U.S. DEPARTMENT OF ENERGY (DOE)
NATIONAL NUCLEAR SECURITY ADMINISTRATION (NNSA)
DEFENSE NUCLEAR NONPROLIFERATION (DNN)

DNN Sentinel

DEFENSE BY OTHER MEANS

Vol. IX, No. 1

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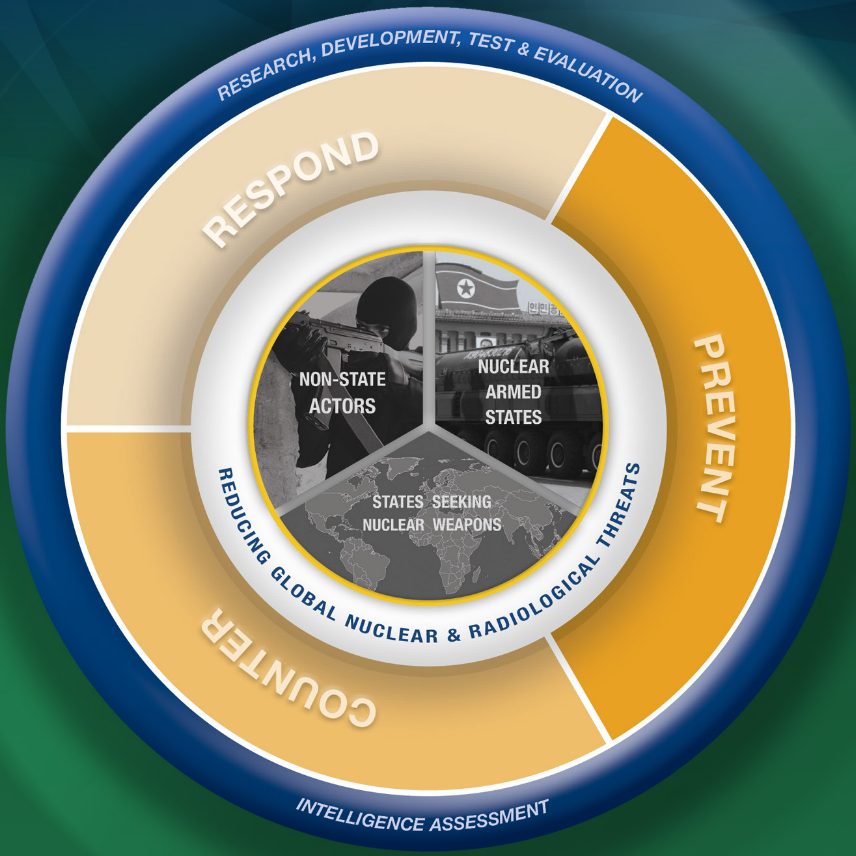

Prevent, Counter, Respond

DNN SENTINEL:
DEFENSE BY OTHER MEANS

VOL. IX, NO. 1

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

From the Deputy Administrator

This Spring, the National Nuclear Security Administration (NNSA) will issue the next edition of *Prevent, Counter, and Respond – A Strategic Plan to Reduce Global Nuclear Threats (NPCR)*. The NPCR articulates NNSA's work to combat nuclear terrorism and proliferation and details NNSA's ability to respond to a myriad of threats.

NNSA's Office of Defense Nuclear Nonproliferation (DNN) implements the NPCR framework of innovate, collaborate, and deliver throughout our work. DNN plays a crucial role in the enduring mission to enhance national security by preventing, countering, and responding to threats domestically and abroad. From providing tailored capacity building trainings to partner countries around the globe to developing new technologies to confront emerging proliferation challenges, DNN is at the forefront of innovative solutions.

In order to effectively prevent, counter, and respond, DNN operates in lockstep with crucial organizational partners. Two such partners include NNSA's Office of Emergency Operations (NA-40) and NNSA's Office of Counterterrorism and Counterproliferation (NA-80). DNN is excited to highlight the dynamic work occurring within both programs in this issue.

We believe that the thread pulling each story together is a single word: partnerships. DNN maximizes the reach of its threat reduction efforts through its robust partnerships at the international, interagency, state, and local levels. Whether it be interorganizational partnerships, partnerships between programs, partnerships between NNSA or the broader Nuclear Security Enterprise, we are stronger together.

Since this is my first DNN Sentinel since becoming the Deputy Administrator, I want to share how proud I am to be part of DNN. As these articles demonstrate, this organization—and NNSA more broadly—is doing vital work in service of national and international security. I am excited to share even more about our work in future issues. If you have topics you want to know more about, please contact us at dl-na-20forcs_aos@nnsa.doe.gov.

Finally, I want to acknowledge and thank Dave Huizenga, Kasia Mendelsohn, and Christine Bent, who all took time from their day jobs over the last year to lead DNN. We are a team and rely on each other to perform our important work on behalf of the nation.

Thank you for opening this edition of the Sentinel and for your role in sustaining these partnerships. I look forward to seeing the ways in which we continue to prevent, counter, and respond, and am honored to highlight your work in the coming pages.

Corey

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NNSA ARTICLES

Interior Security and Law Enforcement (ISLE): Adapting Approaches to Evolving Threats

By Matthew Sick and Bryceon Shulman

DNN's Office of Nuclear Smuggling Detection and Deterrence (NSDD) works with international partners to prevent smuggling of nuclear and radioactive material. For over 20 years, NSDD has adapted deployment approaches as threats change, while maintaining the same objective: to detect, disrupt, and investigate the smuggling of nuclear and radioactive material before it can be used in an act of terrorism. Historical cooperation concentrated on Customs and Border Guard agencies at official points of entry (POE), such as border crossings, airports, or seaports, often with radiation portal monitor installations.

Over time, cooperation expanded to include mobile detection equipment to allow partners more flexibility to monitor additional areas for smuggling. In 2019, NSDD conducted a review of global risks and threats and determined that an expansion of program offerings to assist law enforcement would be important in addressing gaps in global counter nuclear smuggling capabilities. The strategy developed to meet this need was named Interior Security and Law Enforcement (ISLE).

NSDD's ISLE approach expands on NSDD's previous activities with law enforcement and leverages new detection tools to support a whole-of-government approach to counter nuclear smuggling, with a focus on internal security organizations and their jurisdictions. Varying the place and means of detection makes such activities harder for adversaries to predict, which can aid in disrupting smuggling. This strategy aligns with data captured in the International Atomic Energy Agency's Incident and Trafficking Database: Interior security agencies are more likely to be involved in seizures than border control agencies, and materials that ISLE units seize tend to be of higher value to adversaries than materials seized by non-ISLE agencies. Thus, ISLE deployments aim to grow capabilities of the partners most likely to make a significant potential contribution to counter nuclear and radioactive smuggling efforts.

"NSDD's new modular mobile detection systems (MDS) offer increased capability over legacy MDS systems, including live identification, fewer false alarms, directionality, and visual images, all in a package that can be deployed on a wider array of vehicle types. These more flexible and easier-to-use options facilitate the addition of radiation detection into a larger variety of existing missions by more partner agencies."

– Mike Demboski, NSDD Science and Engineering Team

A member of the NSDD team instructs Nigerian Police Force officers on the operation of a radiation detection backpack used in urban areas. Operation of Radiation Detection Backpack for Urban Area Operations

New ISLE deployments build on earlier mobile detection system deployments by focusing on functional missions such as patrol and interdiction teams, investigation and interdiction units, national counterterrorism, and other law enforcement elements. These units frequently operate in urban areas, along critical pathways and infrastructure, and are less likely to be bound geographically like customs and border agencies. Many ISLE deployments will also integrate new modular mobile detection capabilities—detection systems tested and currently in use by other NNSA programs, Federal Bureau of Investigation, Department of Homeland Security, and other U.S. interagency partners. ISLE deployments can also include traditional countersmuggling tools, which can increase the probability of interdiction. A key element of ISLE is new NSDD training modules focused on new equipment suites and operational needs.

By expanding cooperation within the interior of partner countries and engaging new stakeholders, NSDD is enhancing law enforcement capabilities while strengthening the overall nuclear detection architecture. These projects build on NSDD's layered defense strategy and empower ISLE partners to encounter and detect adversaries, materials, or devices in storage, transport, and preparation for malicious use. The introduction of new modular mobile systems is directly in line with NNSA Administrator Jill Hruby's goals of both delivering innovative technology and accelerating innovation on nonproliferation technology.

Matthew Sick is a Foreign Affairs Specialist with the Office of Nuclear Smuggling Detection and Deterrence (NSDD). He provides federal oversight for the office's ISLE projects, in addition to duties as a country manager and lead for the Mobile Detection System (MDS). Bryceon Shulman is a contractor with Culmen International and senior advisor within NSDD, supporting the office as the Subject Matter Lead for ISLE engagements in addition to his other duties.

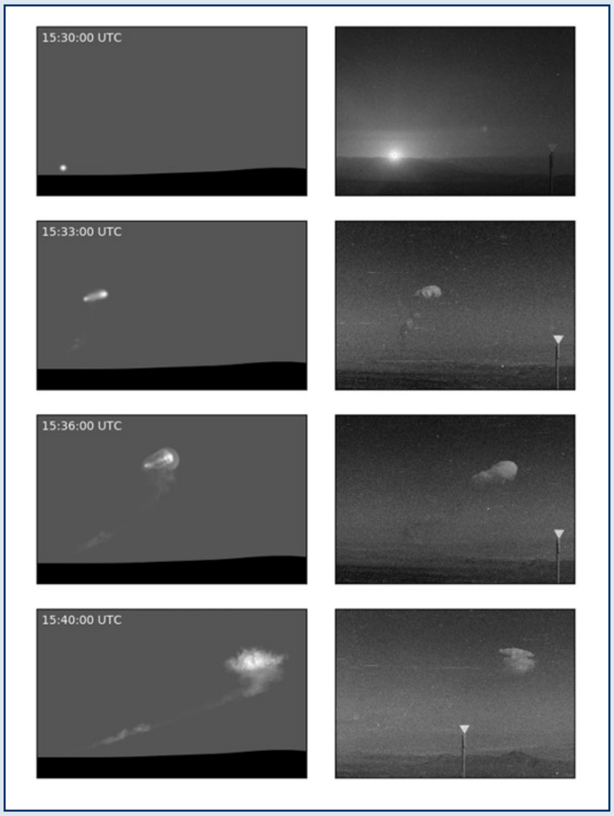
Simulating Nuclear Cloud Rise Anywhere, Anytime

By Katherine Lundquist, Lee Glascoe, and Ben Kennedy

For decades, understanding the behavior of a nuclear mushroom cloud was done through careful analysis of observations made during the testing era. Grainy photos, outdated film, and incomplete weather data made precise calculations difficult. Now, with results published in *Atmospheric Environment*, Lawrence Livermore National Laboratory (LLNL) scientists are improving our understanding of nuclear cloud rise using a widely adopted and highly validated weather modeling tool. The result of this effort will be an enhanced modeling capability that allows responders to better inform decision-makers on the potential dangers following a nuclear detonation.

> ***"This weather model has been in use for about 20 years, and so a lot of validation has gone into [it]," he said. "... [W]e're benefiting from the last 20 years of weather research and forecasting."***
>
> \- Lee Glascoe, LLNL Nuclear Emergency Support Team Program Leader

The Weather Research and Forecasting (WRF) model has been a mainstay in weather forecasting and cloud modeling for decades. The model source code is maintained by the National Center for Atmospheric Research, but it is community-developed, using several contributions from researchers at LLNL. In particular, the LLNL version of WRF is used at the National Atmospheric Release Advisory Center to simulate the transport and dispersion of airborne particulates flowing around terrain features and buildings. Compared to the lower-fidelity simulations often used to model cloud rise for emergency response, a WRF-based model of a nuclear cloud incorporates time-varying weather for the exact location under study. This adaptability and high resolution appealed to one of the paper's authors, Livermore mechanical engineer Katie Lundquist.



Comparison of WRF cloud evolution (left column) to film observations (right column) for the Encore test. WRF results are depicted using a meridional sum of the modeled debris. Note that the camera angle of the observations changed between 15:36 and 15:40 UTC; the post in the foreground of each image can be used as a reference point.

"We have a lot of experience developing this model for other applications, but we thought it was very well-suited to modeling cloud rise," she said. Additional co-authors on the paper include Robert Arthur, Jeffrey Mirocha, Stephanie Neuscamman, Yuliya Kanarska, and John Nasstrom.

While many of the U.S. atmospheric tests were done in the arid environment of Nevada, a future nuclear event could occur anywhere. This makes the use of a weather model with proven operational capability ideal.

The researchers used the "Encore" nuclear detonation May 8, 1953, as a basis for testing their WRF hypothesis. Using global atmospheric data to simulate conditions on that date, they fed the WRF model the parameters of a nuclear fireball. After running the model, their simulation matched the 1953 photos remarkably well.

"We were shocked that it matched so well," said Lundquist, who recently spoke to LiveScience about how mushroom clouds are formed in a nuclear explosion. "The cloud rise simulation is able to match the rise rate and height, as well as qualitative features like the tilting of the cloud and the timing of the cloud breaking apart. We were very pleased with our results, and surprised that we did not have to tune the model to match the observations."

> ***"While many of the U.S. atmospheric tests were done in the arid environment of Nevada, a future nuclear event could occur anywhere making use of a weather model with proven operational capability ideal."***
>
> -Katie Lundquist, LLNL Model Development Lead at the National Atmospheric Release Advisory Center

Cloud Rise– *Continued*

Some of the credit belongs to the WRF model, said Lee Glascoe, LLNL Nuclear Emergency Support Team Program Leader. "This weather model has been in use for about 20 years, and so a lot of validation has gone into [it]," he said. We are "benefiting from the last 20 years of weather research and forecasting."

Glascoe added that the research would have been impossible without the high-resolution simulation capabilities that Lundquist and her team developed and incorporated into the WRF model. The improved sophistication of WRF allows the cloud simulation to predict the "rainout" of radioactive particles, particularly somewhere with more atmospheric moisture than Nevada. All the innovative work at LLNL is creating a model applicable to a wide range of environmental conditions, from a dry, rural environment, to a humid environment, to a densely populated urban area.

"Nobody has the capability for that except Livermore," Lundquist said. "It all comes back to the idea that we need to forecast the consequences of hazardous atmospheric releases. We have the operational mission to do that."

Katherine Lundquist is a computational engineer and leads model development at the National Atmospheric Release Advisory Center at Lawrence Livermore National Laboratory (LLNL). Lee Glascoe is the LLNL Program Leader for the Nuclear Emergency Support Team and has 20 years of experience analyzing and validating numerical modeling of weapons effects. Ben Kennedy is a writer and editor with LLNL's Public Affairs Office and Technical Information Department.

NNSA Representative Leads International Emergency Preparedness and Response Conference

In October 2021, Ann Heinrich, the Director of the Office of Nuclear Incident Policy and Cooperation (NIPC) within NNSA's Office of Counterterrorism and Counterproliferation, had the honor of serving as President of the International Atomic Energy Agency's (IAEA) International Conference on the Development of Preparedness for National and International Emergency Response, or "EPR2021," which took place in Vienna, Austria. The IAEA is a key partner in advancing NNSA's international nuclear security mission. Two representatives from her office, Paloma Richard, and Patrick Disney, also served on the conference's program committee.

NNSA's Ann Heinrich served as President of the 2021 International Conference on the Development of Preparedness for National and International Emergency Response in Vienna.

EPR2021 focused on preparedness for and response to radiological and nuclear emergencies regardless of the cause, including natural disasters, negligence, and malicious acts. Topics included emergency preparedness; emergency management; protection strategies; communication; public health and medical response; international cooperation and assistance; education and training; and lessons learned from past experiences.

It built on themes rising from previous IAEA conferences, including the 2015 International Conference on Global Emergency Preparedness and Response (EPR) and the 2018 International Symposium on Communicating Nuclear and Radiological Emergencies to the Public.

Ms. Heinrich opened the conference alongside IAEA Director General Rafael Grossi and Deputy Director General for Nuclear Security Lydie Evrard. She emphasized the continued importance of multilateral engagement and cooperation in EPR.

"The COVID-19 pandemic has highlighted, among many things, that emergency preparedness and response is a field with profound relevance for individuals, families, communities, nations, and indeed the world—EPR is not an abstract concept," Ms. Heinrich said. "The widespread effects and unpredictability of emergencies—whether a pandemic or a nuclear or radiological incident—makes it clear that the work that we do is so important for the protection of people and the environment."

NNSA's Patrick Disney presented on the value of Convention Exercises at the 2021 International Conference on the Development of Preparedness for National and International Emergency Response.

Ms. Heinrich also chaired the first two terms of the IAEA Emergency Preparedness and Response Standards Committee and, in her opening address, encouraged all Member States to nominate members to actively contribute to its work. Established in 2015, the

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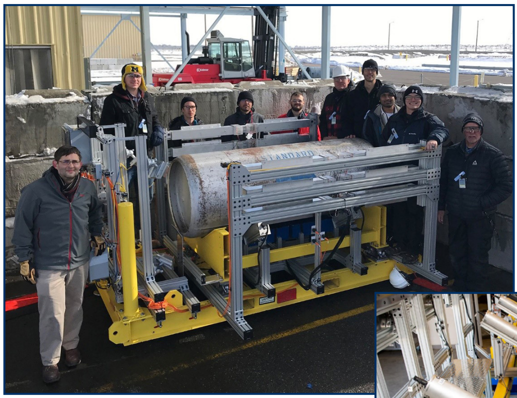
Longstanding Nuclear Safeguards Project Wraps Up with a System Sendoff

By Eric Smith, Mital Zalavadia, and Cornelia Brim

On November 24, 2021, a team of nuclear engineers, physicists, data scientists, mechanical engineers, millwrights, technicians, and managers gathered to bid farewell to a nuclear safeguards system, the components of which had been under development and testing for nearly 13 years. The prototype Unattended Cylinder Verification Station (UCVS), developed to support the International Atomic Energy Agency (IAEA), was then shipped from Pacific Northwest National Laboratory (PNNL) to the IAEA for further testing. More than 40 staff members from PNNL, Los Alamos National Laboratory (LANL), and Oak Ridge National Laboratory (ORNL) contributed to the UCVS development.



In February 2019, collaborators from Los Alamos, Oak Ridge, and Pacific Northwest National Laboratories met during a field trial of an earlier UCVS prototype at Framatome in Richland, Washington. Pictured (from left), James Garner (ORNL), Marc Ruch (LANL in 2019, now with IAEA), David Broughton (LANL), Vlad Henzl (LANL), Eric Becker (PNNL), William Bennett (PNNL), Eric Smith (PNNL), Mital Zalavadia (PNNL), Scott Stewart (ORNL), Lindsay Todd (PNNL, now retired). (Photo permission from PNNL available upon request)

The UCVS is a first-of-a-kind, automated system to provide an independent measurement of the uranium enrichment, uranium-235 mass, and total weight of uranium hexafluoride (UF_6) cylinders used in gas centrifuge enrichment plants (GCEPs) and other UF_6 facilities around the world. Motivated by the need to increase the efficiency of nuclear material accountancy measures at GCEPs, the IAEA proposed consideration of an unattended system for UF_6 cylinder verification in 2007 and 2009 publications. The global volume is estimated at 20,000 cylinders (typically natural uranium and LEU) in active circulation and more than 100,000 cylinders (typically depleted uranium) in long-term storage. PNNL and LANL—as part of the Laboratory-Directed Research and Development (LDRD) projects—developed new nondestructive assay methodologies to meet the IAEA's preliminary requirements. PNNL's approach simultaneously measures the direct gamma ray from uranium-235 and the total neutron emission rate from the cylinder. LANL's approach measures neutron emission rates from the cylinder. The projects were then funded by NNSA's Office of Nonproliferation and Arms Control. Eric Smith, the principal investigator of the PNNL project, described the progress, "The projects proved that these methods could assess the entire volume of the cylinder and accurately determine both uranium enrichment and total uranium mass."

Encouraged by the promising results, the IAEA requested construction and validation of the UCVS through the U.S. Support Program, co-funded by NNSA and the U.S. Department of State in 2013. Under this sponsorship, the LANL and PNNL detection systems were integrated with an ORNL system to identify and weigh cylinders. Savannah River National Laboratory helped with early field trials at a commercial fuel fabrication facility in South Carolina. Additional field trials were conducted at a fuel fabrication facility in Washington State. These trials led to improvements in measurement methods and structural design.

Inside the UCVS, the yellow metal framework and black pads cradle the UF_6 cylinders, much like a boat trailer, while the neutron detectors (rectangular metal running the length of the cradle in the middle of the photo and along the sides) and gamma detectors (silver "cans" positioned at angles the length of the cradle) scan the contents of the cylinder. Photo credit: Andrea Starr, PNNL

Similar to other projects, the UCVS effort was challenged by COVID-19, but project team members were able to find a way to continue.

"Once we wrote a plan to capture the scope of work that included addressing pandemic work restrictions and remote support from our collaborators, PNNL was able to set up a secure remote network for LANL and ORNL" said Mital Zalavadia, UCVS project manager.

In 2020, the project focused on adaptations to the UCVS prototype, primarily on mechanical support structure design. PNNL technicians and engineers made sure the UCVS could house the sensitive detection systems and be robust enough to support the heavy UF_6 cylinders it measures, the largest of which weigh more than 32,000 pounds. Physicists and technicians also optimized performance of the detection systems. Final system tests took place at PNNL during May and June 2021. The IAEA received the UCVS in February 2022 for in-house testing and evaluation. The IAEA will then select a GCEP for UCVS installation and further testing. Ultimately, the IAEA hopes the UCVS will help it achieve an increase in the effectiveness and efficiency of inspections at GCEPs worldwide.

Eric Smith is a Laboratory Fellow and program manager at PNNL, a nuclear engineer by training, and the lead of the UCVS collaboration.

Mital Zalavadia is a physicist at PNNL. He is the project manager and lead on gamma-ray detector development.

Cornelia Brim is a senior communications specialist at PNNL.

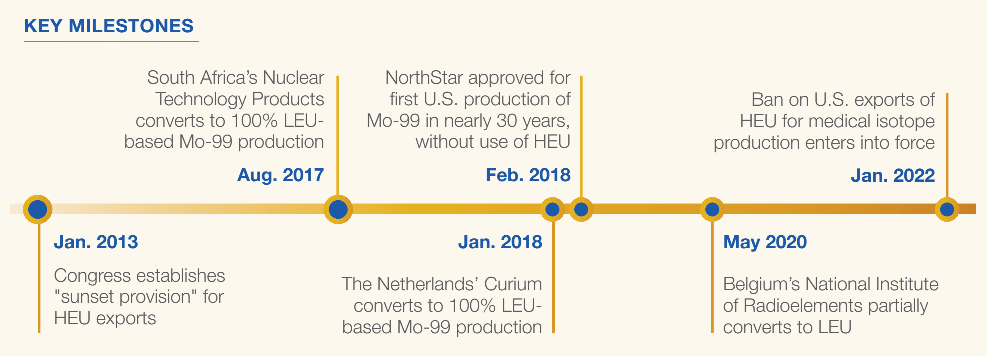
U.S. Ends Exports of Highly Enriched Uranium for Medical Isotope Production

By Max Postman and Brett Cox

In December 2021, U.S. Secretary of Energy Jennifer M. Granholm and U.S. Secretary of Health and Human Services (HHS) Xavier Becerra jointly certified that there now is enough worldwide supply of the medical isotope molybdenum-99 (Mo-99) made without highly enriched uranium (HEU) to meet the needs of patients in the United States. NNSA's Office of Defense Nuclear Nonproliferation (DNN) played an instrumental role in achieving this milestone, which triggered a legal ban on exports of HEU for medical isotope production. The ban entered into force on January 2, 2022.

Until recently, HEU was used widely in Mo-99 production, but concerns about the security and nonproliferation risks posed by HEU led NNSA to pursue non-HEU alternatives to producing this vital medical isotope. Mo-99 is used in more than 40,000 medical diagnostic procedures in the United States each day alone. For decades, the United States had no capability to produce Mo-99 domestically and exported HEU to foreign producers to ensure a stable supply.

Part of DNN's HEU minimization strategy has been to provide financial and technical assistance to the major global Mo-99 producers to convert their processes to use low enriched uranium (LEU) targets. These major global producers include South Africa's Nuclear Technology Products (NTP), the Netherlands' Curium, and Belgium's National Institute of Radioelements (IRE). Australia's ANSTO also is a major Mo-99 producer, but always produced using LEU.



Conversions are complicated projects, as each producer must develop an LEU target and processing line on par with HEU-based production, all while satisfying both nuclear and medical regulators' requirements. Pacific Northwest and Argonne National Laboratories played key roles in this effort by helping NTP, Curium, and IRE to develop and test LEU targets, allowing them to shutter HEU-based facilities and equipment for good.

Operators processing Mo-99 in Curium's LEU hot cell which fully replaced HEU-based production in the Netherlands in 2018.

NTP and Curium completed the conversion process in 2017 and 2018, respectively. IRE partially converted to LEU and began supplying LEU-based Mo-99 to the U.S. market in 2020. IRE does not require any additional HEU and will complete their conversion to 100% LEU-based production by the end of 2022. Annually, these conversions and the enactment of the HEU ban remove dozens of kilograms of HEU from the global commercial supply chain—a major achievement for the nonproliferation community.

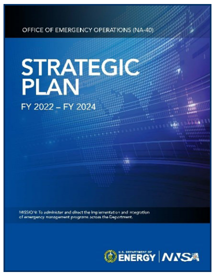
In addition to the collaborations with international partners, DNN also helped achieve a sufficient supply of non-HEU-based Mo-99 by supporting production here in the United States. This includes awarding over $200 million in cost-shared cooperative agreements with U.S. companies; providing technical support from the U.S. national laboratories; and establishing a Uranium Lease and Take-Back Program for industry. One of NNSA's domestic cooperative agreement partners—NorthStar Medical Radioisotopes—is already producing Mo-99 for the U.S. market, and NNSA partners Niowave and SHINE Technologies are in the process of building their production facilities.

Along with the work of our partners in HHS, DNN's work at home and abroad made it possible for the Secretaries of Energy and HHS to issue their landmark certification at the end of 2021. Looking forward, DNN will build on this achievement by supporting IRE until conversion is complete by December 2022 and by working with domestic Mo-99 cooperative agreement partners to achieve large-scale, non-HEU-based Mo-99 production.

Max Postman is the Program Manager for DNN's Domestic Molybdenum-99 Program. Brett Cox is the Program Manager for DNN's International Molybdenum-99 Program.

A New Strategic Path Forward for Emergency Operations

By John Juskie, Matthew Smith, and Jonathan Rosen



Natural and human-caused emergencies continue to evolve in complexity and scope due to rising adversarial threats, natural disasters, and impacts related to climate change. How we plan now for emergencies will affect the DOE enterprise's ability to effectively manage future crises. In 2021, NNSA's Office of Emergency Operations began an initiative to conduct transformational organizational change through the completion of its strategic plan for FY 2022-FY 2024.

The primary role of the office is to ensure DOE and NNSA can fulfill their critical missions in the event of threats or deteriorating conditions. The Office of Emergency Operations is responsible for administering and directing the implementation of all-hazards emergency management programs and continuity of operations across the Department. With this coordinating role, it was critical that the office's Strategic Plan consider various levels and perspectives. The plan was derived from a variety of existing administrative policies, agency strategies, and NNSA's Prevent, Counter, and Respond mission. The foundation of the Strategic Plan rests on four Mission Priorities emphasizing support across the Department as well as a key cross-cutting priority to improve culture and capabilities within the office. They are:

1. Restore overall motivation, optimism, and satisfaction of the workforce
2. Grow internal capacity to provide operative emergency management support
3. Enhance the readiness and effectiveness of the DOE Emergency Management System
4. Lead time-phased integration of the Federal Mission Resilience Strategy across the Department to enhance continuity programs

Focusing on people is crucial to ensuring future mission success, so our first Mission Priority addresses this concern. To fulfill these priorities, the office outlined 14 objectives to accomplish over the course of the next three fiscal years, including:

- Prioritizing professional growth of all personnel at all levels of the organization;
- Manage a headquarters Emergency Operations Center, and headquarters Emergency Management Team, and serve as the Emergency Manager for initial activations of the team;

- Enhance Emergency Management readiness throughout the DOE enterprise;
- Manage and lead the various Departmental continuity programs and ensure interoperability and modernization of the continuity communications systems and infrastructure across DOE/NNSA and with interagency partners.
- Institutionalizing the tenets of the Assess, Distribute, and Sustain model into departmental day-to-day operations.

The plan focuses the Office's programs and personnel to better organize and accomplish the required tasks, which in turn helps the DOE enterprise to respond to emergencies whenever and wherever they occur.

John "JJ" Juskie is the Associate Administrator for Emergency Operations. Mr. Juskie comes to NNSA and the Office of Emergency Operations with a wealth of professional operational and management experience in the emergency management field. Prior to joining NNSA, Mr. Juskie was the acting Director and Assistant Director in the Office of Emergency Management at the Department of the Interior (DOI).

Serving currently as the acting Deputy Associate Administrator for Emergency Operations, Mr. Matthew L. Smith joined NNSA after leading the Department of Health and Human Services' Continuity of Operations Division and serving as the HHS Continuity Manager, in support of the HHS Secretary and the Assistant Secretary for Preparedness and Response. Prior to that assignment, Mr. Smith served in numerous operational and management roles at FEMA, starting with a field assignment before moving to FEMA headquarters in various leadership roles within Hazard Mitigation and National Continuity Programs.

Jonathan Rosen rounds out NNSA's Emergency Operations leadership team as the acting Chief of Staff. Mr. Rosen also comes to NNSA from the DOI where he was with the Continuity Programs Division, providing continuity expertise to DOI leadership.

A Revitalization of Arms Control Research in Defense Nuclear Nonproliferation

By Dr. Yuri Podpaly, Dr. Marc Wonders, and LTC David Matters

DNN R&D is reinvigorating efforts to develop new capabilities for arms control monitoring and verification. This aligns with recent recommendations for increasing technological investments in arms control, such as those from the White House's National Science and Technology Council[1], National Academies of Science, Engineering, and Mathematics[2], and Nuclear Threat Initiative[3]. In this article, we highlight several initiatives to reinvigorate arms control-related research within the office: longer-term planning for high-risk, high-reward R&D; an increased focus on test and evaluation support at the laboratories, plants, and sites; and engagement with stakeholder offices.

In December 2020, DNN R&D and Nonproliferation and Arms Control (NPAC) held a workshop to establish current and future needs in arms control, monitoring, and verification. The workshop was attended by more than 180 personnel from across the complex and led to several community recommendations, including having breakout technical workshops and establishing longer term research planning. In response, DNN R&D sponsored six additional workshops in 2021 focusing on warhead monitoring and verification, nuclear compliance verification, novel technologies, and human capital development. The office also started planning for a major investment into a comprehensive, multi-laboratory venture project to study warhead verification, addressing both longer term challenges and near-term treaty concerns.

Last year, DNN R&D started eleven new projects to address a range of nonproliferation, verification and monitoring, and arms control questions. For example, an area of interest has been the development of new techniques for information barriers – tools for confirming characteristics of a declared object, such as a warhead, without revealing sensitive information. An example technique employs a rotating mask, Figure 1, that can be used for template matching. This mask allows a detector to compare two objects' radiation signatures without knowledge of their internal structures, thus confirming an item as declared without revealing other information, such as weapon design.

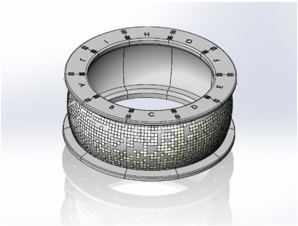


Figure 1. Computer-aided design image of a rotating mask to act as a physical information barrier. Figure provided courtesy of P. Marleau, Sandia National Laboratories.

As part of the renewed focus on arms control, DNN R&D and NPAC have engaged in a coordinated effort to align their plans and improve collaboration between their stakeholder communities. This engagement led DNN R&D to expand its monitoring and verification portfolio to include more nuclear compliance verification R&D. The recently started Test Material Needs for Arms Control project is being driven by this collaboration and is developing the research necessary for producing test samples, Figure 2, for verification team activities.

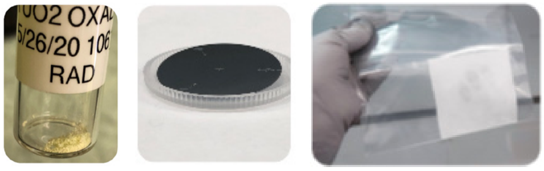


Figure 2. Photographs of example sample types: powder, metal, and swipes, to be developed through a new DNN R&D project. Images courtesy of M. Wellons and team, Savannah River National Laboratory. Original samples developed under previous NPAC program.

Overall, DNN R&D is looking forward to developing a wide array of capabilities over the next several years that provide a range of verification options for future arms control treaty negotiations. As stated by Office Director, Mr. Craig Sloan, "Anticipating future arms control technology needs is difficult, but we need to start developing those technologies now, to provide policy makers options before they enter into treaty negotiations. Additionally, by investing in this area, we are developing the next generation of experts in arms control monitoring and verification technology at the National Laboratories."

Dr. Yuri Podpaly is a Technical Advisor in the Proliferation Detection Office supporting the Emergency Response and Monitoring and Verification portfolios. Prior to joining DNN R&D, Dr. Podpaly was an Applied Physicist at Lawrence Livermore National Laboratory (LLNL) working on a variety of Defense Programs and Nonproliferation projects primarily focused on active interrogation and neutronics.

Dr. Marc Wonders was the 2020-2021 NGFP Fellow in DNN R&D supporting a range of office activities and portfolios, including the Monitoring and Verification portfolio. Prior to his fellowship, he completed his Ph.D. at Pennsylvania State University where his research focused on neutron detection and imaging for nonproliferation. In July 2021, he joined LLNL as a staff scientist.

LTC David Matters, Ph.D., is a Senior Program Manager in the Proliferation Detection Office for Emergency Response and Monitoring and Verification portfolios. Prior to joining NNSA, LTC Matters was a program manager in nuclear weapons effects at the Defense Threat Reduction Agency. He is a U.S. Army Nuclear Countering WMD officer, with active involvement in experimental nuclear physics research to help improve nuclear data.

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[1] *Interagency Working Group on Nuclear Arms Control Verification Challenges and Opportunities, Subcommittee on Nuclear Defense Research and Development, Committee on Homeland and National Security. "Nuclear Arms Control Verification Challenges and Opportunities for Limiting Nondeployed Warheads and Nonstrategic Nuclear Weapons." September, 2021. Distribution limited.*

[2] *National Academies of Sciences, Engineering, and Medicine 2021. Nuclear Proliferation and Arms Control Monitoring, Detection, and Verification: A National Security Priority: Interim Report. Washington, DC: The National Academies Press.* https://doi.org/10.17226/26088

[3] *Nuclear Threat Initiative. "Reducing Nuclear Risks: An Urgent Agenda for 2021 and Beyond." Available at:* https://www.nti.org/analysis/reports/nti-releases-transition-papers-nuclear-and-biological-threats/. *October 26, 2020.*

NNSA and Canadian Nuclear Laboratories Conduct Joint Nuclear Verification Exercise

By Erin Connolly and James Henkel, PhD

In November 2021, NNSA's Plutonium Verification Team and members of Canadian Nuclear Laboratories (CNL) participated in an in-person training exercise at Chalk River Laboratories in Ontario, Canada. The exercise was designed to collect samples from the National Research Experimental research reactor to enhance NNSA's rapid nuclear verification deployment capabilities.

Left: Team members from NNSA's Plutonium Verification Team and Canadian Nuclear Laboratories the National Research Experimental Reactor.

Above: Team members from NNSA's Plutonium Verification Team and Canadian Nuclear Laboratories assembling the tool used during the exercise.

"The Plutonium Verification Team is an essential part of NNSA's nuclear nonproliferation mission and ensures that the United States is prepared to support a variety of scenarios should they occur."

Assistant Deputy Administrator of Defense Nonproliferation

During the exercise, the Plutonium Verification Team trained to use a special verification tool built by the Mechanical Equipment Development branch of CNL, which produces one-of-a-kind tooling and equipment for nuclear power plants and utilities in Canada and for CNL's research and environmental remediation missions. In preparation for the exercise, the team coordinated with the National Research Experimental facility's decommissioning staff to test the new tool safely. The research reactor—Canada's first—was shut down in 1992 after operating for 45 years. It is now being prepared for decommissioning.

The verification tool allowed the team to collect metal samples from the interior pipes of the heavy water-moderated nuclear reactor to verify its operational history. The team also practiced "freeze" verification scenarios on the National Research Universal nuclear reactor. These hands-on activities facilitate sharing of expertise and experience among the NNSA team members and between the U.S. and Canadian counterparts.

The Plutonium Verification Team is a standing team in NNSA's Office of Nonproliferation and Arms Control (NPAC) that is prepared to implement negotiated verification measures in plutonium handling facilities.

"The Plutonium Verification Team is an essential part of NNSA's nuclear nonproliferation mission to develop and maintain unique capabilities on behalf of the United States to respond to a variety of nonproliferation scenarios," said Richard Goorevich, Assistant Deputy Administrator of Defense Nonproliferation and the head of NPAC.

"Global security, by its very definition, requires international cooperation, just as was demonstrated in this recent exercise," said Bhaskar Sur, Head of CNL's Safety & Security Directorate. "We were pleased to work with other leading national laboratories in supporting the Plutonium Verification Team, sharing knowledge and best practices, working together toward a safer and more secure world."

In addition to CNL's capabilities in nuclear forensics, detection, and safeguards, the execution of this exercise drew on CNL's deep experience in remote tooling built over many years of reactor support, as well as the operational strength of NNSA's team in facility decommissioning. Material samples extracted during the exercise will be used to help CNL decommission the reactor.

The United States and Canada continue to be close partners in their effort to prevent proliferation and reduce the risk of nuclear terrorism.

Members of the team include 15 experts from Pacific Northwest National Laboratory, Savannah River National Laboratory, Los Alamos National Laboratory, Sandia National Laboratories, and NNSA headquarters.

Erin Connolly is an NNSA Graduate Fellow in the Office of Nuclear Verification (NA-243).

James Henkel, PhD, is the Deputy Program Director for Nuclear Compliance and Verification in the Office of Nuclear Verification (NA-243).-Richard Goorevich,

Scribe3D©—More Than Just a Tabletop Exercise

By Todd Noel and Stephen Stromberg

To test physical security systems at facilities that house nuclear, radioactive, biological, or chemical materials, facility personnel often use tabletop exercises to discuss potential attacks and evaluate current system effectiveness. Previously, these exercises involved a paper map of the facility, with red and blue plastic figurines and toy vehicles representing the attack and response forces.

Not anymore.

"While tabletop exercises are an important tool for testing physical security designs, a three-dimensional model that coordinates multiple response factors in real time can reveal weaknesses not visible on paper," said Jordan Parks, Manager of Global Security Analysis & Simulation at Sandia National Laboratories. "Attacks can come from every possible direction—defense is not two-dimensional."

Developed at Sandia National Laboratories in support of the NNSA Office of International Nuclear Security's (INS) "Prevent" mission to thwart theft and sabotage, Scribe3D is a next-generation physical protection system analysis tool. It uses modern game engine technology to let users develop, play out, and analyze scenarios and exercises using a variety of high-fidelity facilities, props, personnel, weapons, and vehicles. Scribe3D is also used to study the impact of security upgrades at INS sites, provide a cost/benefit analysis, and help determine a roadmap for continued security improvements.

"The tool continues to evolve based on customer need," said Parks. "In 2021, we used Scribe3D to create training videos that reflect actual theft and sabotage events and to visualize next-generation threats such as attacks by unmanned aircraft systems or drones."

The ability to generate videos from any Scribe3D exercise also allows users to share tabletop exercises or create customized video content for continued training improvement.

Also new this year, the Sandia Global Security Analysis & Simulation team added a networking capability that allows Scribe3D users to conduct remote tabletop exercises, which reduces the cost of travel and risk of multi-agency or multi-national exercises during the pandemic. The team also added an integrated design toolkit with software that enables user terrain creation, facility modeling, physical security system layout, path analysis, and tabletop creation all in one tool, rather than paying for and integrating multiple tools.

Example for hypothetical scenario generated within Scribe3D with timeline and adversaries.

Still image generated by Scribe3D of a hypothetical facility on fire.

Scribe3D has gained wide domestic and international acceptance and has been licensed to 27 U.S. government agencies and national laboratories, 17 foreign national partners, four academic partners, and four commercial partners, with demonstrations set to take place in 11 countries this year.

Best of all, the Scribe3D software is freely licensed to partners. More information about the software, detailed technical specifications, and specifics about in-person or online user training is available at insetools.sandia.gov or by contacting Jordan Parks at mjparks@sandia.gov.

Todd and Stephen are software engineers in the Global Security Analysis and Simulation department at Sandia National Laboratories. They lead the Scribe3D development and outreach team and work with domestic and international partners to create and facilitate security exercises.

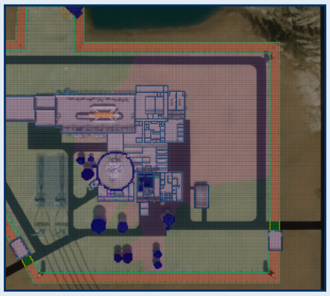
PathTrace—Simple Pathway Analysis and Exploration Tool

By Austin Orr

An individual determined to steal sensitive nuclear, radioactive, chemical, or biological materials, or to sabotage a facility housing these materials, will search for and use the path of least resistance to reach their target. PathTrace, developed by physical protection experts at Sandia National Laboratories (SNL) in support of NNSA's Office of International Nuclear Security, is a path analysis tool that uses established algorithms to help facility operators identify site security risks and vulnerabilities.

Users upload floorplans of real-world or hypothetical facilities, define site security components, detection areas, response force times, and targets, and use PathTrace to test the design and strength of their systems to find the quickest, stealthiest, and most vulnerable pathways to target locations. Depending on outcomes, users can vary the parameters of the attack, response force, or the security technologies of the facility, to see how these changes affect site security.

"The hidden strength of this tool is that its analytical algorithms draw from the real-world experience and scientifically-based data gathered throughout SNL's more than 75 years of nuclear security work," said Jordan Parks, Manager of Global Security Analysis & Simulation at SNL. "PathTrace is like a team of physical protection subject matter experts integrated into an easy-to-use, visually intuitive tool."



Overhead shot of a facility with PathTrace generated overlay.

Some of the uses for PathTrace include:

- Security-by-design. Early use of PathTrace can help developers evaluate and consider design and construction choices that integrate security into plans. Engineers in NNSA's Advanced Reactor Safeguards and the company X-Energy are using this tool to inform next-generation advanced and small modular reactor security designs.
- Vulnerability assessment and training. Facility operators can use PathTrace to identify site security risks, make changes on paper, re-analyze, and continuously improve security. Operators in Jordan, Mexico, and Egypt are in the process of licensing and applying PathTrace to their facilities.
- Assessment of upgrades PathTrace can help facility operators and government regulators evaluate upgrades to facility procedures or technologies to ensure they meet specifications and state/international requirements. In 2021, PathTrace was used to assess and verify facility upgrades at facilities in Romania and Nigeria.

"Multi-target path analysis is another of PathTrace's unique capabilities," said Parks. "For instance, sabotage or insider attacks may include targets in multiple locations. PathTrace is the only tool that can help operators evaluate multi-target scenarios to improve security preparedness and staff training."

International partners, U.S. Government agencies, universities, and commercial entities can license PathTrace for free. No advanced training or specialized hardware is needed to use this tool. More information about PathTrace is available at insetools.sandia.gov or by contacting Jordan Parks at mjparks@sandia.gov.

Austin is the primary software engineer leading the development of PathTrace. To continuously improve this valuable tool, he works with physical security subject matter experts to establish algorithms that help facility operators identify site security risks and vulnerabilities.

Conference – *Continued*

committee is the premiere international forum where IAEA Member States can discuss, develop standards and guidance for, and advance EPR principles.

EPR2021 was conducted in a hybrid format, held both in-person in Vienna and virtually. This format allowed a wider and more diverse audience to participate. There were 536 participants registered, including representatives from 90 IAEA Member States and nine international organizations – more than the previous two IAEA emergency preparedness conferences.

NNSA representatives from across the Nuclear Security Enterprise also chaired a session, delivered presentations, and presented posters on a variety of EPR topics, including considerations for using unmanned aerial systems in radiation monitoring; combating disinformation and malinformation during an emergency; lessons learned from prior radiological releases; U.S. participation in IAEA Convention Exercises; and international EPR cooperation for major public events.

EPR2021 was a key event to further progress and build international capacity for response, and a conference report will be produced by the IAEA summarizing all conference sessions. The report will include six key recommendations from Conference President Heinrich and will encourage decision makers and relevant organizations to dedicate themselves to their implementation. Helena Craig is an NGFP Fellow in the Office of Nuclear Incident Policy and Cooperation (NIPC). Patrick Disney is a Foreign Affairs Specialist contractor in NIPC. Paloma Richard is a Management and Program Analyst in NIPC.

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