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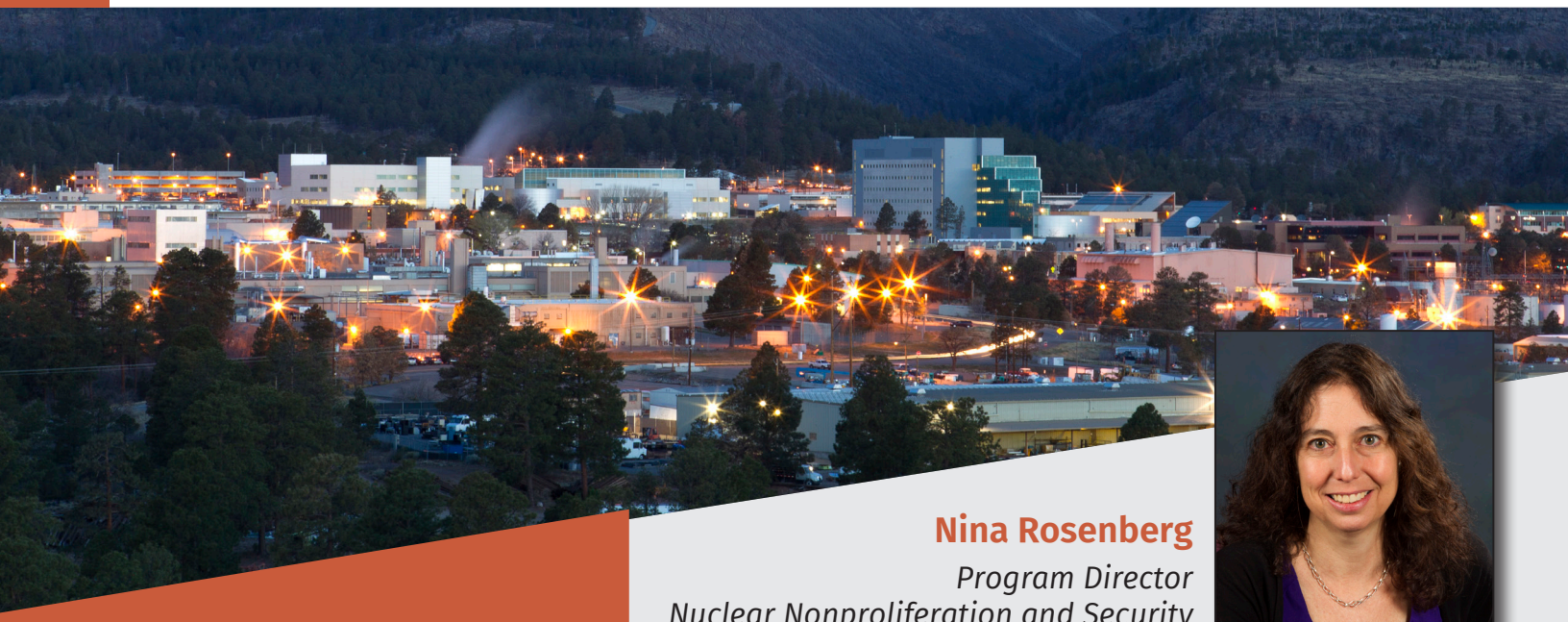
Nuclear Nonproliferation and Security Program Office

HIGHLIGHTS

2017

Los Alamos NATIONAL LABORATORY EST.1943



Nina Rosenberg

Program Director
Nuclear Nonproliferation and Security
Los Alamos National Laboratory

"Using our strengths as a nuclear weapons laboratory, the scientists and engineers at Los Alamos work hard every day to develop new tools and provide expertise to address national and global nuclear nonproliferation and security challenges. We are proud to share highlights of our 2017 accomplishments with you and look forward to continuing to work with our sponsors and partners on this vital mission."

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Bob Shirey

Deputy Program Director
Nuclear Nonproliferation and Security
Los Alamos National Laboratory

"Our work is central to Global Security at the Laboratory and plays an important role supporting Strategic Deterrence. I am proud to now be part of the GS-NNS team."

Overview

The **Nuclear Nonproliferation and Security** (NNS) Program Office within the Global Security Directorate at Los Alamos supports the Laboratory's mission of strategic deterrence through activities aimed at detecting and preventing nuclear proliferation and improving nuclear and radiological security. The program portfolio includes research and development, deployment activities, and policy support. In FY17, work for NNSA's Defense Nuclear Nonproliferation office (DNN, or "NA-20") made up 80% of the NNS portfolio; therefore, most of our work is aligned with DNN's mission.

We support DNN's Office of **Global Material Security** (GMS) by providing mission support to efforts aimed at increasing the security of vulnerable nuclear and radiological materials and improving the ability to detect the illicit trafficking of those materials.

- The Off-Site Source Recovery Program (OSRP) recovers and disposes of disused sealed radioactive sources in the interest of national security and public health and safety. Los Alamos has the lead for domestic transuranic and large beta and gamma sources that do not have a commercial disposal pathway.
- For GMS's Nuclear Smuggling Detection and Deterrence (NSDD) program, we provide technical support for the installation and maintenance of radiation detection systems at sites all over the world, as well as test and evaluate new detection technologies. In FY17 we safely completed more than 138 trips, traveling to 45 countries, in support of NSDD.
- We work with GMS to improve the security of nuclear material globally, including this past year providing key training support, sealed sources, and reference materials for the recently opened China Center of Excellence (COE) for Nuclear Security.

Los Alamos supports DNN's Office of **Research and Development** (R&D) through a broad range of activities.

- Our work includes the development of new technical capabilities to detect and characterize foreign nuclear material production and weapons development activities, often utilizing unique testbeds and facilities in Los Alamos and Nevada.
- Los Alamos is working with several other national laboratories to develop and validate physics models to advance our capability to monitor and analyze foreign non-nuclear explosives tests. We played a major role in a series of DNN R&D high explosive (HE) signature tests in Nevada in spring 2017.
- Los Alamos R&D activities support treaty verification and monitoring, nuclear forensics, and nuclear emergency response.
- A major activity at Los Alamos for R&D is our support for the nation's space-based nuclear detonation detection capability. The U.S. Nuclear Detonation Detection System (USNDS) comprises two satellite constellations: Global Positioning System (GPS) and geosynchronous. Los Alamos designs, develops, manufactures, delivers, and supports the operation of detection instrument payloads for both satellite constellations.
- We continued our strong support for DNN R&D's three university consortia through a variety of engagements. Most notably this past year, we hosted 20 students at Los Alamos for eight weeks for the inaugural Keepin Nonproliferation Science Summer Program.

We support DNN's Office of **Material Management and Minimization** (M3) in its mission to minimize and, where possible, eliminate nuclear materials.

- We continued our work on the molybdenum-99 (Mo-99) program to encourage the establishment of Mo-99 production without highly enriched uranium (HEU) in the United States. Los Alamos supports the program by developing technical solutions to improve the viability of commercial Mo-99 production.
- Los Alamos continued to support M3's work to convert civilian research and test reactors that use weapons-usable nuclear material to materials that are not of proliferation concern. Our expertise in nuclear fuels and material science supports the development of new fuels and technologies to support conversion efforts.

- Finally, the Advanced Recovery and Integrated Extraction System (ARIES) program at Los Alamos supports the disassembly of plutonium (Pu) components and their conversion to oxide for use in the production of mixed-oxide (MOX) fuel or for dilution and disposal.

Los Alamos supports DNN's Office of **Nonproliferation and Arms Control**, and related programs in the **State Department**, by providing leadership and technical expertise in support of U.S. efforts to strengthen international nuclear nonproliferation and arms control regimes.

- The Laboratory is a recognized world leader in the development of safeguards technologies, having invented or developed nearly every neutron nondestructive assay (NDA) instrument used by the International Atomic Energy Agency (IAEA), as well as training IAEA inspectors. This year we concluded our celebration of our 50th year of support for international safeguards with a two-day International Nuclear Safeguards Symposium.

- We engage with international partners across the world to build technical capabilities and enhance capacity through educational training programs and workshops.

- We work to limit the spread of sensitive materials, equipment, and technologies through DOE NNSA-led collaborations with international partners to build and maintain national export control systems, by supporting multilateral supplier regimes and U.S. licensing and interdiction groups and reviews.

- The Laboratory continues to provide leadership and technical expertise on efforts to advance verification and monitoring capabilities that may be used in future nuclear rollback scenarios and arms control treaties. Los Alamos provided the Deputy Inspection Team Leader for the LETTERPRESS nuclear verification exercise held in the United Kingdom this year. The exercise included experts from the U.K., U.S., Sweden, and Norway as part of the Quad Nuclear Verification Partnership.

National Aeronautics and Space Administration (NASA) programs make up the remainder of the NNS portfolio. The science and technology developed through NASA's programs position the Laboratory for cutting-edge research that is essential for developing core expertise and capabilities that support the Laboratory's national security mission. Los Alamos has been a major part of several recent NASA science missions with a strong hardware role, being the lead institution for an instrument on these missions. In addition, Los Alamos utilizes its unique Pu production expertise to produce Pu-238 heat sources to power NASA's deep space missions, including the Curiosity Mars Rover and the future Mars 2020 mission.

The following report covers highlights from our 2017 activities.

Global Material Security

OSRP BY THE NUMBERS

Since 1997

40,000
Radioactive sealed sources have been removed

containing more than
1.25 million
curies

from over
1,400
industrial, educational, healthcare, and governmental facilities worldwide

Off-Site Source Recovery Program

Los Alamos has the lead in OSRP for domestic transuranic and large beta and gamma sources that do not have a commercial disposal pathway. We have been working since 1997 to remove radioactive sealed sources from industrial, educational, healthcare, and government facilities worldwide. This past year, OSRP recovered over 2,200 disused sealed radioactive sources, including a total of 39 high-activity beta/gamma devices.

This year the Los Alamos OSRP team, Brazil's Nuclear Energy Commission, and Canada's Office of Global Affairs concluded a three-year collaborative effort to remove 81 medical devices containing disused sealed radioactive sources from Brazil's national storage repository in São Paulo, Brazil. Cobalt-60 sources totaling more than 29,000 curies were removed from the medical devices using a mobile hot cell, which provided the necessary shielding to safely handle and package the highly radioactive sources.

OSRP supports training on radioactive source search and secure techniques to other countries' regulatory authorities and first responders. This year Los Alamos supported a range of packaging, transportation, and search and secure training topics for authorities from Honduras, Kazakhstan, Egypt, Tunisia, Libya, Algeria, El Salvador, and Bosnia-Herzegovina.

Los Alamos staff supported the IAEA with expert missions to several countries to assist in collecting information to complete national inventories and develop national strategies for disused sources. Los Alamos also provided technical expertise in the areas of borehole disposal and reuse and recyle of disused

The first two Cobalt-60 source containers awaiting OSRP shipment from São Paolo, Brazil.

Nuclear Smuggling Detection and Deterrence

The NSDD program provides technical support for the installation and maintenance of radiation detection systems at sites all over the world and tests and evaluates new detection technologies. This past year, Los Alamos safely completed travel of more than 138 trips to 45 countries in the support of NSDD-related activities including site surveys, acceptance testing, assurance visits, training, exercises, meetings, and workshops.

The Los Alamos team was an integral part in accomplishing GMS/NSDD metric goals.

These goals included

- completion of installations (acceptance testing) of 26 sites,
- delivery of 14 mobile detection systems,
- transition of maintenance responsiblity for 82 sites to host countries,
- participation in a pilot program associated with the Strategic Airport Initiative, and
- the development of the Maritime Vectors Partnership.

Anthony Valdez testing the compact RSI Spectroscopic System before outreach engagement with NSDD partners.

Obie Gillispie (right) and a local maintenance provider (left) performing maintenance on Spectroscopic Portal Monitor during training.

The Los Alamos NSDD Forensics Team developed and participated in several training and workshop activities in 12 countries. Activities also included participation in several U.S. Interagency working groups, the R&D Joint Program review, and the Nuclear Materials Information Program (NMIP) Technical Nuclear Forensics Project review.

Members of the Los Alamos NSDD Science and Engineering Team completed an advanced secondary and in-motion application evaluation for two new radiation monitoring systems and multichannel analyzer replacement testing and evaluation. The team also participated in scientist-to-scientist meetings and outreach with China, South Korea, Spain, and the Border Monitoring Working Group supported under the IAEA.

INTERNATIONAL NUCLEAR SECURITY

Los Alamos experts continue to provide key support to the China Center of Excellence (COE) for Nuclear Security. Los Alamos supported several successful trips to the China COE to lead technical training and to receive radioactive sealed sources and uranium (U) certified reference materials. The successful receipt of this set of materials enables the China COE to effectively conduct all planned NDA training. The first roll-out of neutron NDA training was held in August 2017. Los Alamos staff also travelled to the China COE for development of additional training materials and curricula, such as gamma-ray training and isotope ratio measurements using thermal ionization mass spectrometry (TIMS).

Los Alamos hosted representatives from the Japan Atomic Energy Agency Integrated Support Center for Nonproliferation and Security (JAEA-ISCN) to familiarize ISCN staff with the U.S. National Laboratories' capabilities in nuclear security training, and to demonstrate methodologies to develop nuclear security expertise.

Los Alamos also supports the GMS's cyber security program. The Los Alamos cyber security experts took part in ongoing IAEA technical cyber security consultancies focused on e-learning and development of content for a series of online computer security training courses for IAEA Member States.

The Los Alamos cyber team also supported the development of the International Training Course in cybersecurity for nuclear security, to be held at Idaho National Laboratory (INL) in late 2018.

Los Alamos nuclear material accounting and control (NMAC) experts continue to support the IAEA on the development of training materials and hands-on exercises for the NMAC for Practitioners course. The pilot course is scheduled to be held at Los Alamos for IAEA member states in August 2018.

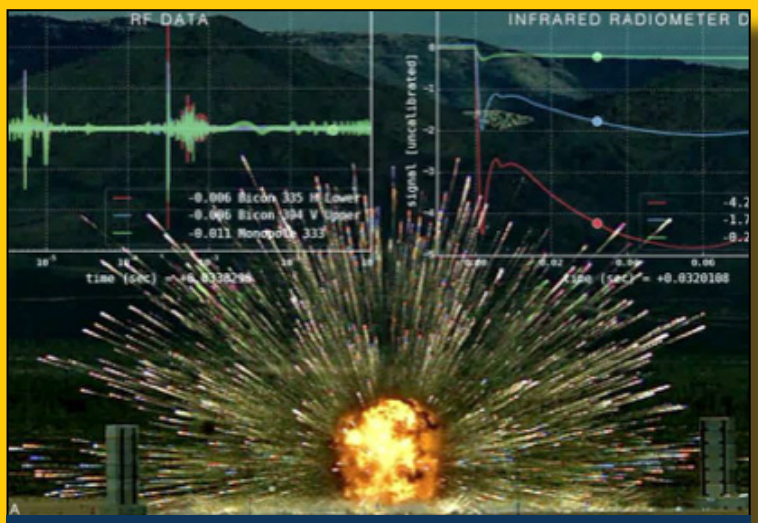
The U.S. team in front of an aerial photograph of the Qinshan Nuclear Power Plant during a China COE meeting.

Research and Development

Our work for R&D includes the development of new technical capabilities to detect and characterize foreign nuclear material production and weapons development activities, often utilizing unique testbeds and facilities in Los Alamos and Nevada and in partnership with other Laboratories. Our work also includes R&D for nuclear safeguards and emergency response. We develop and support sensor payloads for space-based nuclear detonation detection.

Los Alamos is working with several other national laboratories on DNN R&D research efforts that combine advanced physics design codes with newly developed models to advance our capability to monitor and analyze foreign non-nuclear explosives tests. The research team has jointly developed predictive, end-to-end modeling capabilities that can help differentiate weapons development from conventional HE tests. The researchers have developed a science-based simulation framework to model the characteristics and signatures of a non-nuclear test device, from the early detonation to late time combustion, to identify key observable impacts based on the device design. The modeling predictions are then tested against actual data collected from high explosive tests conducted at the Nevada National Security Site (NNSS).

High Explosive Testing



High explosive signature test conducted by Los Alamos and several other Labs at NNSS in spring 2017.

DNN R&D executed a series of HE signature tests at NNSS in spring 2017. This included nine high-fidelity detonations, each generating unique data sets that will expand signature of interest libraries and validate recently developed end-to-end simulations. Los Alamos was responsible for design and fabrication of six of the test articles, led HE operations, and fielded several diagnostic instruments.

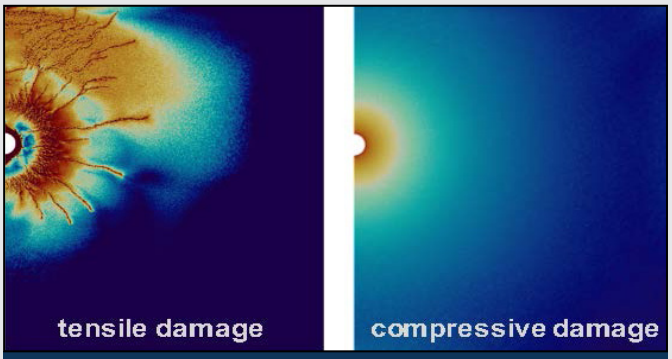
Developing an understanding of proliferation processes and their potential observable signatures is a key aspect of developing detection and characterization capabilities. Scientists and engineers at Los Alamos support numerous modeling and measurement efforts to interpret and quantify collected signals of interest. This year Los Alamos completed a scoping study investigating the types of signals that might be used for characterization of reactor operations. This work will feed into a multilaboratory, multiyear effort to develop data analytic tools to exploit Multi-Informatics for Nuclear Operation Scenarios (MINOS).

Los Alamos is working with several other DOE NNSA national laboratories to plan development of advanced data analytics capabilities for proliferation detection. The effort will measure the performance of new data analytics methods by applying them to data collections from NNSA proliferation demonstration test beds. It will capitalize on DOE NNSA subject matter expertise to develop predictive models that provide a context for optimal application of data analytics to proliferation detection, and it will focus data analytics R&D at the DOE NNSA national laboratories to optimize industry and academic advances for proliferation detection.

Detecting and characterizing underground nuclear explosions

Los Alamos is researching key challenges in detecting low-yield underground nuclear tests. Energy and material from an underground nuclear explosion is released in a variety of forms including mechanical waves (seismic and acoustic), electromagnetic waves, and radionuclides. Los Alamos researchers are exploiting the mathematical ties that multi-phenomenology sensor signatures have to an explosive source to guide the development of new error models used in assessments. Key to this approach is the validation of physical models of signatures through historical data and large-scale field experiments expressly designed to validate advanced physical models.

The final experiment in a series of six in Phase I of the Source Physics Experiment (SPE) was conducted at NNSS in October 2016. Los Alamos experts were key to the design, execution, and analysis of this large multi-institution campaign. SPE seeks



Los Alamos researchers are developing advanced models of tensile and compressive damage from an underground nuclear explosion to better predict prompt injection of radionuclides and long-term seepage. These graphics depict a damage metric representing the potential to permanently deform the material.

to improve the nation's capability to detect and characterize underground nuclear explosions to help develop an advanced capability for the U.S. to monitor low-yield nuclear testing. The six Phase I experiments were chemical explosions conducted in granite at different depths and explosive weights. Los Alamos experts are now participating in the preparation of a subsequent series of SPE tests. Phase II will focus on softer, less structured rock—alluvium—and will provide new information to improve understanding of issues relevant to nuclear explosions in these different geological conditions. The SPE team successfully conducted an integrated system test at NNSS in November 2017 in preparation for the new SPE tests in 2018.

While the SPE is focused on the first few seconds of an underground nuclear explosion, the multi-laboratory Underground Nuclear Explosion Signatures Experiment (UNESE) seeks to understand local, diverse, nonprompt signals, both physical and radiochemical. The UNESE campaign has been conducted primarily at NNSS at a testbed that is the site of a legacy underground nuclear explosion. Los Alamos scientists are contributing to a better understanding of the nonprompt physical signatures using measurements and analyses from a variety of remote sensing, surface, and subsurface techniques. These physical signatures methods also aid in identifying subtle geological features useful for identifying fractures and potential pathways for gas migration.

Los Alamos GBD III production teams with their completed eighth and final payload subsystems.

Treaty verification and monitoring

Los Alamos supports the multilaboratory Warhead Measurement Campaign (WMC), which aims to develop analytical models to record and simulate expected radiation signatures of U.S. stockpile weapons systems information that will be useful in any future discussions on arms control agreements. In FY17, we focused on the preparation for measurements of weapons at the Pantex Plant as well as archiving data from previous measurements of weapons and weapons components. Los Alamos has played a central role in addressing need-to-know issues associated with the sensitive nature of data related to WMC and has also assumed responsibility for providing measurement team input to the authorization process for nuclear explosives operations at Pantex.

Developing tools and capabilities for nuclear emergency response

Los Alamos supports the development and demonstration of advanced diagnostics for emergency response, as well as the underlying research on materials and HE behavior that allows for more accurate and timely information for emergency responders to nuclear incidents.

In support of the Materials venture, first-of-their-kind simultaneous X-ray diffraction and X-ray phase contrast imaging measurements were executed at the Advanced Photon Source at Argonne National Laboratory (ANL). Los Alamos National Laboratory, Lawrence Livermore National Laboratory (LLNL), and Sandia National Laboratories (SNL) have a working group to formulate image analysis tools for this type of data.

For the HE venture, Los Alamos executed three thermal validation experiments and observed some unanticipated results. The project also developed a compelling empirical description of energy release and detonation velocity behavior for explosives that appears to have broad applicability across classes of explosives.

Space-based Nuclear Detonation Detection

Los Alamos and Sandia continue to build Global Burst Detector (GBD) payloads for deployment on GPS Block III satellites. In FY17, Los Alamos and Sandia delivered the GBD III-6 and GBD III-7 payloads for host satellite integration. The eighth (and final) payload delivery in this block was made in November 2017. Block III payloads are scheduled to be deployed on GPS-III satellites starting in FY18. Meanwhile, Los Alamos matured designs for the GBD III-Prime payload, targeted for GPS-III satellites -11 and beyond. These efforts included significant interaction with the USAF Space and Missile Systems Center (SMC) to finalize technical specifications for the satellite-to-payload interfaces.

For the geosynchronous constellation, Los Alamos continued fabrication of the third Space and Atmospheric Burst Reporting System (SABRS-3) payload. The SABRS payload replaces the neutron, gamma-ray, and particle detectors fielded on Defense Support Program satellites in the 1970s through the 1990s. It augments the optical, radio frequency, X-ray, and particle sensors of the GBD payloads fielded on GPS satellites.

Los Alamos also continued fabrication and testing of the Space and Endo-Atmospheric NUDET Surveillance Experimentation and Risk Reduction (SENSER) payload. SENSER will be an experiment suite developed by Los Alamos and SNL to demonstrate and exercise new technical capabilities that could be folded into future USNDS systems. Based on several years of Laboratory R&D, SENSER is the first on-orbit experiment to incorporate all of the major detection modalities used for USNDS: X-ray, gamma, neutron, radio frequency, and optical. Results from the SENSER experiments will provide a direct comparison of new technologies to those currently employed.

Los Alamos continues to support the NNSA partnership with the U.S. Air Force Space Test Program (STP) to deploy SABRS-3, SENSER, and seven other Government payloads to geosynchronous orbit on STP Satellite-6 (STPSat-6).

Los Alamos continued to perform new research aimed at future advancements in Space-based Nuclear Detonation Detection (SNDD); in particular, work continues on the Distributed Infrastructure Offering Real-time Access to Modeling and Analysis (DIORAMA), a computer modeling and simulation system that captures knowledge about nuclear detonation source term modeling, propagation of weapons outputs and effects in the atmosphere and space, sensor performance, and scenarios that can use this information in analyses of sensor (and system) performance. An initial version of this code system was completed and released to the SNDD community, and is being formally validated by a semi-independent team at LLNL.

Los Alamos Combined X-ray and Dosimeter (CXD) and Burst Detector Dosimeter for Block II-R (BDD-IIR) instruments are fielded on GPS satellites. Each of these instruments measures a wide range of energetic electrons and protons. In January 2017 these data were publicly released under the terms of the Executive Order for Coordinating Efforts to Prepare the Nation for Space Weather Events. The specific goal of releasing space-weather data from national-security assets such as GPS satellites is to enable broad scientific community engagement in enhancing space-weather model validation and improvements in space-weather forecasting and situational awareness. In February 2017, a Los Alamos feature article providing an overview of the data was published in Space Weather, a journal of the American Geophysical Union.

Los Alamos staff prepare one of the SENSER payload subsystems for vibration testing.

Ground-based Nuclear Detonation Detection

Los Alamos completed and published a comprehensive technical report reviewing progress in the Ground-based Nuclear Detonation Detection (GNDD) program over the past decade: Trends in Nuclear Explosion Monitoring Research & Development — A Physics Perspective. This 2017 monograph reviews the accessible literature as it relates to nuclear explosion monitoring and the Comprehensive Nuclear-Test-Ban Treaty for four research areas: source physics (understanding signal generation), signal propagation (accounting for changes through physical media), sensors (recording the signals), and signal analysis (processing the signal). Over 40 trends are addressed, such as moving from 1D to 3D earth models, from pick-based seismic event processing to full waveform processing, and from separate treatment of mechanical waves in different media to combined analyses. Highlighted in the document for each trend are the value and benefit to the monitoring mission, key papers that advanced the science, and promising research and development for the future. Los Alamos produced the monograph in collaboration with Lawrence Livermore National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, and the U.S. Naval Research Laboratory.

Nuclear Forensics

Los Alamos supports NNSA's research and development in nuclear forensics in areas of predetonation materials forensics and in postdetonation signatures analysis. In FY17, several high-priority nuclear data measurement campaigns were also conducted, which resulted in reduced uncertainties of nuclear data used in sample triage, debris diagnostics, and device modeling and simulation codes. In particular, the capability to measure neutron reaction rates on an absolute fission basis has now been restored (after a nearly 20-year hiatus) at the National Criticality Experiments Research Center (NCERC) facility at NNSS. Over the past year, more than 50 historical nuclear test explosion debris (fallout) samples were prepared and analyzed for trace actinide isotopic composition using spectrometry capabilities and facilities at Los Alamos. These samples will be used to inform future modeling and simulation efforts that will improve national nuclear forensics capabilities.

Los Alamos publication reviewing progress on Nuclear Explosion Monitoring over the past decade.

As part of the 2017 Keepin Nonproliferation Science Summer Program students participated in a wide range of tours and hands-on activities.

University Consortia

Los Alamos is a member of three university consortia that support the nation's nuclear nonproliferation and security mission. Each of these consortia is made up of multiple universities and national laboratories and each has its own focus: the Nuclear Science and Security Consortium (NSSC), the Consortium for Nonproliferation Enabling Capabilities (CNEC), and the Consortium for Verification Technology (CVT). Individual consortia are funded at $25M over five years by DNN R&D. These funds go to support the university members of the consortia, including students and post-docs.

During summer 2017, we conducted the inaugural Keepin Nonproliferation Science Summer Program. This program gave 20 summer student interns, from all three university consortia and representing 14 different universities, the opportunity to spend eight weeks at Los Alamos performing research with a Los Alamos scientist and participating in lectures and tours to provide broad exposure to the nonproliferation mission space. The program was a tremendous success in strengthening the national security workforce pipeline and was determined to be both "positive" and an "emerging best practice" by the NSSC External Advisory Board at its September 2017 meeting.

James Miller supported the NSSC Nuclear Analytical Techniques summer school in August 2017 at the University of California, Davis. Miller delivered a talk to 17 students (approximately half were NSSC) on gamma ray spectroscopy as related to the Radiological Triage program and toured laboratory spaces and analysis experiments being conducted as part of the summer school.

Rian Bahran visited the University of Nevada at Las Vegas (UNLV) main campus and was hosted by the university radiochemistry program faculty. Rian gave a special departmental seminar, toured the radiochemistry experimental laboratories, and had meetings with NSSC-affiliated faculty, staff, postdocs and graduate students in an effort to strengthen existing relationships and create new partnerships between both institutions.

Material Management and Minimization

National Criticality Experiments Research Center (NCERC) assists Japan

In FY17, the laboratory continued to conduct experiments in collaboration with JAEA, constructing a Pu critical system with fuel recently received from INL's Zero Power Physics Reactor (ZPPR) facilty. The ZPPR plates are of similar design to those previously used at the fast critical assembly (FCA) in Japan. These efforts followed experiments on HEU and low-enriched uranium (LEU) systems performed in FY16. The project began in support of the repatriation of HEU and Pu fuel that was originally loaned to Japan for their FCA. Japan planned to use the FCA to generate data in support of the development of an accelerator-driven waste transmutation facility. As part of the agreement to repatriate the fuel, Los Alamos agreed to perform similar experiments needed by Japan to develop the data. While Japanese scientists observed, Laboratory experts conducted experiments at NCERC and the data was delivered to these scientists. The fuel was repatriated through Savannah River National Laboratory (Pu) and Y-12 National Security Complex (HEU) in prior years.

Mo-99 production without HEU

Laboratory researchers partnered with two companies to develop technologies and methods for the reliable production of the medical isotope Mo-99 without using HEU.

NorthStar Medical Radioisotopes uses enriched Mo targets in an accelerator to produce Mo-99. In FY17, Los Alamos supported this effort by operating a production-scale prototype helium (He) flow loop for a series of 1000 hour tests that represent the time scale of production facility operational runs. Los Alamos researchers validated their heat transfer models with lab-based experiments. Also in FY17, a larger target holder that improves production rate for the end user was tested.

SHINE Medical Technologies is working to develop an accelerator driven, low-enriched uranium LEU solution-based method to produce Mo-99 as a fission product. Los Alamos has developed a computational fluid dynamics model of an experiment performed at ANL where an electron beam was targeted at a uranyl sulfate solution, generating heat and radiolytic gas bubbles.

Los Alamos released a code called SimApp as open source software. SimApp enables time-dependent simulations of aqueous fissile solutions. Los Alamos worked with SHINE engineers to incorporate the code into the SHINE Quality Assurance program for use supporting their NRC license application process.

New fuel reactor conversions

Los Alamos continued to support development of new fuel for reactor conversions this past year. We supported the major irradiation test for the national reactor conversion program, MP-1, where test samples will be inserted into the Advanced Test Reactor (ATR) at INL to show that the new fuel is a suitable LEU replacement for the existing HEU fuels used by the domestic High Power Research Reactors. Forty-eight qualification foils were coated using plasma spraying to deposit the zirconium passivation layer on the fuel. Plasma spraying reduces the nonrecyclable waste. The Los Alamos National Laboratory Process Qualification Report for MP-1 Plasma Spraying was accepted and approved in April 2017. This is a major milestone required prior to spraying fuels for the MP-1 test in the ATR. Los Alamos purchased a Medicoat plasma spray station to support the next phase of the project that includes coating much longer test foils.

Throughout 2017, Los Alamos researchers performed simulations to understand the flow and mixing of material during the Y-12 MP-1 casting process. The goal is to increase the material uniformity of the casting (e.g., U-235 and Mo distribution). In 2016, Laboratory scientists developed a laser ablation method to map the U-235 distribution on the surface of a Y-12 MP-1 LEU-Mo casting. The method was further refined in 2017 and standards were used to provide an absolute calibration of the results. These maps provide a better understanding of mixing during casting and validate the downblending model developed by Los Alamos staff.

New ARIES pit cutter glovebox undergoing leak testing.

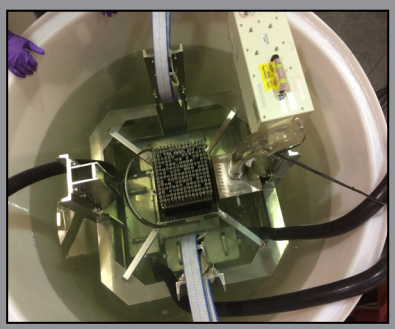
ARIES

The ARIES program at Los Alamos supports the disassembly of Pu components and their conversion to oxide for use in the production of MOX fuel or for dilution and disposal. The base mission for the ARIES program in FY17 continued to be to produce Pu oxide from surplus Pu that meets the specifications for production of MOX fuel (2 metric tons). The program also conducted detailed studies to develop a lifecycle cost estimate for a Dilute and Dispose option and submitted a draft version to NNSA in August 2017. Either continuing with the MOX disposition option or implementing a change to a Dilute and Dispose option is likely to increase the program's producation mission significantly.

ARIES completed restart of all oxide processing operations in February 2017 after a facility-wide operational pause at the PF-4 Plutonium Facility required all ARIES operations to complete a formal readiness process. The program then successfully produced 100 kg of oxide through disassembly, conversion, processing, and characterization operations. The program also successfully completed weld fit-up for the new pit cutter glovebox, completed a major revision of its throughput model, and completed a Management Self-Assessment for the Direct Metal Oxidation (DMO)-3 furnace, which has never been used in production.

Nonproliferation and Arms Control

NUCLEAR SAFEGUARDS
LOS ALAMOS NATIONAL LABORATORY



Nuclear Safeguards

Los Alamos is a recognized world leader in nuclear safeguards. The 61st and 62nd Nondestructive Assay IAEA Inspector Training Courses were held at Los Alamos in 2017.

This past year, as part of the Spent Fuel NDA project, Los Alamos staff continued work on a Differential Die-away (DDA) instrument, an active neutron-based technique that measures prompt neutrons emitted by induced fission which then travel through a spent fuel assembly to He-3 detectors on the other side; and a Differential Die-away Self Interrogation (DDSI) instrument that allows coincidence counting from spontaneous and (α, n) neutrons in detectors surrounding an assembly both with and without a cadmium liner. The purpose of these measurements is to estimate fissile mass and/or verify initial enrichment/burnup from a spent fuel assembly. Fresh fuel measurements were performed with the DDA instrument at Los Alamos and the results were presented by Garrett McMath at the 2017 Institute of Nuclear Materials Management (INMM) conference. Alexis Trahan and Garrett McMath traveled to Sweden in October 2017 to prepare and place the DDSI instrument in the pool at the Clab interim storage facility for upcoming measurements.

DDSI instrument at the Clab interim storage facility in Sweden (top). DDA instrument fresh fuel measurement at Los Alamos (bottom).

Engagement with international partners

Los Alamos continued engagement with international partners across the world to build technical capabilities and enhance capacity. For example, during November 2016, Los Alamos hosted the U.S. Labs Study Tour on Safeguards for South East Asia partner countries of Cambodia, Malaysia, Myanmar, Thailand, and Vietnam. The purpose of the visit was to empower these partners with knowledge and tools that could help advocate for Additional Protocol (AP) ratification in their respective countries, share U.S. AP ratification and implementation experiences, introduce key elements of State infrastructure required for effective implementation of the AP, and tour U.S. facilities and share lessons learned in safeguards applications.

Nuclear controls for dual-use technology

As part of our support of international outreach objectives, Los Alamos staff apply comprehensive, expert knowledge of nuclear and WMD-related export controls to help build the capacity of foreign partners to regulate strategic trade and to deter, detect, and interdict illicit transfers. Los Alamos has been organizing or supporting up to a dozen bilateral, regional, or multilateral export control engagements per year since 2005 for countries at all stages of nonproliferation development, often in cooperation with regulatory or enforcement organizations such as the U.S. Department of Commerce, U.S. Homeland Security Investigations, and the World Customs Organization.

In March 2017, Los Alamos hosted the Counter Proliferation Investigations Training (CPIT). This course provided an overview of the equipment, facilities, and technologies used in nuclear weapon design and fabrication and addressed the extent to which weapons-related strategic commodities are currently sought by proliferators. The nineteen participants included export enforcement agents, analysts, prosecutors, and others working counter proliferation investigations focused on nuclear-related strategic commodities.

Advanced verification and monitoring capabilities

We continue to provide leadership and expertise on efforts to advance verification and monitoring capabilities that may be used in rollback scenarios and arms control treaties.

Nuclear physicist Morag Smith from Los Alamos served as the Deputy Inspection Team Leader during the 2017 LETTERPRESS exercise held at the former U.K. weapons base, Royal Air Force Honington, in Suffolk. The exercise included experts from the U.K., U.S., Sweden, and Norway as part of the Quad Nuclear Verification Partnership and examined the technical details for implementing a nuclear arms control regime that included weapon dismantlement. The event included training and the exercise with teams assuming roles as hosts and inspectors.

Participants of the LETTERPRESS nuclear verification exercise in the United Kingdom.

State Department

The NNS portfolio supports U.S. State Department activities closely aligned with our DNN Office of Nonproliferation and Arms Control programs. This includes work funded by the Program of Technical Support to Agency Safeguards (POTAS), Export Control and Related Border Security Program (EXBS), and the State's Verification fund and often consists of training workshops in partner countries.

For example, under POTAS in October 2017, Martyn Swinhoe attended the Technical Meeting on Statistical Methodologies for Safeguards organized in Vienna by the IAEA. The purpose of the meeting was to review developments in statistical methodologies that could improve the interpretation of inspection data, start the process for the review of International Target Values, and discuss tools for the evaluation of safeguards effectiveness under the State Level Concept.

A "selfie" of the NASA Curiosity Rover in Gale Crater, Mars, at a location where a Los Alamos-led team using ChemCam discovered boron in light-toned calcium sulfate veins.

NASA Programs

Our current involvement in NASA mission areas includes the ChemCam spectral instrument on the Curiosity Mars Rover (part of the Mars Science Laboratory), the HOPE plasma composition instrument on the twin Radiation Belt Storm Probe Spacecraft in Earth's magnetosphere, and the energetic particle instrument team for the Magnetospheric Multiscale Mission. We are also still providing ongoing support to our plasma instrument on the Advanced Composition Explorer, our Energetic neutral Atom Imager on the Interstellar Boundary Explorer, and the on-board processing on the SWIFT gamma-ray burst mission. Los Alamos is providing active instrument development for the Mars 2020 mission as the lead institution for the SuperCam instrument as well as a support role on the SHERLOC instrument through development of the spectrometer electronics. The Laboratory has been awarded a NASA technology development grant to mature a new spectral instrument for a future Venus lander mission.

Los Alamos is actively involved in the planning of new NASA missions, both as the lead institution and in partnership with our academic colleagues. These include high-profile missions that are highly ranked in the NASA Decadal planning: a heliospheric boundary mapper mission and a new concept for active experiments in the Earth's magnetosphere using a Los Alamos-developed electron gun in space. Los Alamos is also working with the Southwest Research Institute to provide a plasma instrument for their planned NASA MIDEX concept, and we are collaborating with the Jet Propulsion Lab on a planned instrument concept that will be used to collect spectra on comets, planetary atmospheres, and interstellar medium.

The Laboratory continues to provide a unique U.S. capability to NASA in its Space and Defense Power System program, which is focused on the production of Pu-238 fuel sources. In FY17, Los Alamos produced thirteen General Purpose Heat Source fueled clads. As the production agency, Los Alamos works with INL supporting NASA's Radioisotope Power Systems. Continued collaborations with Oak Ridge National Laboratory on oxide fuel fabrication will develop a new source to replace our primarily Russian-purchased material.

Los Alamos leads the NASA-funded "Kilopower" R&D effort for small space-based nuclear reactor design. Recent work has demonstrated promise for a path to a possible flight implementation in the near future. This year Los Alamos, along with NASA and DOE partners, completed plans for a kilowatt-level test at the NNSS. Those tests began in November 2017 and will continue through March 2018.

Major Events

50 Years of Nuclear Safeguards at Los Alamos

We ended our celebration of 50 years of Los Alamos support to International Safeguards in July 2017 with a very successful two-day International Nuclear Safeguards Symposium. The Symposium included a Keynote Address delivered by IAEA Deputy Director General and Head of the Department of Safeguards, Tero Varjoranta, and included a series of panel discussions with a number of distinguished invited guests. Former Laboratory Director Sig Hecker concluded the Symposium with a lunchtime Keynote presentation.

Nancy Jo Nicholas, then Associate Director for Threat Identification and Response, and Terry Wallace, then Principal Associate Director for Global Security, at a special 50th reception at the Bradbury Science Museum.

IAEA Deputy Director General and Head of the Department of Safeguards, Tero Varjoranta, delivering the Keynote Address at the 50th Anniversary of Nuclear Safeguards at Los Alamos Symposium.

Nuclear Proliferation Data Analytics Workshop

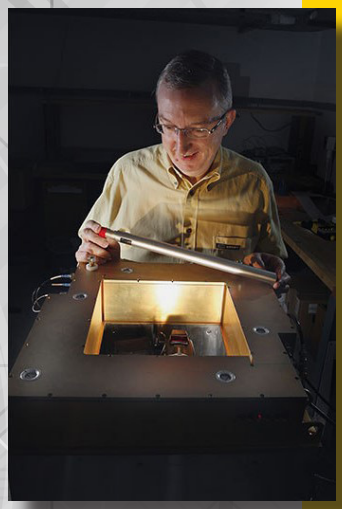
Los Alamos hosted a successful Nuclear Proliferation Data Analytics Workshop in September 2017. Senior leaders from across the interagency (DNN R&D, Intelligence Community, Department of Defense) plus several National Laboratories attended. The workshop covered the state-of-the-practice, state-of-the-art, and state-of-the-future of data analytics for addressing complex nuclear proliferation detection challenges.

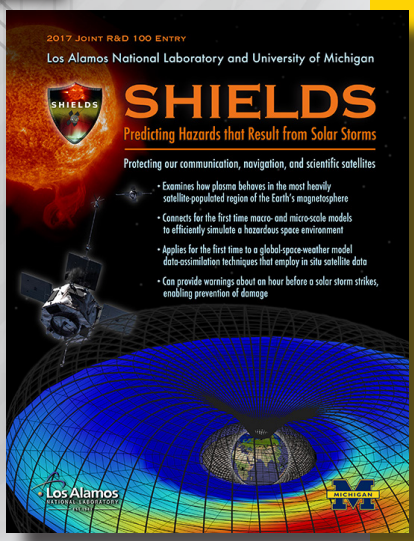
Nuclear Explosion Monitoring: 60 Years of Science and Innovation

Los Alamos staff supported an event "Nuclear Explosion Monitoring: 60 Years of Science and Innovation," on Capitol Hill in November 2016. The event featured hands-on demonstrations of monitoring and verification technology from the national labs and the international monitoring community. Speakers included Secretary of Energy Ernest Moniz, Senators Tom Udall and Ed Markey, and Dr. Lassina Zerbo, Executive Secretary of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization.

DOE Secretary Moniz and Los Alamos Director McMillan visit Aviva Sussman's display at a Capitol Hill event recognizing 60 years of Nuclear Explosion Monitoring.

Awards and Staff Recognition





Two Los Alamos employees were recognized in 2017 by the Institute of Nuclear Materials Management. **Nancy Jo Nicholas**, then the Laboratory's Associate Director for Threat Identification and Response, was recognized with the Edway R. Johnson Meritorious Service award for long-term outstanding service to the Institute, as well as for noteworthy contributions to the nuclear materials management profession. **Martyn Swinhoe**, a physicist in the Safeguards Science and Technology group, received the Vincent J. DeVito Distinguished Service award for development, implementation and assurance of technical success for nuclear measurement systems in civilian nuclear fuel cycle facilities worldwide.

Tess Light, Intelligence and Space Research Division, was awarded the Laboratory's prestigious Fellows Prize for Outstanding Leadership. Light is the Lab's chief scientist for our SNDD program, leading strategic and tactical planning. She also serves as the SNDD Electromagnetic Pulse (EMP) phenomenology chief scientist and is recognized as a national authority for EMP nuclear detonation signatures.

The **Space Hazards Induced near Earth by Large, Dynamic Storms (SHIELDS) Space Weather Platform** was named a 2017 R&D 100 Winner. SHIELDS protects communication, navigation, and scientific satellites orbiting the Earth's magnetosphere by predicting hazards resulting from solar storms that cause space weather. Researchers developed the software platform to understand, model, and predict this weather about an hour before it hits satellites, enabling instruments to be placed in a safe mode. This work builds upon space environment expertise from our SNDD and NASA programs and was conducted in collaboration with the University of Michigan.

United States
Department of Energy

The Secretary's Appreciation Award

Source Physics Experiment (SPE) Phase I Team

The Los Alamos SPE Team received the **DOE Secretary's Appreciation Award** as well as a **Los Alamos Large Team Distinguished Performance Award** for their significant achievements on the first phase of the Source Physics Experiment *(described in detail on page 9)*.

Laura Smilowitz, Chemistry Division, was named a Fellow of both the American Physical Society and the American Association for the Advancement of Science. Smilowitz was recognized for her work toward advancing our understanding of thermal explosions. Both NNSA Defense Programs and DNN benefit from her contributions in this field.

Los Alamos Distinguished Performance Individual Award: Johnna Marlow, Nuclear Engineering and Nonproliferation Division, led Los Alamos' project to develop the NDA measurement portion of the China Center of Excellence for Nuclear Security.

Los Alamos Distinguished Performance Small Team Award: The **Fuel Cask Tomography Team** was recognized for the first NDA of a fuel cask for nuclear safeguards. The team uses a process called muon tomography to "see" inside an unopened cask.

Nuclear Nonproliferation and Security Program Office

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Nuclear Nonproliferation and Security Program Office

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