









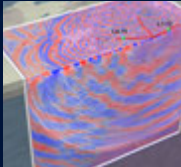

DNN Sentinel

➤ DEFENSE BY OTHER MEANS

VoL. VI, No. 1

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Michael Hamel, Nuclear Engineering and Radiological Science Ph.D. student, uses a headset with a radiation imaging array to demonstrate the use of augmented reality to find nuclear materials hidden in a room.
Image credit: Joseph Xu, Michigan Engineering

DNN SENTINEL: DEFENSE BY OTHER MEANS

VOL. VI, NO. 1

<https://www.energy.gov/nnsa/missions/nonproliferation>

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NNSA/DNN QUICK LINKS

Follow the links below to learn more about recent NNSA and DNN activities.

Press Releases

Four new consortia across 12 schools will introduce students to nuclear security missions

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) has expanded its Minority Serving Institution Partnership Program (MSIPP) to include four new consortia across 12 schools.

<https://www.energy.gov/nnsa/articles/nnsa-expands-stem-program-minority-serving-institutions>

NNSA donates container to International Atomic Energy Agency for shipping radioactive sources

Lisa E. Gordon-Hagerty, the Administrator of the Department of Energy's National Nuclear Security Administration (DOE/NNSA) presented the International Atomic Energy Agency (IAEA) with a container for transporting highly radioactive materials Sept. 17 during the Annual Regular Session of the IAEA General Conference in Vienna.

<https://www.energy.gov/nnsa/articles/nnsa-donates-container-iaea-shipping-radioactive-sources>

Articles

DOE's representative in Japan discusses his successes in energy and nuclear security

The enduring missions of NNSA and the Department of Energy (DOE) stretch many years into the future and many miles in every direction. There is a network of highly capable foreign affairs specialists stationed abroad in partner countries – including one of our closest allies – Japan.

<https://www.energy.gov/nnsa/articles/doe-s-representative-japan-discusses-his-successes-energy-and-nuclear-security-there>

NNSA and the Netherlands help Kazakhstan improve radioactive source management

NNSA partnered with the Netherlands to complete two major radioactive source management projects in Kazakhstan during July, moving radiological security ahead in the Central Asian country.

<https://www.energy.gov/nnsa/articles/nnsa-and-netherlands-help-kazakhstan-improve-radioactive-source-management>

NNSA reaches settlement agreement with MOX Services

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) has reached a comprehensive settlement agreement with MOX Services and its parent companies to resolve all contract closeout matters pertaining to the Mixed Oxide Fuel Fabrication Facility (MOX) Project at the Savannah River Site in Aiken, South Carolina.

<https://www.energy.gov/nnsa/articles/nnsa-reaches-settlement-agreement-mox-services>

NNSA Joins Partner Countries for First-Ever International Symposium on Securely Transporting Nuclear, Radioactive Materials

NNSA Press Release

Representatives from NNSA joined more than 30 partner countries in Tokyo for the first International Transportation Security Symposium for nuclear and radioactive materials last November. It was hosted by the Ministry of Foreign Affairs of Japan with support from the Japan Atomic Energy Agency's Integrated Support Center for Nuclear Nonproliferation and Nuclear Security.

Leaders from governments, industry, academia, and civil society gathered to discuss the complex and unique risks surrounding the transportation of nuclear and radioactive materials. Moving these materials poses a special security challenge because of their vulnerability during shipment.

"NNSA joins with the IAEA and its members around the world in a commitment to improving the security of nuclear and other radioactive materials in transit," said Art Atkins, Assistant Deputy Administrator for DNN's Office of Global Material Security, who provided opening remarks at the symposium. "Thwarting terrorism is one of our primary missions, and a key way we do so is by achieving mutual understanding on guidelines at meetings with partners."

In 2016, the United States reinforced its commitment to transportation security when it joined 14 other countries in subscribing to Japan's Joint Statement on Transport Security of Nuclear Materials, now known as International Atomic Energy Agency (IAEA) Information Circular 909. Since 2016, two additional countries have subscribed for a total of 17 subscribers. The circular calls on countries to support the IAEA and counter the threat of nuclear and radiological terrorism by developing solutions and training to mitigate the risks involved with moving nuclear and radioactive material.

The symposium brought the international community together to seek solutions to mitigate transportation security risks and strengthen international security regimes. A schedule of future related events will be presented during the IAEA's International Conference on Nuclear Security (ICONS) in February.

NNSA contributes a broad range of experience, expertise, and tools to support partners in developing national comprehensive programs to prevent the theft of nuclear and radioactive material during transport both domestically and abroad.



Representatives from more than 30 countries came together in Tokyo to discuss the safety and security of radioactive material in transit.

M3 Office of Material Disposition Completes Large-Scale Uranium Downblend Campaign

By Paloma Richard and Whitney Baillie

In June 2019, DNN's Office of Material Management and Minimization's (M3) completed the Repurposed Excess Uranium (REU) Project, which downblended 10.4MT of highly enriched uranium (HEU) into low-enriched uranium (LEU). This work was executed by the M3 Office of Material Disposition's Uranium Program.

This project is part of a broader Uranium Program effort to disposition 186 MT of surplus uranium by 2030. As of January 2020, the Uranium Program has dispositioned 163.5 MT of the 186 MT total. This constitutes the disposition of enough weapons-usable material for more than 6,500 nuclear



An operator in Y-12's 9212 complex prepares a pan of uranium metal to be canned and packed in shipping containers.



Broken uranium metal from a hollow log casting is being packed into an offsite shipping can. The can is lined with a metal screen to protect it from potential sharp edges of the material. This material was produced using existing supplies of highly enriched uranium. The can of metal will be packaged into an ES-3100 shipping container and shipped to Nuclear Fuel Services for down-blending.



An employee packs a can into the ES-3100 shipping container for offsite shipment to Nuclear Fuel Services for down-blending. ES-3100s are routinely shipped via Office of Secure Transportation convoys.

As the most recent large-scale campaign of this nonproliferation initiative, the REU Project downblended 10.4 MT of HEU into 220 MT of LEU that is no longer suitable for nuclear weapons use. The resulting LEU equals approximately 5 nuclear reactor reloads and will be used to support the Department's long-term tritium management plan. REU started in 2015 and the last shipment of resultant LEU occurred less than four years later, in June 2019. The REU Project used HEU that had been declared surplus to defense needs.

"This project has ensured that the material will never again be used in nuclear weapons and contributed to our Nation's security," said Lisa E. Gordon-Hagerty, DOE Under Secretary for Nuclear Security and NNSA Administrator. "Our nonproliferation team is one of a kind and we are all safer today thanks to their tireless efforts."

weapons. This effort contributes to M3's nonproliferation mission to disposition excess or surplus weapons-usable material. The LEU produced from this effort supports the production of strategic materials, such as tritium, to advance departmental goals. This is vital, as the United States no longer has the domestic capability to enrich natural uranium to fuel commercial reactors that produce tritium.

The REU project was composed of multiple teams from various organizations internal and external to NNSA, including the

continued on page 5

Dr. Park Leads NNSA Team at Comprehensive Test Ban Treaty Science & Technology Conference

By Tim Evans



Dr. Park and the NNSA team at SNT2019. Photo credit: Colin Peters, UNVIE

Dr. Brent K. Park led an NNSA team in June 2019 to the seventh Comprehensive Nuclear-Test-Ban Treaty (CTBT) Science & Technology Conference in Vienna, Austria. More than 1,100 participants from nearly 100 countries met to further enhance the strong relationship between the scientific and technological community and the Preparatory Commission for the CTBT Organization (CTBTO PrepCom). More than 50 NNSA experts from five DOE National Laboratories and NNSA Headquarters attended. Experts from the United States presented on a wide range of topics supporting the International Monitoring System (IMS) and International Data Centre (IDC), showing the depth of NNSA's technical contributions to international nuclear explosion monitoring. NNSA efforts include support for

re-engineering the waveform analysis software of the IDC and the ability to integrate regional seismic data into IDC products, improving the capability to detect and evaluate small releases from nuclear explosions with the next generation Xenon International system, and better understanding the effects of emissions from medical isotope production on nuclear explosion monitoring. Pacific Northwest National Laboratory Director Steven Ashby and Los Alamos National Laboratory Director (Emeritus) Terry Wallace also attended, along with officials from the U.S. Department of State and Department of Defense.

While in Vienna, Dr. Park also met with CTBTO PrepCom Executive Secretary Lassina Zerbo and toured the new IDC Operations Centre. NNSA will continue to look for ways to further contribute to the operation and improvement of the IMS and IDC.

Tim Evans is the Nuclear Testing Limitations Program Manager in DNN's Office of Nuclear Verification within the Office of Nonproliferation and Arms Control (NPAC). He has been with DOE for 28 years, with the past 10 in NPAC, managing NNSA's support for CTBT activities.

Downblend Campaign- Continued



private sector. The teams working on this effort included subject matter and technical experts from M3, the NNSA Production Office, NNSA Acquisition and Project Management, Consolidated Nuclear Security, Nuclear Fuel Services, Westinghouse Government Services, and BWX Technologies, Inc. This endeavor required a heightened level of coordination, professional execution, and commendable project management.

Left: Nuclear Fuel Services uses the solvent extraction process to remove impurities from the material received from Y-12. The solution will continue to be purified before being down-blended with a diluent solution to produce a batch of material nominally enriched to 4.95% U-235 assay.

The teams' efforts were recognized by the M3 Assistant Deputy Administrator, on behalf of the NNSA Administrator, immediately following the REU closeout meeting in October 2019 at Y-12 National Security Complex in Oak Ridge, TN. The next major downblend campaign of this magnitude will not be complete until 2025.

Paloma Richard is the HEU Disposition Program Manager in the M3 Office of Material Disposition. She leads the disposition of HEU and manages its provision to advance multiple DOE and NNSA objectives.

Whitney Baillie is the NGFP Fellow for the M3 Office of Material Disposition. She supports the HEU Disposition Program, Plutonium Disposition Program, and International Program.

Safeguards Projects Provide Experience for Students, Early Careerists

By Holly Trelue

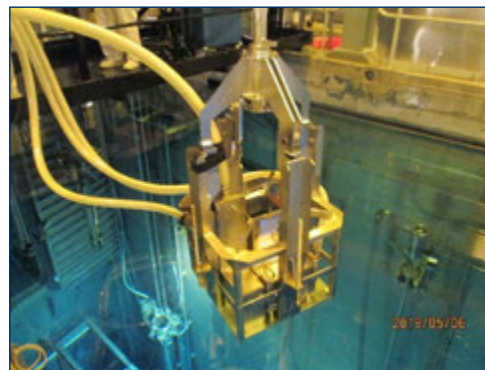
In 2009, DNN's Office of International Nuclear Safeguards (OINS) initiated a project to develop and test integrated technologies to improve nondestructive assay (NDA) measurements of spent nuclear fuel assemblies. In conjunction, OINS's Human Capital Development (HCD) program supported research on particular tasks.

The spent fuel NDA project not only has advanced technology designed for spent fuel assembly characterization, but also has provided research opportunities for almost 20 students, post doctorates, and early career staff. Many individuals initiated modeling of a particular technique and then wrote a thesis, dissertation, and/or journal article involving measurements with the as-built instrument. Of 11 students and postdocs who worked on the project, seven have remained involved in the OINS's Safeguards Technology portfolio.

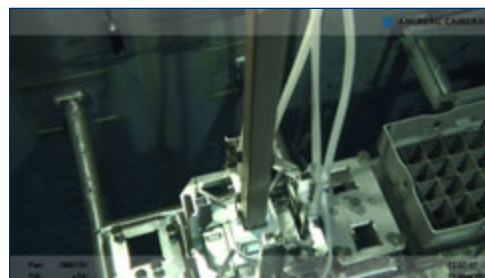
In May 2019, a team at Los Alamos National Laboratory (LANL), including Garrett McMath, Paul Mendoza, Carlos Rael, and Margaret Root, investigated one of the integrated instruments, differential die-away (DDA) built for NDA measurements of spent fuel assemblies in Sweden. The DDA instrument comprises a neutron generator housed on one side of a spent fuel assembly with pods of detectors on the other three sides. The neutron generator provides neutrons that induce fissions in the assembly, and time-dependent neutron detection after a pulse provides key information about spent fuel assembly characteristics. The team conducted over 200 individual measurements on 25 pressurized and boiling water reactor fuel assemblies. Analyses currently are underway to evaluate results from several different instruments that measured the same assemblies in Sweden for an integrated assessment of the technical goals of the project.

Root and Mendoza gained valuable experience from this program. Both received HCD funding as students at laboratory and participated in several successful safeguards projects as early career staff members in the Safeguards Science and Technology group. This year, Root hosted a cross-pollination workshop for subject matter experts across LANL to encourage the exchange of ideas between the nonproliferation and space science divisions. Mendoza's expertise in data analytics and support from HCD allowed him to become a key member of the spent fuel NDA project, especially with regard to the analysis of list mode data.

HCD supports efforts to enhance the professional development of students and early career staff members and preserve continuity of knowledge across generations of international safeguards experts.



Instrument lowering into spent fuel pool



Boiling water reactor assembly lowering into the instrument



Swedish and LANL team members

Human Capital Development in Practice: The Success of DNN's Dr. Anagha Iyengar

By Amber Morgan

The Human Capital Development (HCD) program in DNN's Office of International Nuclear Safeguards (OINS) works to recruit, train, educate, and retain the next generation of safeguards professionals. Dr. Anagha Iyengar, a general engineer in OINS, benefited from a number of these HCD programs throughout her early career and now uses those experiences every day as she supports DNN's mission to prevent, detect, and deter the proliferation of nuclear weapons. In fact, HCD programs sponsored by OINS inspired her initial interest in international nuclear safeguards as an undergraduate student at the University of California (UC), Berkeley, supported an educational tour of safeguards implementation at advanced nuclear fuel cycle facilities in Japan when she was a graduate student, and funded her doctorate research on verification of spent nuclear fuel for safeguards applications.

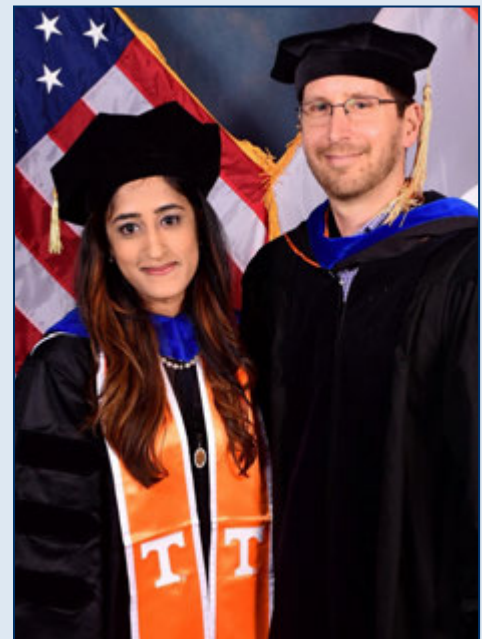
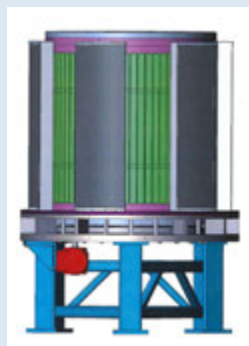
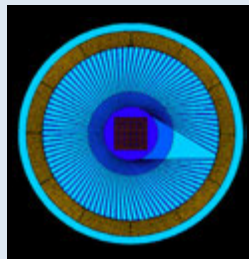
As an undergraduate nuclear engineering student at UC Berkeley, Iyengar was introduced to the field of international nuclear safeguards through an HCD-funded Next Generation Safeguards Initiative (NGSI) internship at Lawrence Livermore National Laboratory. Iyengar credits that experience with altering her academic focus.

"[That] internship inspired me to change my career from focusing on nuclear energy and reactor physics to nuclear safeguards and nonproliferation," Iyengar said. She went on to complete a second NGSI internship at Sandia National Laboratories the following summer, where she worked on a project focused on holdup measurements using fast neutron signatures.

After completing her master's in nuclear engineering at the University of Tennessee (UT), Knoxville, she joined NNSA as a Nonproliferation Graduate Fellow in the Safeguards Technology program, where she worked on safeguards technology development with end-users at the International Atomic Energy Agency (IAEA) and European Atomic Energy Community (EURATOM).

"It was gratifying to see the safeguards tools and technologies developed actually be used in the field," Iyengar said of her time in the Safeguards Technology program.

Following her fellowship at NNSA, Iyengar continued to support the Safeguards Technology program as a contractor, coordinating the office's safeguards engagement with EURATOM. After a year, she decided to return to UT Knoxville to pursue a doctorate in energy science and engineering. She also applied to the Nuclear



Left: 3D rendering side and top view of the spent fuel fast neutron emission tomography system that Anagha Iyengar worked on as an NNIS Fellow, which was funded by DOE/NNSA's Office of International Nuclear Safeguards' Human Capital Development Program. *Photo credit: ORNL and Anagha Iyengar.* **Right:** Anagha Iyengar with her Research Advisor, Paul Hausladen. *Photo credit: GradImages*

Nonproliferation and International Safeguards (NNIS) Fellowship program. Also funded by HCD, the highly competitive NNIS Fellowship provides tuition and stipends to technical Ph.D. students committed to safeguards relevant research. The NNIS Fellowship provided Iyengar the opportunity to work at Oak Ridge National Laboratory (ORNL) and pursue research on a gap in international nuclear safeguards: the verification of spent nuclear fuel before final disposition.

As a Ph.D. student, Iyengar supported Dr. Paul Hausladen to develop an imager that used the passive neutron signature from spent nuclear fuel to detect partial defects in the assembly and ensure that operator declarations are accurate to the pin level. The envisioned concept of operations would be to use it to verify the integrity of spent fuel prior to final disposition. The design for the tool incorporated realistic constraints that would determine the usability and acceptability of the tool in nuclear facilities, such as the size, weight, and measurement time. For her dissertation, "The Design of an Imager to Safeguard Spent Fuel Using Passive Fast Neutron Emission Tomography," Iyengar identified the optimal physics design for the imager.

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20 Years Later: Celebrating the Office of Nuclear Smuggling Detection & Deterrence

By Reema Verma

DNN's Office of Global Material Security (GMS) marked the 20th anniversary of its Nuclear Smuggling Detection and Deterrence (NSDD) program on May 21 with a VIP event in Washington, DC. Members of Congress, senior U.S. Government officials, and DOE/NNSA National Laboratory directors gathered to recognize the program's 20 years of success. The event showcased NSDD's evolution and key program areas, and accomplishments, and plans for the future.

During the event, Lisa E. Gordon-Hagerty, DOE Under Secretary for Nuclear Security and NNSA Administrator, delivered a keynote address applauding NSDD.

"America, our allies, and the world are safer thanks to NSDD's efforts over the past two decades to mitigate the threat of terrorists gaining possession of smuggled nuclear and radioactive materials that could be weaponized," she said.

NSDD, originally known as the Second Line of Defense program, began as a bilateral engagement between DOE and



Lisa E. Gordon-Hagerty, DOE Under Secretary for Nuclear Security and NNSA Administrator, delivered a keynote address during the Nuclear Smuggling Detection and Deterrence program's 20th anniversary event.

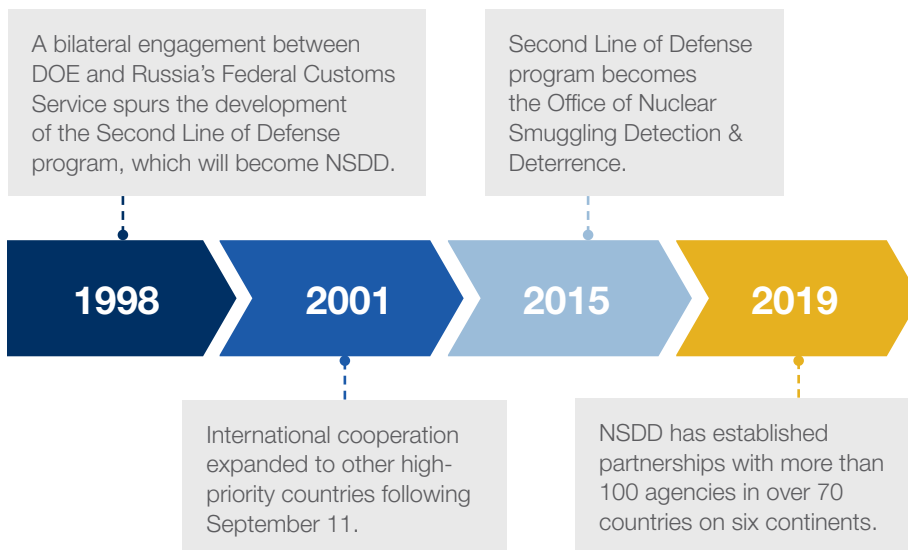
Russia's Federal Customs Service to prevent the smuggling of nuclear and radioactive materials through Russian air, land, and sea ports of entry. Following the events of September 11, the program

expanded international cooperation and now works with over 70 countries.

This global influence was the topic of two panel discussions during the anniversary event. During the first panel, representatives from NSDD's partner countries provided regional perspectives on countering nuclear smuggling and NSDD's global impact. In the second panel, panelists from NSDD's counterparts in the Departments of State, Homeland Security, and Defense explored interagency challenges and opportunities related to countering nuclear smuggling. These interagency and international partnerships are key to NSDD's continued success.

NSDD currently has partnerships with more than 100 agencies in over 70 countries on six continents, strengthening

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NSDD Director Laurel Cotton and Deputy Director Daniel Abeyta provide Administrator Lisa Gordon-Hagerty, left, with an overview of one of the electronic map displays.

global security through a multi-layered and integrated detection network. The program also receives technical expertise support from seven DOE/NNSA National Laboratories across the United States, including Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Sandia National Laboratories, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory. These labs support NSDD by evaluating emerging technologies, deploying and testing radiation detection equipment, offering troubleshooting and maintenance support, providing training, and conducting nuclear forensics activities.

“By providing equipment and training for police, border security, and security services throughout the world, NSDD has built a global community capable of interdicting and investigating cases of nuclear material smuggling,” Gordon-Hagerty said. “Moreover, NSDD has garnered support from both side of the aisle as demonstrated by the Members of Congress here today.”

Congressional members and NNSA leadership were given a VIP tour during the anniversary event. Attendees were also encouraged to engage with a series of interactive displays featuring NSDD’s work.

Building upon its two decades of experience, NSDD will continue to be a leader in the prevention of nuclear and radioactive materials smuggling in cooperation with international partners from law enforcement, border security, and intelligence agencies. As the threat evolves, NSDD continues to identify new strategies and pursue engagements with new partner countries and organizations. Therefore, NSDD is poised to address tomorrow’s threats in the global effort to prevent nuclear smuggling.

Reema Verma is a Foreign Affairs Specialist with the Office of Nuclear Smuggling Detection and Deterrence. Her previous experience includes working in the non-governmental/think tank sector where she worked for the Nuclear Threat Initiative (NTI) and Stimson Center.

“The NNIS fellowship was instrumental in my being able to showcase my work as a researcher to an international community,” said Iyengar, who presented her research at the IAEA Safeguards Symposium as well as the European Safeguards Research and Development Association conference.

In addition to her research, Iyengar took a variety of nuclear policy courses as part of her interdisciplinary Ph.D. program, which was jointly developed with ORNL and UT Knoxville. The intersection of Iyengar’s policy and technical experience afforded her the opportunity to brief elected officials on nuclear waste management at the Waste Isolation Pilot Plant and Yucca Mountain. Dr. Iyengar credits NNIS for these opportunities to supplement her educational and professional experiences.

After completing her doctorate, Dr. Iyengar returned to DNN’s OINS as a program manager overseeing the Sub-Saharan Africa portfolio for the International Safeguards Engagement Program (INSEP). She also supports INSEP as a technical advisor for all safeguards engagement with advanced technology partners. Iyengar brings a wealth of technical safeguards experience to her interactions with international partners, sharing her excitement to work in a field “where we can genuinely collaborate with partners because it’s in everyone’s best interest to promote safeguards.” On her experience fusing her technical and policy knowledge to support NNSA’s mission, Iyengar said “it’s nice to see that science can cross borders.”

Amber Morgan is the NNSA Graduate Fellow in DNN’s Office of International Nuclear Safeguards within the Office of Nonproliferation and Arms Control.

Developing NNSA's Future Leaders, One Relationship at a Time

By Malika Taalbi

Living in Beijing can pose some interesting questions: Where can I find the best dumplings in the city? How will I communicate with the repair technician, who doesn't speak English, to fix my kitchen exhaust fan? How can I cross the street among the cars and scooters coming from every direction? How do I say "left hand" and "right hand" in Mandarin when taking biometric fingerprints for visa applicants? And, of course, how can I best represent the Department of Energy (DOE)'s diplomatic, energy, and nuclear program interests while interacting with U.S. and Chinese counterparts?

Thankfully, these questions were easily answered – except, perhaps the dumplings – during the 60 days that I was on detail to the DOE-China office at the U.S. Embassy in Beijing. The DOE Overseas Corps conducts numerous efforts in support of DOE's role to promote and coordinate energy, environmental, science and technology, nuclear security, and nuclear nonproliferation programs and policies. The opportunity for this detail came through my participation in NNSA's Mid-Level Leadership Development Program (MLDP) and was an excellent way to complete a yearlong effort learning about leadership and activities within NNSA's labs, plants, and sites.

NNSA's MLDP is sponsored through the NNSA Office of Learning and Career Management and is designed to help high-potential individuals become more effective leaders across the Nuclear Security Enterprise. Over the course of the program, participants take several courses in organization and leadership, meet with NNSA senior officials and mentors, and work on a rotation to expand their skills and experience. In addition, MLDP participants also work together on a capstone project to support a major NNSA policy activity like strategic planning, peer reviews, or governance and management.

At the close of the year, participants receive a Leadership Education and Development Certificate from the U.S. Office of Personnel Management.

Since joining NNSA in 2014 through the NNSA Graduate Fellowship Program, I have been fortunate to work on a variety of projects within DNN. I currently work in the Office of Global Material Security (GMS), which seeks to prevent the use of nuclear and radioactive materials in acts of terrorism, in part by promoting the adoption and development of alternative technologies that do not use these sources. This is an important mission that I have been proud to help develop, and I now manage the international portfolio for this work as a complement to the office's Cesium Irradiator Replacement Project.

MLDP provided an excellent opportunity to continue growing my skills as a leader, hear new perspectives on management from NNSA leadership, and learn from my peers among the cohort. In addition, my time at the embassy was a unique opportunity to better understand the context of our work within the broader equities of the Department and gain in-depth international diplomacy experience. Working alongside U.S. interagency colleagues to advance national interests during this complicated time in U.S.-China relations was a foundational experience that will continue to influence my growth and contributions at NNSA. Finding the best dumplings was just a bonus.

Malika Taalbi is a Foreign Affairs Specialist in DNN's Office of Global Material Security, Office of Radiological Security (ORS) and manages the ORS International Alternative Technology portfolio. Malika received her Master of International Public Affairs from the University of Wisconsin-Madison and has previous experience in public policy research, community organizing, and international relations.



Top and middle: May 13, 2019 marked the graduation of the third class to complete the Mid-Level Leadership Development Program, NNSA's flagship program for high potential individuals looking to rise to leadership roles within the agency.

Bottom: Malika Taalbi at the U.S. Embassy Beijing.

The Source Physics Experiments: Detection R&D to Improve Monitoring of Foreign Underground Nuclear Explosions

By Brian Paeth and Megan Slinkard

Countries seeking to advance their nuclear weapons capabilities conduct underground nuclear explosion tests for technical or political purposes. The energy released from these tests generates seismic waves that can be detected by global monitoring networks. Discriminating between large underground explosions and earthquakes is generally straightforward. For smaller explosions, however, discrimination and yield estimation can be more difficult. The Office of Defense Nuclear Nonproliferation Research and Development (DNN R&D) developed the Source Physics Experiment (SPE) series to improve U.S. monitoring capabilities to discriminate and determine the yield of small nuclear explosions that can be lost amid noisy background sources.

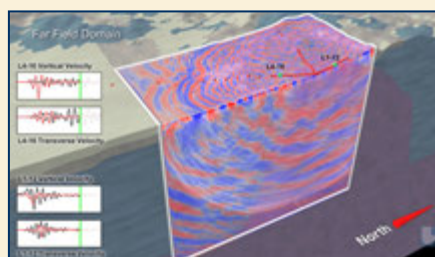
DNN R&D's nuclear test detection program sponsored a series of underground chemical explosions at two testbeds adjacent to historic nuclear tests at the Nevada National Security Site (NNSS). Using chemical explosions as a proxy for nuclear explosions, SPE created data to develop and validate physics-based models. SPE was carried out in two phases: six experiments in granite (Phase I, 2011–2016) and four experiments in alluvium (Phase II, 2018–2019). The experiments were executed in partnership with NNSS, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Sandia National Laboratories, and the University of Nevada-Reno.

In each phase, the same borehole was used for the explosive source and the same sensor network recorded experimental data. By varying the yield and depth of burial, researchers created ratios to compare and contrast sources. For each testbed, instrumentation holes were drilled next to the source to facilitate the installation of accelerometers. Other diagnostics included subsurface and surface accelerometers, seismometers, infrasound sensors, and airborne photogrammetry.

Each experiment generated terabytes of data for validating models and testing hypotheses. Results from Phase I have already provided insights into the physics behind the generation and modeling of geophysical effects. Researchers discovered that yield estimates for two frequently used seismic explosion source models could be off by a factor of two or more for small-yield, over-buried explosions. Additionally, researchers confirmed hypotheses that explosions cause seismic shear waves by driving motion on pre-existing rock joints. SPE also improved understanding of how those waves are transferred to distances of 200 kilometers or more.



Initial lowering of the 20,000 pound vessel for the second SPE Phase II experiment at U-2ez. When emplaced at a depth of 984 ft., this vessel contained the equivalent of 50 tons of TNT.



SPE leverages expertise and computing capabilities to improve predictive modeling of energy propagation from chemical detonations.

Achieving results required multi-disciplinary and multi-laboratory collaboration. SPE leveraged NNSA capabilities to engineer complex field experiments and exercise test readiness. Experts in drilling, high explosive operations, containment, timing and firing, data acquisition, distributed sensor networks, and site characterization contributed to and were integrated tightly with a multi-laboratory science plan. These aspects propelled the team closer to achieving the overall goal of a physics-based model.

SPE is a foundational DNN R&D effort to reduce nuclear threats by providing expertise and tools that the United States can use to independently verify international compliance with treaties and commitments. Moving forward, SPE will continue to improve confidence in U.S. capabilities to monitor and detect underground nuclear explosive testing and to discriminate between small underground explosions and earthquakes.

Brian Paeth is a Senior Program Manager in DNN R&D's Office of Proliferation Detection and is responsible for improving capabilities to detect underground nuclear explosions. Prior to joining NNSA, Brian served in the U.S. Air Force for 25 years as a nuclear and missile operations officer in a variety of operational and staff assignments, most recently at the Department of State.

Megan Slinkard is a Technical Advisor for DNN R&D's Nuclear Test Detection and Ground-based Nuclear Detonation Detection programs. Megan has worked at Sandia National Laboratories for 15 years, where her research focused on improving seismic and infrasound monitoring capabilities.

Decade of International Nonproliferation Cooperation Culminates with Reactor Conversion and Highly Enriched Uranium Removal in Nigeria

By Annelise Plooster and Jaci Dickerson

In October 2018, DNN's Office of Material Management and Minimization (M3), in cooperation with Nigeria, China and the International Atomic Energy Agency (IAEA) converted Nigeria's NIRR-1 Miniature Neutron Source Reactor (MNSR) from the use of highly enriched uranium (HEU) fuel to low-enriched uranium (LEU) fuel. The HEU was removed shortly after, making Nigeria the 33rd country plus Taiwan to be HEU-free. NNSA began working with Nigeria on this project in 2006.

Manufactured by the China Institute of Atomic Energy (CIAE) and located at the Centre for Energy Research and Training (CERT) at Ahmadu Bello University in Zaria, Nigeria, the NIRR-1 is used for educational and training purposes. For example, researchers use the NIRR-1 to determine soil mineral content to better help Nigeria's farmers calculate the amount of fertilizer needed for crops to grow in the region.

For over 40 years, the Department of Energy has helped countries around the world to convert their civilian research reactors to use LEU fuel and return the HEU to its country of origin, eliminating the risk that this material could be used in an improvised nuclear device. Efforts to convert MNSRs internationally have brought together experts from the IAEA, China, the United States, and the countries who operate MNSRs – Ghana, Nigeria, and Pakistan. China converted the prototype facility in Beijing in 2016. One year later, the Ghanaians converted their MNSR reactor and returned the HEU fuel to China, making Ghana HEU-free and setting the stage for Nigeria to convert its reactor.

To do so, CIAE fabricated the LEU core, which was shipped to Nigeria. A diverse team of scientists then inserted the LEU core and slowly brought it to full power. For several more weeks, the core, safety rod, and other elements of the reactor were thoroughly tested before the NIRR-1 was commissioned as an LEU-fueled reactor.

The effort to return the HEU fuel to China was carefully synchronized to ensure the security of the material and the safety of everyone involved. A team from M3 oversaw the activities carried out by the Nigerian technical staff from the CERT, with packaging and shipping experts from Russia and the Czech Republic supporting the operation.



LEU pins being packaged for shipment to Nigeria

The team had to complete the delicate, time-consuming task of transferring the HEU into a large, heavily shielded transportation cask, then seal and test it to ensure that no radioactivity would be released. The entire transport package – designed for safe and secure transport of spent nuclear fuel by air – weighed more than 30 tons. The Nigerian team later drove the material in a secure convoy from Zaria to Kaduna, and loaded it onto an Antonov AN-124 cargo plane, where it was flown 8,000 miles to China.

In addition to making Nigeria HEU-free, the conversion has helped the university expand their research and training. The conversion commissioning process provided new

experimental data where the control rod was repeatedly pulled in several quick steps. Researchers at CERT and their students have used this data to develop models to demonstrate the passive safety and self-limiting mechanisms of the MNSR design.

The conversion process also provided a proving ground for the Nigerian Nuclear Regulatory Authority to establish requirements and procedures for the commissioning of a nuclear reactor. The training for the regulators provided by Argonne National Laboratory and their experience in reviewing and approving the conversion will aid in the country's future plans to establish a commercial nuclear power plant.

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