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

DNN Sentinel

DEFENSE BY OTHER MEANS

VOL. XI, NO. 1

IN THIS ISSUE:

Adapting, Responding, and Incorporating

with a focus on Emerging Technology

DNN SENTINEL:
DEFENSE BY OTHER MEANS

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

From the Deputy Administrator

This edition of the Sentinel coincides with my second anniversary as Deputy Administrator for Defense Nuclear Nonproliferation. Looking back on these two years, I find myself marveling at the dedication of the people in DNN as they confronted challenge after challenge in our mission space. I am proud to be counted among them.

One of the major challenges we have had to face as an organization is emerging technology. Lately it seems as though there is a new iPhone update, a new must-have gadget, or some kind of "once in a generation" technological breakthrough every day. Emerging Technology has expanded into every corner of our personal and professional lives, including the defense and nonproliferation space. Technological advancements like AI, microelectronics, and fusion are both enabling and testing NNSA's ability to adapt, respond, and innovate. From a nonproliferation perspective, these critical emerging technologies are key to responding to an evolving threat environment.

That said, new technology is built from and within the technological world that we have been working in for decades. We have to think holistically in how we approach these new technologies, evaluating their risks and benefits, to see how they can integrate into and affect the capabilities we already have or are seeking. This requires a creative approach to problem solving which allows us to consider how we might be more agile in integrating new and old technology moving forward. By emphasizing creative approaches, NNSA can combat normal bureaucratic resistance to change.

DNN has risen to the challenge of incorporating the fast-paced emergence of technological capabilities into the way we approach our mission. Over the past fifteen years DNN's R&D program, for example, has seen exponential growth, evolving from a "hobby shop" with small individual projects to a much larger enterprise as the strategic mission started focusing more on the importance of technology. Today, most of R&D's budget is allocated to larger projects where problems require multidisciplinary expertise with input from multiple laboratories. Most emerging technologies don't sit squarely inside one topic or threat category.

While evaluating emerging technologies for risks from a national security perspective, it is important that we simultaneously consider how these new technologies can be leveraged while implementing and maintaining necessary security guardrails. This requires a deeper understanding of the assets and resources we have readily available to us at our national laboratories' facilities and sites. Together with our national laboratories, DNN is confident we'll be able to incorporate creative solutions that allow us to adapt and respond together towards a more secure future.

As I enter my third year as Deputy Administrator, I look forward to seeing how DNN manages the challenges and opportunities of working this technology-forward environment. I hope this issue of the DNN Sentinel highlights some of the ways it is already doing so, for the benefit of NNSA and the United States.

Corey

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Gamma-Ray Imaging Helps Us See What Is Left Behind

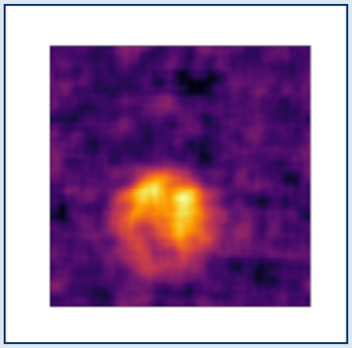
By Francisco Gonzalez

The Office of Material Management and Minimization (M3), Office of Plutonium Disposition continues to work towards disposal of 34 metric tons of surplus weapons-grade plutonium through the Surplus Plutonium Disposition (SPD) program. SPD employs a dilute-and-dispose strategy, which reduces the material's attractiveness by blending plutonium oxide with an adulterant and packages it for safe disposal as transuranic waste at the Waste Isolation Pilot Plant (WIPP) in New Mexico. An ongoing capital line item, the SPD project aims to quadruple the number of gloveboxes the program employs for downblending by approximately 2030.

The ability to accurately measure quantities of nuclear material is essential to the safety and security of this mission. Holdup—nuclear material left behind in gloveboxes, for example—is a particular measurement challenge. When material is deposited in a crevice, absorbed into a surface, or hidden out of view, it must be located and quantified to fulfill nuclear material accounting requirements, minimize potential radiological dose to workers, and increase nuclear criticality safety.

The established method to measure holdup is by detecting gamma rays emitted by the material. Gamma rays are a high-energy form of electromagnetic radiation that are not visible but provide an identifiable signature of the material in a detector. This established approach measures only the intensities of certain gamma rays from the source. However, these measurements are hampered by uncertainties in the locations and properties of the plutonium deposits. Additionally, new gloveboxes set up by the SPD project will be shielded, further complicating the ability to perform measurements using this method.

M3 initiated the Strategic Laboratory Assessment (SLA)—a collaboration between Oak Ridge (ORNL) and Savannah River National Laboratories (SRNL)—in 2020 to identify and explore innovation and technology opportunities to make the surplus plutonium disposition mission faster, cheaper, and safer. The SLA team works closely with Savannah River Nuclear Solutions (SRNS), the contractor who manages plutonium downblending operations at the Savannah River Site (SRS), to explore implementation of a novel technology to measure holdup material.



A gamma-ray image acquired during a proof-of-concept experiment reveals the distribution of plutonium oxide inside a glovebox. Photo Credit: Jacob Daughhetee, ORNL

Commercial gamma-ray imagers from H3D based on room-temperature detectors are a recent innovation enabling this work. Photo credit: Klaus-Peter Ziock, ORNL.

Commercial gamma-ray imagers, which function like cameras for gamma radiation, are a recent innovation that identify radioactive sources and quantify the amount of material in the source. The SLA team is investigating employing gamma-ray imagers for mapping plutonium inside the SPD gloveboxes. The resulting gamma-ray images can then be mapped to the glovebox layout, providing pictures of the plutonium inside. Using these images, the evolution of holdup over time can be accounted for to inform plans for glovebox cleaning and identify problem areas.

In spring 2023, a gamma-ray imager produced by H3D was temporarily incorporated into an operating glovebox by SRNS at SRS to provide a proof of concept for gamma ray imaging in the context of plutonium downblending. By analyzing data from this deployment, the imaging team successfully determined the amount of holdup plutonium in an outlet-air filter with improved precision when compared to the established method. The images also provided snapshots of nuclear material during processing that displayed locations of plutonium elsewhere in the glovebox.

In future work, gamma-ray imaging is intended to enable continuous measurements of the glovebox with automated operation and data analysis for rapid decision-making. The method will use data from multiple imagers, which would ultimately be integrated into glovebox light fixtures. Using multiple imagers provides the opportunity to triangulate radioactive material for three-dimensional reconstruction and increases the visible area of the glovebox. Analysis algorithms are being designed to provide holdup measurements in a matter of minutes to reduce outages

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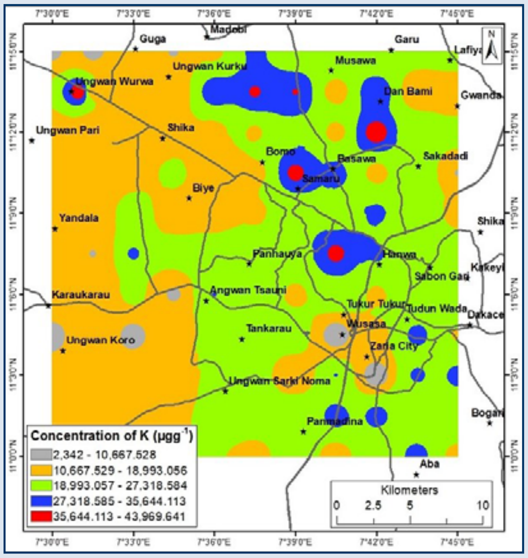
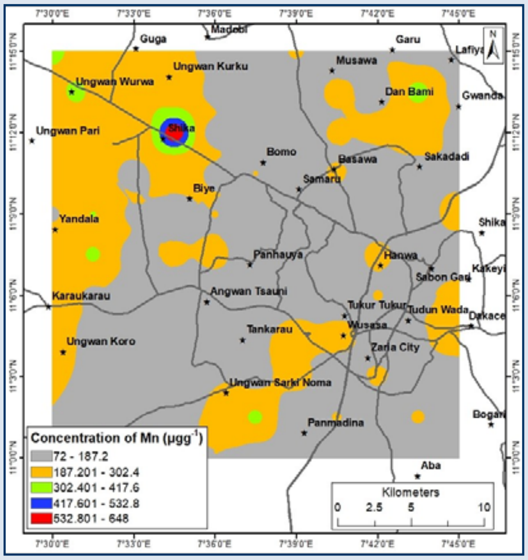
Nigeria's Converted MNSR Continues to Provide Valuable Scientific Insights

By Alexandra Meehan

In 2018, Nigeria successfully converted the NIRR-1, a Miniature Neutron Source Reactor (MNSR), from weapons-usable highly enriched uranium (HEU) to low enriched uranium (LEU). The conversion of research reactors around the world from HEU to LEU fuels is part of international efforts to minimize the civilian use of HEU and reduce associated security and proliferation risks. The conversion project was initiated by the Nigeria Atomic Energy Commission (NAEC) and the International Atomic Energy Agency (IAEA), with support from China, Norway, the United Kingdom, and the U.S. Department of Energy's National Nuclear Security Administration (NNSA). The conversion of NIRR-1 allowed for the successful repatriation of more than 1 kilogram of Chinese-origin highly enriched uranium (HEU), making Nigeria HEU-free. Five years later the NIRR-1 continues to provide valuable scientific insights for Nigeria.



Above: Geochemical map showing the distribution of Potassium (K) in the area of study. Below: Geochemical map showing the distribution of Manganese (Mn) in the area of study.



Nigeria faces a growing threat due to food insecurity. As a result of environmental degradation, climate change, and conflicts, Nigerian food production has been in decline. This reduction in overall food production can be partially attributed to the loss of key nutrients in the soil.

In 2022, the Centre for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria, launched a pilot project entitled "Soil Fertility and Geochemical Mapping of Arable Lands in Nigeria," to map soil fertility across an initial set of four local Government Councils (i.e., Zaria, Sabon-Gari, Giwa, and Kudan in Kaduna State), with the goal of expanding the project across the entire nation.

This project aims to assist Nigerian farmers in identifying which nutrients are deficient so they can apply the most effective fertilizers on their crops to increase yields.

To accomplish this goal, CERT leveraged the multi-element capabilities of Nigeria's NIRR-1, which is specifically designed for Neutron Activation Analysis, to analyze trace minor, and major elements in multiple soil samples from each of the four local councils. Using this Multivariate Statistical Analysis, the CERT team found three geochemically distinct groups in local soil samples. The geochemical characteristics, with a few exceptions, compared favorably with other agrarian soils in the world, meaning that the soil can be used and improved effectively.

CERT then created detailed geochemical maps of each region to illustrate the sample testing results to highlight the variability of Nigerian soil across the different Government Councils. These maps will be used to assist Nigerian agricultural experts in defining quick and affordable methods to improve both farming practices and nutrient enrichment efforts to improve food production across the country.

Alexandra (Alex) is a federal program manager for the Office of Reactor Conversion and Uranium Supply's Proliferation Resistance Optimization (PRO-X) Program within DOE/NNSA.

Risks and Opportunities of Artificial Intelligence Foundation Models

By Paul Adamson

In recent years, the world has witnessed an unprecedented explosion in generative artificial intelligence (AI), thanks in no small part to the rise of foundation models. These massive deep neural networks have become the bedrock upon which several creative and transformative AI applications have been built. Both commercial and open-source initiatives have harnessed the power of foundation models to unlock new possibilities in a wide array of domains.

The term "foundation model" refers to the underlying architecture and pre-trained weights of these neural networks, which can then be fine-tuned for specific downstream tasks. Foundation models are exceptionally large neural networks that have been designed to understand and generate human-like text, images, and even audio. While training the largest foundation models takes tens or hundreds of terabytes (or more) of training data and can cost millions of dollars in specialized computational power, the fine-tuning process can generally be done with much less data and for much lower cost.

Foundation models are exceptionally large deep neural networks that have enabled the emergence of generative artificial intelligence that is designed to understand and generate human-like text, images, and even audio.

The STEEL THREAD venture in DNN R&D is leveraging the billion-dollar investment in foundation models to develop a "model in a month" capability to enable rapid deployment of future AI capabilities to detect, locate, and characterize nuclear threats.

One of the most prominent foundation models is the "generative pre-trained transformer" (GPT) model developed by OpenAI (e.g., GPT-3, -3.5, and -4) that enables ChatGPT and recent enhancements to the Microsoft Bing search engine. Similarly, Google's Pathways Language Model 2 (PaLM 2) is powering Google Bard, an experimental productivity tool. OpenAI and Microsoft have also partnered with GitHub to provide an AI pair programmer, which is a tool designed to assist developers with writing code, called Copilot.

In parallel, open-source projects have played a pivotal role in democratizing AI. Hugging Face's Transformers library provides thousands of pretrained models and Google's TensorFlow has allowed developers to quickly build on the progress made by both the commercial and open-source communities. This open collaboration has helped foster an environment of innovation and creativity.

Risks and Opportunities in Nuclear Security

However, with great power comes great responsibility, and the misuse of generative AI poses several risks in various nuclear security domains. For example, generative AI can be exploited to create convincing deepfake audio, video, or text, potentially undermining trust and security. AI could enable cyberattacks targeting critical infrastructure, including nuclear facilities, with enhanced sophistication and velocity. Finally, as AI models are trained on vast datasets, there is a concern that sensitive information may be more easily aggregated and accessible.

When applied responsibly, AI has the potential to enable broad positive transformations in nuclear security. For instance, in certain verification and monitoring applications where limited real-world images exist, generative AI can produce synthetic images that can be used to train computer vision models. Similarly, AI models can also help analysts assess geopolitical situations, detect potential threats, and provide useful insights. Finally, AI-powered translation and communication tools can facilitate dialogue between nations, potentially reducing misunderstandings and enhancing diplomatic efforts.

STEEL THREAD Venture

The DNN R&D venture STEEL THREAD is leveraging the billion-dollar investments in foundation models from industry and open source to combine it with unique DOE & NNSA expertise in nonproliferation, sensors, and facilities. This work combines the efforts of five DOE & N NSA national laboratories (LLNL, LANL, SNL, PNNL, and ORNL) and includes (1) the development of foundation models for nonproliferation detection, localization and characterization, (2) the creation of mission-focused benchmarks and best practices to evaluate foundation models, and (3) the development of human-AI partnership capabilities to evaluate foundation model trustworthiness. These efforts will improve end-user interactions with AI models, boost model performance, and deliver value to the end-user for gaining insights about proliferation threats.

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Physics Experiment-1: Detection R&D to Improve Monitoring of Evasive Underground Nuclear Explosions

By Brian Paeth, Beth Dzenitis

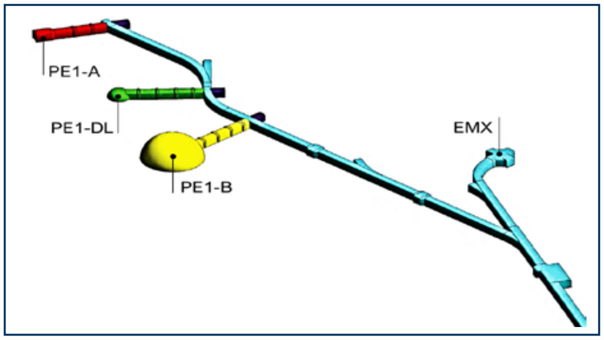
For political or military reasons, countries may seek to advance their own nuclear weapons capabilities by evasively conducting an underground nuclear explosion (UNE). Detecting a UNE generally involves monitoring prompt signals from shock effects and non-prompt signals from decaying radionuclides. Decoupling, when an explosion is detonated in a large cavity deep underground, can make the shock effect of a large explosion appear smaller. While decoupling does not eliminate seismic signals, it does change how prompt and non-prompt phenomena interact with the surrounding environment. The challenge of understanding those interactions led the Office of Defense Nuclear Nonproliferation Research and Development (DNN R&D) to develop a program to improve U.S. capabilities to detect and characterize low-yield, evasively conducted UNEs.

The crafts needed to complete the horizontal concrete plug included carpenters and ironworkers who built the bulkheads needed to support five separate grout pours over five months.

This research is performed by Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Pacific Northwest National Laboratory, and Sandia National Laboratories. The scientific focus is to validate physics-based models and data-based algorithms for predicting and detecting signatures from low-yield, evasively conducted UNEs. Because historical data from low-yield decoupled nuclear tests is limited, researchers, in partnership with the Nevada National Security Site (NNSS), designed an integrated field experiment campaign, Physics Experiment 1 (PE1), to validate predictive models and detection algorithms against ground truth data.

PE1 is a multi-year campaign of seven experiments at the NNSS consisting of separate chemical high-explosive (HE), tracer, and electromagnetic sources, which are capable of producing prompt seismic and electromagnetic signals and emulating the transport and chemistry of non-prompt radionuclide signals. No nuclear material is used in these experiments. Using proxies for nuclear explosions follows what was done in past monitoring R&D experiments—most notably the Nonproliferation Experiment (NPE) in 1993 and the Source Physics Experiment (SPE) in 2011–2019.

The PE1 testbed is at P-tunnel in Area 12 at the NNSS, where preparations for a nuclear test were discontinued with the 1992 nuclear explosive test moratorium, leaving a series of mined drifts available for other uses. The first phase of PE1 testbed development was conducted 2021–2022 and included P-tunnel infrastructure updates, targeted site characterization campaigns, excavation of 3 experiment drifts, drilling, and coring of 18 instrumentation boreholes, and emplacement of nearly 1,000 sensors. During this time DNN conducted, three experiments—two focused on measuring atmospheric flow patterns and material releases in complex terrain on the surface and one designed to produce low-frequency electromagnetic signals for the explosive experiments and detecting these signals underground and on the surface.



The planned layout of the four subsurface experiments in Physics Experiment 1 (PE1). Existing P-tunnel drifts are shaded blue. Excavation of new drifts (red, green, yellow) for the experiments occurred in 2021. Excavation of the PE1-B and PE1-DL cavities are planned to start in 2024.

By mid-2023, the team emplaced the HE source and tracers for the first explosive experiment, PE1-A, and filled the voids between the HE source and surrounding geology with approximately 5,000 sandbags and loose sand to ensure adequate coupling. They then constructed a 56 ft horizontal concrete plug in the drift leading to the HE chamber to confine tracer materials and explosive by-products, driving the migration path of these elements into the surrounding geology with the resulting detonation pressure. These efforts required extensive craft labor and coordination to mix, deliver, and pour over 350 cubic yards of concrete.

The PE1-A experiment began on October 18, 2023. Experts used accelerometers, seismometers, infrasound sensors, electromagnetic sensors, and chemical and radiotracer samplers to collect measurements. This data will support first-principal model validation, address the seismic equivalence factor for chemical and nuclear explosions, and facilitate verification of analytical methods for low yield monitoring. A team of scientists, engineers, miners, drillers, and trades worked together successfully in a complex environment.

For the three remaining experiments, including two chemical explosions and a surface radiotracer release, a second testbed development phase is needed. This development will begin in 2024 with the excavation of two experiment chambers, drilling and coring of additional instrumentation boreholes, site characterization, and instrumentation emplacement activities.

The equipment in P-Tunnel used to generate the synthetic electromagnetic signal used in the April 2022 PE1 experiment.

Experiment Name	Date	Short Description and Scientific Basis
METEX	March 20–28, 2021	The Meteorology Experiment (METEX) captured wind and thermodynamic conditions in the planetary boundary layer that influence atmospheric transport and diffusion of smoke in complex terrain. Thirty-four smoke releases were conducted over 7 days to study plume behavior out to 5 km.
EMX	April 25–28, 2022	The Electromagnetic Experiment (EMX) emulated the late-time electromagnetic signature of an underground nuclear explosion. Electromagnetic transmissions were measured from a synthetic EM source located in P-Tunnel on sensors in the tunnel and on Aqueduct Mesa about 1 km away.
REACT	October 14–17, 2022	The Release Activity Experiment (REACT) optimized sensor locations and exercised the radiotracer release system. Six radiotracer and smoke releases were conducted over 4 days to evaluate sample collection processes out to 5 km to inform models for sensor placement during METREX, which is intended to acquire data at tens of kilometers.
PE1-A	October 18, 2023	Experiment A (PE1-A) detonated a fully coupled 16.3 metric ton chemical HE source (Comp-B) with collocated stable and radiotracers at a depth of 267 m. It produced the largest seismic signal of the planned PE1 series, and the transport and chemistry of the tracers was studied over several weeks.
METREX	TBD	The Meteorology and Tracer Release Experiment (METREX) will build upon REACT, with the goal to extend the radiotracer sensor locations out to about 30 km.
PE1-B	TBD	Experiment B (PE1-B) has the same explosive yield as PE1-A but will be conducted in a cavity sized to create a fully decoupled seismic signal—the smallest of the PE1 series.
PE1-DL	TBD	Experiment DL (PE1-DL) has the same explosive yield as PE1-A and PE1-B but will be conducted in a smaller cavity to create a partially decoupled seismic signal.

Physics Experiment 1 (PE1) experiments and their objectives.

Brian is a Senior Program Manager in DNN R&D's Office of Nuclear Detonation Detection and directs efforts involving large field campaigns designed to improve capabilities to detect and characterize underground nuclear explosions. Prior to joining NNSA in 2018, he served in the U.S. Air Force for 25 years in a variety of nuclear-related operations and staff assignments, most recently at the U.S. Department of State.

Beth is a Senior Project Engineer at Lawrence Livermore National Laboratory in Global Security's N-Program and has been the Venture Manager and Experiment Lead for the first large-scale field experiment, Physics Experiment 1 (PE1) since 2018. Prior to this programmatic assignment, she led the execution of nine explosive experiments at the NNSS.

The Role of Nuclear Power in Future U.S. and Global Clean Energy Strategies

By Stella Gae Bub

Introduction

The world is facing an unprecedented energy crisis, and the need for clean, sustainable, and reliable sources of energy has never been more urgent. Nuclear power has long been touted as a potential solution to this crisis, offering a low-carbon alternative to fossil fuels. In this article, we will explore the role of nuclear power in future US and global clean energy strategies, highlighting the benefits of nuclear power and the challenges it poses for nuclear safeguard efforts.

Benefits of Nuclear Power

Nuclear power offers several benefits over other sources of energy, including:

1. ***Low-carbon emissions:*** Nuclear power is a low-carbon source of energy, producing virtually no greenhouse gas emissions during operation. This makes it an attractive option for mitigating climate change.

2. ***High energy density:*** Nuclear power has a high energy density, meaning that a small amount of fuel can produce a large amount of energy. This makes it an efficient source of baseload power.

3. ***Reliability:*** Nuclear power plants have a high capacity factor, meaning that they operate at or near full capacity for a high percentage of the time. This makes them a reliable source of electricity.

4. ***Job creation:*** The nuclear industry is a significant employer, providing high-paying jobs for thousands of workers.

5. ***Medical applications:*** Nuclear technology has numerous medical applications, including the diagnosis and treatment of diseases such as cancer.

The increased diversity of nuclear reactor types will drive innovation and competition in the nuclear industry, leading to more efficient and cost-effective nuclear power plants.

The Potential Increase in Diversity of Reactor Types

One of the key trends in the nuclear industry is the development of new reactor types, which offer improved safety, efficiency, and cost-effectiveness. These new reactor types include small modular reactors (SMRs), which are smaller and more flexible than traditional reactors, and advanced reactors, which use new technologies to improve safety and efficiency.

The increased diversity of reactor types will drive innovation and competition in the nuclear industry, leading to more efficient and cost-effective nuclear power plants. However, it will also pose challenges for nuclear safeguard efforts, as regulators will need to ensure that these new reactor types meet strict safety and security standards.

Regulators will need to ensure that new reactors are built and operated safely and securely, and that they meet strict international safeguards and nonproliferation standards.

The Increased Number of Reactors

Another trend in the nuclear industry is the construction of new reactors, both in the US and around the world. According to the World Nuclear Association, there are currently 60 reactors under construction globally, with hundreds more planned or proposed.

The increased numbers of reactors will provide a significant boost to global clean energy efforts, but it will also pose challenges for nuclear safeguard efforts. Regulators will need to ensure that these new reactors are built and operated safely and securely, and that they meet strict international safeguards and nonproliferation standards.

Conclusion

In conclusion, nuclear power has an important role to play in future US and global clean energy strategies. The benefits of nuclear power, combined with the development of new reactor types and the construction of new reactors, make it a promising solution to the world's energy crisis. However, the increased diversity of reactor types and the increased numbers of reactors will pose significant challenges for nuclear safeguard efforts, requiring regulators to ensure that these new technologies are developed and deployed safely and securely.

**This article was written by AI.*

Stella is a researcher in DNN R&D.

U.S. Laboratories Begin Production of Nuclear Reference Particles

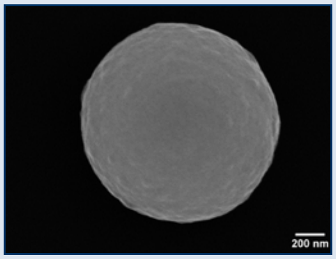
By Drs. Timothy Pope, Matthew Wellons, Travis Tenner, and Ning Xu

At the end of September 2022, a U.S. DOE laboratory team demonstrated to the IAEA the successful production of quality control reference materials for analysis of particles in environmental samples. "The science is great!", exclaimed Steven Balsley, Director of IAEA Safeguards Analytical Services, during the demonstration. This capability has been long sought by the IAEA to reinforce quality management of environmental sample analysis in the IAEA's Network of Analytical Laboratories (NWAL). Savannah River National Laboratory (SRNL) and Pacific Northwest National Laboratory (PNNL) joined Forschungszentrum Jülich (FZ Jülich, Germany) as the only three laboratories in the world capable of providing this support to the IAEA.

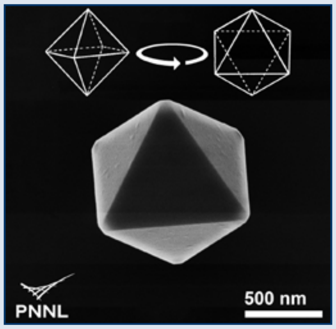
The collection of environmental swipe samples is an essential tool used by the IAEA Department of Safeguards to verify the peaceful use of nuclear material. IAEA safeguards inspectors collect samples by swiping clean cotton cloths across surfaces in a facility to pick up millions of tiny, micrometer-sized dust particles. IAEA inspectors carry the swipe samples back to IAEA Headquarters where they are anonymized and distributed to NWAL for analysis. Analysis of samples reveals presence of nuclear materials, such as separated plutonium or highly enriched uranium, and the age of the nuclear material. The IAEA evaluates samples taken from the same locations over many years to study a facility's operation history, and to detect activities not declared to the IAEA.

Analysis of particle material collected by swipe is accomplished using highly sensitive mass spectrometers that can measure the isotopic composition of individual particles to determine their enrichment level and processing history. Quality control reference materials for instrument calibration and measurement validation are vital to generate accurate and precise measurement data. However, up to now the IAEA did not have access to a broad range of particle reference materials at the micrometer size with relevant chemistry and specific isotope ratios.

With support from DNN, SRNL and PNNL have worked for almost a decade to develop two distinct production methods for tailored nuclear particle standards. SRNL uses an aerosol-based, spray-drying approach which transforms the target particles suspended in liquid into droplets that are then sprayed and dried to the desired size. PNNL uses a hydrothermal direct-synthesis method that produces single crystal particles by controlling temperature and high pressure of a target composition. Both approaches have generated uranium particles with specific compositions to compare against matter collected by environmental swipe sampling.



Above: Scanning electron micrograph of a mixed uranium-plutonium oxide particle displaying spherical morphology and approximate diameter of 1.09 µm. Below: Microscopy image of a uranium oxide particle produced by the PNNL hydrothermal method.



Los Alamos National Laboratory (LANL) provides analytical support to characterize the nuclear particle products to ensure IAEA specifications are met. SRNL produced the first ever uranium-plutonium containing particles.

SRNL and PNNL are the only producers of mixed actinide particles. PNNL is developing the first uranium-thorium containing particles for use as age-dating standards. The addition of U.S. laboratories to the IAEA NWAL as reference particle producers provides sustainable support to aid the IAEA in drawing safeguards conclusions

Matthew is the principal investigator for the particle working standards development project and a portfolio manager in the National Security Directorate at SRNL. Matt has over a decade of R&D experience leading projects focused on addressing various nonproliferation and nuclear safeguards technical challenges, including development of aerosol and inkjet-based synthesis platforms for the manufacture of reference particulate materials for the IAEA.

Timothy is the principal investigator for the particle working standards development project and a materials scientist in the Engineered Materials Group of the National Security Directorate at PNNL. Tim has extensive background with over ten years of experience in synthesis and characterization of advanced materials and led the team to develop the hydrothermal synthesis methods to produce uranium and mixed actinide reference materials.

Travis is co-principal investigator for the particle working standards development project and a scientist in the Chemistry Division at the LANL. Travis has over 15 years of experience in secondary ion mass spectrometry and supports the characterization of reference particles generated by SRNL and PNNL.

Ning is a LANL actinide analytical chemist and serves as a technical advisor in the Office of Nonproliferation and Arms Control, International Nuclear Safeguards, managing the particle working standards development project.

Gamma-Ray Imaging Helps Us See What Is Left Behind– *Continued*

The novel application of this imaging technology in nuclear material handling gloveboxes has implications beyond the surplus plutonium disposition mission. These innovations have the potential to support missions throughout the DOE/NNSA complex and can help the U.S. achieve its nonproliferation goals.

Francisco is a Radiation Detection and Imaging Scientist at Oak Ridge National Laboratory. He holds a PhD in nuclear physics from Indiana University, and in addition to his present imaging research, he has previously worked on precision neutron decay physics.

Risks and Opportunities of Artificial Intelligence Foundation Models– *Continued*

As an experiment and demonstration of the power of foundation models, LLNL developed a simple workflow to generate Sentinel articles using three widely distributed open-source models, Falcon, LLaMa2, and StableBeluga2. The models were “sandboxed” in a secure way on a closed network with no connectivity to the outside world, and a range of prompts were used to generate convincing articles for a variety of nuclear nonproliferation topics. See if you can spot one of those articles in this edition of the Sentinel! (Hint: there is one numerical value in the article that had to be updated for correctness since the data used to train the foundation model had outdated information.)

Paul is the DNN R&D Senior Program Manager for Data Science