace an earlier 3-frame design, allows experimenters 40+ radiographs per event as opposed to the 21 provided in the current system, and with fewer cameras.

Materials experiments at MaRIE will demand unprecedented time-resolved imaging capabilities, and many of the technologies featured in this prototype, e.g., improvements in in-pixel memory and quantum efficiency, are promising additions to the suite of technologies researchers can employ in conceptual designs. MaRIE is the Laboratory's proposed Matter-Radiation Interactions in Extremes experimental facility for the study of time-dependent mesocale materials science.

A technique pioneered at Los Alamos, proton radiography is well suited to the study of dynamic processes in materials, featuring excellent contrast and the capability to radiograph dynamic events on short time scales (e.g., a few microseconds) multiple times during its evolution. With the LANSCE accelerator's capabilities, the number of radiographs is limited only by the camera technology.

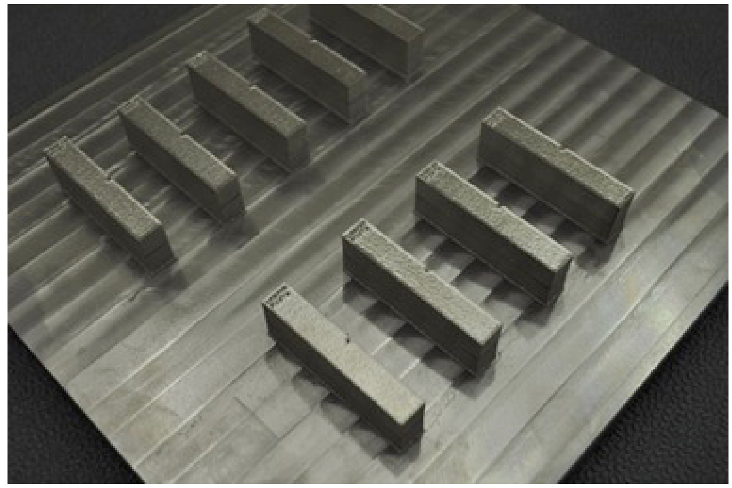
While the goal for the current experimental run cycle was to prove that the camera could operate in the harsh ionizing environment of the proton beam, an aggressive push by Physics Division personnel prepared the camera to take data in a dynamic experiment. In its first deployment, the camera was used to record the evolution of Richtmeyer-Meshkov instabilities at late times (see photo). Future efforts will focus on quantitative characterization of the camera's capabilities (i.e., measurements of transfer curves) and integration of the sensor into a production camera design. This work was supported by Los Alamos's Science Campaign 3 and is part of the Laboratory's national security science mission and Materials for the Future science pillar.

Technical contact: Johnny Goett

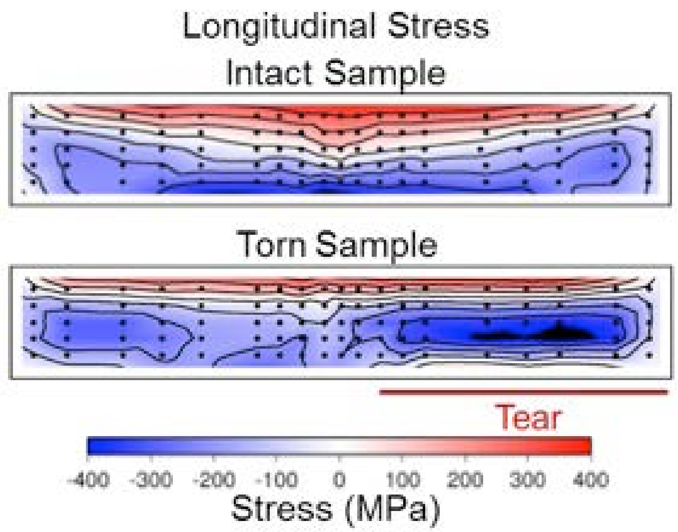
SMARTS reveals residual stresses in additively manufactured parts

At the Lujan Center, an experiment using SMARTS, the spectrometer for materials research at temperature and stress, revealed how build failure effects residual stresses in additively manufactured parts. Understanding how residual stress develops during additive manufacturing is critical to qualify parts for critical applications.

In the experiment, 14 stainless steel samples were additively manufactured on a steel base plate—one nearer the edge of the plate than is usually attempted. SMARTS was used to measure residual stresses in several (4) of the parts. In general, the residual stresses in all of the parts were within the measurement uncertainty of each other, despite differing processing parameters, with the



Stainless steel samples additively manufactured on a steel base plate. A sample near the edge tore away from the base plate during the build.



Data showing that stress in the intact sample provides a large bending moment, likely driving the tear. In turn, the tear alters the heat flow and constraint on the part from the base plate. The tear between the support mesh and the build plate results in an asymmetric stress field in the part that remains after removal from the plate.

exception of the one near the edge. The edge sample, in particular, was unique in that the mesh sub-structure on which that sample was built tore from the base plate during the build. This altered the heat flow out of the part as well as the mechanical constraint of the part during deposition, resulting in a significantly different residual stress field. The implication is that this part will distort differently then the parts that did not tear when removed from the base plate, and could be out of dimensional tolerance. Moreover, the different residual stress could affect the performance, i.e. time to failure, of the part. Understanding the sensitivity of the part to factors that may change (e.g. powder conditions or laser power) and how it may change in processing is critical to qualifying the manufacturing process. The Lujan Center at the Los Alamos Neutron Science Center provides

continued on next page

SMARTS reveals cont.

unique hardware and software capabilities for rapid bulk microstructural characterization to accelerate qualification of additively manufactured materials. These results are an example of decades of experience with large data-sets that provide foundation for data analysis of MaRIE experiments in material discovery. MaRIE is the Laboratory's proposed experimental facility for Matter-Radiation Interactions in Extremes.

Participants include Don Brown and Sven Vogel (Materials Science in Radiation and Dynamics Extremes, MST-8) and Adrian Losko (University of California, Berkeley and MST-8). Science Campaign 1 and Directed Stockpile Work funded the research, which supports the Laboratory's Stockpile Stewardship mission and Materials for the Future science pillar.

Technical contact: Don Brown

Successful run cycle cont.

Run cycle highlights

The 2015 LANSCE run cycle enabled the success of mission critical and collaborative experiments, including the following.

- With the completion of a digital data acquisition upgrade, enabled by LANSCE's 120-Hz accelerator operation, the Chi-Nu program to measure prompt fission neutron spectra (PFNS) can now handle the full data rate with no dead time. Highlights included the acquisition of low-energy uranium-235 PFNS data taken below 1 MeV outgoing, which reduced uncertainties; high-energy uranium-235 PFNS data above 1 MeV; and plutonium-239 data, enabled by a new PPAC with better fission/alpha discrimination from Lawrence Livermore National Laboratory.

- Investments in the linac through the Risk Mitigation Strategy benefitted the Proton Radiography Facility, which with an extended run cycle, completed conceptual, proof of principal, and collaborative experiments. The Proton Radiography facility fired 31 dynamic experiments, 29 in support of the Laboratory's weapons program. The facility had 43 users, 15 of which were external to the Laboratory, including from the Atomic Weapons Establishment, United Kingdom; Lawrence Livermore National Laboratory; and the Aberdeen Proving Ground of the Army Research Laboratory. The 2015 run cycle extension also allowed pRad to complete two important shots in the Cyclops series; perform an experiment design to test pRad capabilities for the Renner Fast Track (Sushi) conceptual experiment for plutonium; and complete a collaborative experiment with AWE.

- UCNtau is a new active in situ ultracold neutron detector installed and run during the recent run cycle. Based on ^{10}B/ZnS:Ag UCN detector technology developed at Los Alamos, the detector demonstrated the anticipated ~five-fold improvement in statistical efficiency.

- Using DANCE, the detector for advanced neutron capture experiments, Lujan Center researchers completed 11 proposed experiments with collaborators from Lawrence Livermore National Laboratory; North Carolina State University; CEA, the French Alternative Energies and Atomic Energy Commission; the University of Frankfurt; and the Lab's Chemistry Division. National security nuclear science research centered on: uranium-236/238 capture cross sections, uranium-235 capture isomers and fission, and capture on fission products. Much of the work was for Los Alamos's Laboratory Directed Research and Development program and a DOE Early Career Award to study "Neutron Reactions Relevant to Basic and Applied science." Preliminary studies on using flight path 13 (60 m) for total cross section measurements were conducted.

From Gus's desk cont.

program. This change has been noticed at the highest levels of our Laboratory's management and we have been widely recognized for our contributions. A clear demonstration of the high-level support we are receiving is the support for replacing the current 1L target in the Lujan Center. This is roughly a $10M item and we have been going after special NNSA funding for this, known as capability-based investments. The Lujan target was the top priority coming out of the Laboratory and has survived the first round of cuts at NNSA.

One of my goals as the LANSCE User Facility director is to better integrate the mesa and develop the notion of a shared fate. It is easy to look only at the work that we do each day and ignore the other work that goes on here at TA-53. The accelerator is the backbone that binds the mesa, providing proton beams that we all use to carry out our research. It is an expensive facility to operate and the justification for that funding is really the sum of all the work that occurs here at LANSCE. I look forward to working with everyone in the coming years and I am optimistic as I look to our future.

LANSCE User Facility Director Gus Sinnis

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