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IN THIS ISSUE:

Shaping the Future of Nuclear Security

DNN SENTINEL:
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From the Leadership of the Office of Defense Nuclear Nonproliferation

As more traditional, state-based political and military crises have once again taken center stage, global attention on both nuclear security and the threats posed by non-state-actors has waned. During the era of Nuclear Security Summits, dozens of actions and commitments were made—and delivered—by leaders to advance global nuclear security. Since then, however, it sometime has been challenging to maintain attention on these issues, even as the threat of nuclear and radiological terrorism has not gone away. Indeed, the challenges to strengthening global nuclear security have grown even more complex.

The number of nuclear facilities is expected to expand over the coming decades, as countries look to deploy small modular and advanced reactors to help meet their climate and energy security goals. While nuclear energy must be a part of addressing the climate crisis, this expansion of nuclear technology for peaceful uses may create new vulnerabilities. Rapidly emerging technologies, such as artificial intelligence, advanced cyber capabilities, and uncrewed aerial systems, can be applied to support our efforts to counter theft of nuclear material and sabotage of nuclear facilities. However, they can also be used to strain and subvert the existing nuclear security regimes, frameworks, and tools available to us.

It is imperative for the United States and the international community to work together to stay vigilant and sustain nuclear security efforts. This month, Deputy Secretary of Energy David Turk is heading the U.S. delegation to the fourth International Conference on Nuclear Security (ICONS) in Vienna, Austria. This year's ICONS, which gathers international nuclear security policymakers and practitioners every four years, offers a critical opportunity for the United States to refocus international attention and promote progress towards meeting these critical challenges to global nuclear security. We are honored to support the Deputy Secretary in helping to lead the charge at this year's ICONS. We hope that the articles included in this issue of the Sentinel highlight some of important ways that DNN is working to enhance global nuclear security.

Jeff

Acting Principal Assistant Deputy Administrator

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NNSA ARTICLES

Words From the White House on ICONS 2024

In March 2023 the Biden Administration started implementing National Security Memorandum 19 (NSM-19), a comprehensive strategy for addressing its nuclear security priorities, especially the threats posed by nuclear terrorism. Just ahead of the 2024 International Convention on Nuclear Security (ICONS), Pranay Vaddi, Special Assistant to President Biden and Senior Director for Arms Control Disarmament and Nonproliferation at the National Security Council, took time to discuss how NSM-19 advances the Biden Administration's approach to nuclear security and how it intersects with the goals of ICONS.

Pranay Vaddi, Special Assistant to President Biden and Senior Director for Arms Control Disarmament and Nonproliferation at the National Security Council

"The Biden Administration wants NSM-19 to have an enduring impact and become part of the IAEA's function," Vaddi said. ICONS is an opportunity to push that message forward and show that we are walking the walk.

"Since the last ICONS (in 2020), the United States has demonstrated leadership on nuclear security by converting research reactors from highly enriched uranium to low-enriched uranium; removing and disposing material; transitioning away from radiological sources in hospitals domestically; and participating in an International Physical Protection Advisory Service (IPPAS) mission," he said.

In a period of heightened great power competition it is essential to maintain focus on the nuclear threats posed by non-state actors.

"The absence of cooperation from U.S. counterparts—i.e., Russia and China—makes it difficult to address nuclear terrorism as an international issue. Addressing risks of nuclear terrorism cannot wait until the geopolitical environment is more favorable."

The United States is working to adapt to this uncertain landscape, maintain attention on the threat of nuclear terrorism, and address the risks posed by a diverse range of actors. During ICONS and beyond, U.S. agencies will deepen international cooperation where it is possible and expand partnerships in new places to combat emerging threats. As an example, Vaddi pointed to the G7 Non-Proliferation Directors Group, where consistency and transparency offer opportunities to cooperate to reduce nuclear risks.

Cooperation on nuclear security is not limited to the international space. NSM-19 reaffirms the Biden Administration's commitment to work with state, local, and tribal governments on nuclear security in line with the National Security Strategy. A key part relates to risks posed by new nuclear technologies and balancing the competitiveness of U.S. nuclear industry and proliferation risks.

"New technologies present exciting opportunities as the United States look towards nuclear energy as a vital part of the solution to the ongoing climate crisis," Vaddi said. "When we export our tech we are exporting our nonproliferation practices."

The United States wants to avoid additional nuclear risks that might arise with technological advances in less strict security environments. Emphasizing the importance of nuclear safety, security, and safeguards by design, and only sourcing nuclear fuel from suppliers that uphold nuclear security standards can improve implementation for nuclear newcomers.

"By setting the highest security standards and implementing them, the United States Government establishes a blueprint for other countries and industry to follow," he said. Through open communication and expanded outreach, the United States can ensure that its policies are reflected by industry to improve nuclear security and expand industry innovation and competition.

As the nuclear security environment changes, national risk-mitigation frameworks must adapt. NSM-19 is the first time that the security of radioactive material has been highlighted as a specific area of national concern. The memorandum seeks to address the uncertainty created by new technologies and their possible implications for proliferation in the nuclear space.

With the increase in nuclear energy and advanced reactors, there will be new countries exploring nuclear energy—NSM-19 helps create a world where they can pursue peaceful uses of nuclear technologies while mitigating proliferation risks.

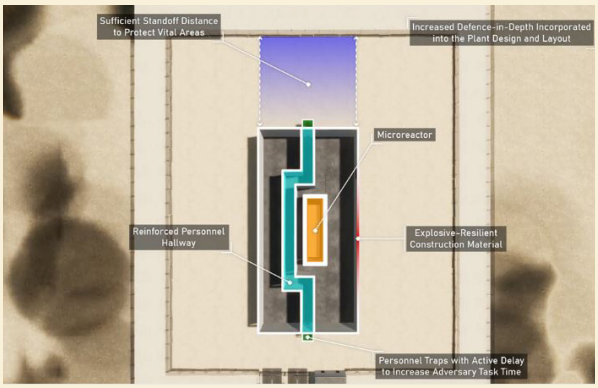
The world is looking towards nuclear energy as a solution for the climate crisis while also facing uncertainty about nuclear security in armed conflict. As more nuclear technologies are deployed for peaceful uses, proliferation risks accompany them. ICONS presents an opportunity for the United States to refocus the international community on combatting nuclear terrorism, reducing risks, and encouraging the peaceful use of the atom across the world.

"ICONS offers a platform for the Administration to integrate NSM-19 into the existing international structures and norms the U.S. seeks to reinforce," Vaddi said.

Making New Nuclear Reactors More Secure

By Jorge Navarro, PhD., Mikhail Pellegrino, JD, Troy Alexander, Anagha Iyengar, PhD., Adam Williams

Nuclear security by design (SeBD) is a risk-based approach that seeks to eliminate a system's vulnerabilities to theft, sabotage, or other malicious acts by integrating security features early in the design process. SeBD emphasizes the consideration, during the system and facility design phase, of the security aspects for a facility during all phases of its lifecycle, from conceptual design, through construction, operation, and decommissioning. Adopting a SeBD methodology early in the design phase allows for the optimization of a facility's components or layouts to reduce security risks, while still meeting the functional design requirements and preventing the need for expensive retrofits or added security resources later.



What is Security by Design?

Risk-based approach to nuclear security that seeks to eliminate vulnerabilities to theft, sabotage, or other malicious acts by integrating security features early in the design process and throughout the facility life cycle.

> ***"Working with industry on safeguards and security by design increases the proliferation resistance of American nuclear technologies. By ensuring that our designs meet the highest standards of nonproliferation, we can decrease the burden on importing countries and increase the worldwide adoption of American technologies."***
>
> NNSA Administrator Jill Hruby's Remarks to the Commission on Nuclear Energy and Climate Security of the Council on Strategic Risks I, October 12, 2023.

SeBD is a concept that has been garnering increased attention in the nonproliferation community and gaining traction among the nuclear industry—particularly in response to increasing interest both domestically and internationally in advanced and small modular reactor (A/SMR) technologies. As most of the A/SMR technologies under consideration for future deployment are currently in the design stage, they present a clear opportunity for applying SeBD.

Most A/SMR designs currently under development in the United States and in other countries differ significantly from the commercial reactors operating today, which largely use light-water reactor technology. Some of these new concepts introduce a number of potential security challenges, including:

- Embarking countries may not have sufficient national infrastructure for nuclear energy programs, including experience in nuclear security programs.
- A/SMRs being designed to utilize High Assay Low Enriched Uranium (HALEU) fuel, and different fuel forms like Tristructural Isotropic (TRISO) pebbles, which require additional considerations for security.
- A/SMR designs that do not yet have mature approaches for nuclear material accounting and control.
- New siting scenarios that introduce novel security challenges, such as new threat vectors, adversary types, and challenges in responding to security incidents.

The security challenges associated with A/SMRs make it necessary to enhance traditional approaches and protection strategies. Considering these risks and identifying measures to mitigate them during the design stage itself are at the heart of SeBD.

INS created the International Nuclear Security for Advanced Reactors program (INSTAR), which takes a three-pronged approach to enhancing the security of A/SMRs:

1. To make future U.S. reactors more secure for deployment around the world, INS develops technical tools for SeBD technical partnerships with U.S. nuclear industry vendors.
2. To support nuclear infrastructure development, INS works bilaterally with partner countries to support strong nuclear security frameworks in future markets.
3. To maintain the global nuclear security regime, INS collaborates with the International Atomic Energy Agency on technology inclusive guidance and infrastructure development.

INSTAR is already having an impact. Collaborations have been established with three U.S. A/SMR developers, and INS-funded work is in progress at national laboratories to support these collaborations. Current efforts are underway to work with additional partners. In addition, INSTAR is developing tools and analytical approaches including economic analysis of protection strategies, novel approaches for protection strategies and prioritization of protection areas, and integrated modeling and simulation capabilities to address the safety-security interface

Mikhail Pellegrino serves as a NNSA Graduate Fellow for the Office of International Nuclear Security (INS). Troy Alexander serves as an intern in INS and is pursuing his undergraduate degree. Dr. Jorge Navarro is a nuclear engineer from Oak Ridge National Laboratory, who supports INS. Dr. Anagha Iyengar is the Deputy Director of the INS Analytics and Innovation Program, which includes the International Nuclear Security for Advanced Reactors (INSTAR) element. Dr. Adam Williams is an engineer from Sandia National Laboratories, who supports the INSTAR program.

GMS Enhances Ukrainian Nuclear Security During Crisis and Prepares for Post-conflict Support

On February 24, 2022, Russia invaded Ukraine, which marked the first major armed conflict in a country with operating nuclear power plants. Since then, Ukraine's nuclear security regime has faced many unprecedented challenges, including the armed seizure of, and ongoing hostilities around, the Chornobyl and Zaporizhzhia nuclear power plants, as well as the increased risk of damage to sites housing radioactive materials due to shelling, bombing, and missile strikes. These events have had a destabilizing effect on global nuclear safety and security.

The DNN Office of Global Material Security's (GMS) decades-long partnerships and relationships with Ukrainian nuclear security stakeholders, including site personnel, regulatory authorities, law enforcement, and security contractors, helped build technical and operational expertise, security infrastructure, and a robust security culture at nuclear and radiological facilities across the country. Ukraine has used this increased baseline capacity to respond to the challenges caused by Russia's unlawful invasion.

DNN is helping reduce the security risks at Ukraine's nuclear power plants.

GMS Portfolio Manager

One challenge is the expanded range of threat actors. The previous assumption that nuclear installations would be "off limits" to state actors is no longer valid, as proven by the capture of Chornobyl and Zaporizhzhia and the shelling at the Khmelnytskyy Nuclear Power Plant. Security solutions designed to withstand a terrorist attack, for example, require supplemental capabilities to address more capable state-based threats. GMS is working to address this new challenge by developing approaches to counter uncrewed aerial systems (drones), improve cybersecurity, and harden critical targets. As Russia continues to undermine nuclear security norms, GMS is analyzing what additional nuclear security vulnerabilities exist. These vulnerabilities may include requirements to protect nontraditional nodes, such as the electrical grid that are vital for the safe and secure operation of nuclear power plants.

During the ongoing crisis, GMS has supported Ukrainian partners as they increase the resiliency of safety and security measures in the face of prolonged disruption in power, water, communications, and support infrastructure. GMS is also facilitating cooperation and coordination among military and civilian nuclear security stakeholders that must work together to manage the security of radioactive material at civilian facilities within conflict areas.

We are helping the Ukrainians improve physical protection and cybersecurity systems as well as replace old or unreliable equipment. We are also providing the tools and training to help them mitigate insider threats.

GMS Portfolio Manager

Damage to the roof of a facility housing radioactive sources as a result of Russian shelling.

GMS's support of Ukraine is part of a broader strategy to build and sustain the country's nuclear security capacity into the future. GMS is assessing what will be needed after hostilities end as Ukraine rebuilds its nuclear security infrastructure.

Reconstruction and recovery in Ukraine will be a significant challenge. A recent joint assessment by Ukraine, the World Bank, the European Commission, and the United Nations, estimates the overall cost at almost $500 billion.[1] The report found that the cost of direct damage in Ukraine since Russia's invasion began has reached almost $152 billion–with transport, industry, and energy among the most affected sectors.

[1] *The World Bank, the Government of Ukraine, the European Union, the United Nations. (2024, February). UKRAINE Third Rapid Damage and Needs Assessment (RDNA3) February 2022 – December 2023.* ***https://ukraine.un.org/sites/default/files/2024-02/UA%20RDNA3%20report%20EN.pdf***

continued on page 7

Improving Nuclear Security in Space via the Low Earth Orbiting Nanosatellite Integrated Defense Autonomous System (LEONIDAS): Showing the Way to Rapidly Test and Qualify Microelectronics for Space-based Monitoring

By Captain Christopher McCartan, NNSA; Joshua Donckels, Sandia National Laboratories

New state-of-the-art microelectronics cannot be used in national security space applications until these devices undergo tests against space radiation environments that qualify them for satellite-based systems. To improve timeliness, the NNSA DNN R&D Space-based Nuclear Detonation Detection (SNDD) program sponsored Sandia National Laboratories in collaboration with the National Aeronautics and Space Administration (NASA) and the commercial space company NanoRacks to develop, build, test, deliver, and support operations for a payload (LEONIDAS) to demonstrate a way to rapidly test and qualify new electronics in space (see Figure 1).

LEONIDAS contained the first modern electronics system-on-chip (SOC) in space to receive programming commands, control on-board sensors, collect and process data, and transmit them down to Earth. After assembly at SNL (see Figure 2), LEONIDAS was launched in August 2023 and integrated on the NanoRacks External Platform (NREP) of the International Space Station (ISS) for 93 days of operation. LEONIDAS captured images of earth through an optical sensor controlled by a SOC from the Advanced Micro Devices (AMD) company using its Versal adaptive computational and control architecture.

This is a trailblazing application of this payload. LEONIDAS demonstrates a fast path for testing technologies on orbit. In this design, the electronic board was modular to incorporate various novel features like data topology characterization and Machine Learning algorithm development. The system was reconfigured during space deployment, enabling agile testing and testing of new capabilities in relevant mission environments.

"We have successfully demonstrated a massive shift from legacy models for space systems which normally require a decade or more from concept to launch," said Joshua Donckels, Manager of the Space Flights Systems – Future Concepts at Sandia. "The AMD Versal SOC was first released to the public in 2021 and was operating on-orbit on the ISS only three years later—populated on a custom flight board by Sandia."

Figure 1: Placing this payload, which includes an advanced microprocessor system on a chip, aboard the International Space Station helps SNL researchers evaluate advanced electronics rapidly for use in national security systems.

"We have successfully demonstrated a massive shift from legacy models for space systems which normally require a decade or more from concept to launch," said Joshua Donckels, Manager of the Space Flights Systems – Future Concepts at Sandia. "The AMD Versal SOC was first released to the public in 2021 and was operating on-orbit on the ISS only three years later—populated on a custom flight board by Sandia."

LEONIDAS achieved several milestones over its three months in space. It collected imagery through the Versal SOC via the NanoRacks External Platform interface, then sent to the ISS and through a downlink to the NASA ground station antennas for successful transmission at Sandia. It completed a full reprogramming of the Versal SOC device while in orbit to demonstrate modular algorithms and mission processing. Sandia completed three reprograms of the Versal during the mission—on top of several flight

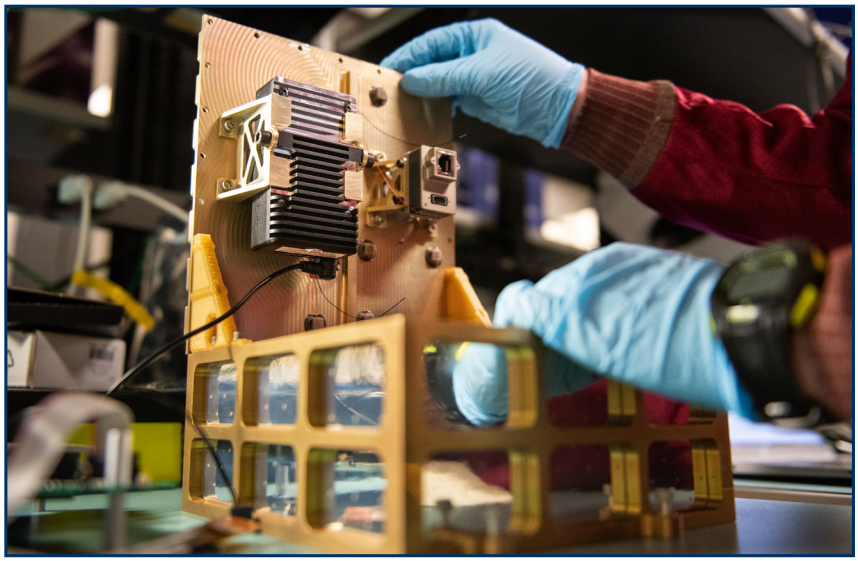


Figure 2: Thomas Bradshaw, lead computer engineer for the project, prepares a payload for integration testing at Sandia National Laboratories.

software updates—without any impact on performance. It detected lightning events with the onboard optical sensor over the Chocó Rainforest of Ecuador and over parts of Singapore and Australia (see Figure 3).

Figure 3: First Collection from LEONIDAS over Australia.

The next step is for Sandia to retrieve the electronics and see how well the materials withstood the harsh environment of space.

The success of LEONIDAS and related Sandia technology developments will help the SNDD program shorten its design cycle, increase mission capability, and hasten deployment of next-generation space-based sensors used in global nuclear monitoring. These are vital to the U.S capability for nuclear treaty monitoring and supporting this key mission.

Capt. Christopher McCartan currently serves as the Chief Engineer of the SNDD program that provides the vital U.S. capability to monitor nuclear treaties as well as support the nuclear warfighting mission.

Joshua Donckels is the Manager of the Space Flights Systems Future Concepts at Sandia.

Ukrainian Nuclear Security – *Continued from page 5*

GMS priorities during reconstruction and recovery will include:

- ***Nuclear Material Security:*** Bolstering energy security and overall resiliency of the electricity grid by reducing the risk of sabotage at all nuclear power plants through physical protection, cybersecurity, and insider threat mitigation; rebuilding safety and security systems at sites which have been occupied or withstood significant damage; and providing expert analysis to Ukrainian partners for use in diversification away from Russian supply chains.
- ***Radiological Security:*** Technical assistance for verifying radioactive material inventory; recovering radioactive materials; addressing damage to facilities housing radioactive materials; enhancing the security and law enforcement response capabilities at prioritized facilities; verifying and improving transport security capabilities; and rebuilding Ukraine's cancer treatment capacity with a focus on medical linear accelerators in lieu of radioactive source-based devices.
- ***Counter Nuclear Smuggling:*** Assisting partners to continue radiation detection activities while repairing and rebuilding detection architecture that was damaged or destroyed during the Russian invasion.

GMS has over 20 years of experience in over 100 countries maintaining international focus on nuclear security and partnering to address emerging geopolitical and technological challenges. GMS was ready to assist Ukraine when war broke out and will be ready to assist during reconstruction and recovery. This effective partnership is a testament to GMS's relevance in today's evolving security landscape.

DNN Support for the Amended Convention on Physical Protection of Nuclear Material

By Patricia O'Brien, Taylor Hart-McGonigle

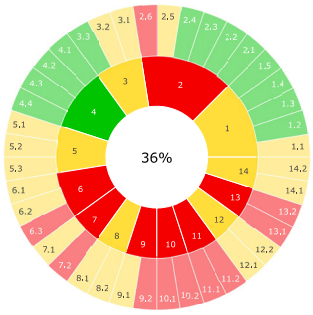
The Office of International Nuclear Security (INS) advances U.S. efforts to prevent theft and sabotage of nuclear material and facilities worldwide by working with partner countries to support sustainable national infrastructure for the implementation of the Convention on Physical Protection of Nuclear Material (CPPNM) and its Amendment.

NNSA held a side event at the International Atomic Energy Agency's Conference on Nuclear Law. It focused on leveraging the criteria in a key convention to support effective nuclear security regulation.

Since it entered into force in 2016, the CPPNM has formed the cornerstone of the international nuclear security architecture. It is the only legally binding international instruments requiring the physical protection of nuclear material in international transport. With its amendment, in force since 2016, signatories must protect nuclear material in domestic use, storage, and transport from theft as well as nuclear facilities from sabotage.

The Amendment also lays the foundation of national physical protection regimes through fundamental principles of physical protection and creates a strong legal basis for the protection of nuclear material and facilities worldwide against terrorists and other actors with malicious intent.

One of the goals of the International Atomic Energy Agency (IAEA) and the U.S. Government is to have every state, regardless of its nuclear material usage, ratify the Amended Convention on Physical Protection of Nuclear Material (A/CPPNM) to prevent the theft of nuclear material, sabotage of nuclear facilities, and counter nuclear smuggling.



Sample A/CPPNM implementation score.

To advance this mission, INS developed an online, self-assessment tool that international partners can use to assess implementation of the Convention in a State's regulatory and legal framework. Based on the A/CPPNM's 12 Fundamental Principles of Physical Protection, this tool guides international partners through a series of questions to informally assess their adherence to the Convention. It is designed to help states understand what is needed to implement A/CPPNM, assess the existing legal framework, identify gaps in implementation, and inform the development of future regulations by providing helpful references and relevant guidance. After partners provide their input, the tool generates a colorful graphic displaying their overall A/CPPNM implementation score.

There was not previously an easy way for the international community to evaluate if a state's legal and regulatory framework addressed all elements of the A/CPPNM. The Criteria for A/CPPNM Self-Assessment Tool (CBSAT) fills this gap.

> ***"The Amended Convention on Physical Protection of Nuclear Material provides an important legal framework for nuclear security worldwide. This tool fills a critical gap in the international community to access the Convention's implementation."***
>
> Christine Bent, Assistant Deputy Administrator for the Office of Global Material Security

Initially designed to be an anonymous resource to encourage honest responses, this tool has since been used by INS to support bilateral engagements. The tool improved INS' ability to support international partners by identifying specific areas of collaboration to promote effective nuclear security regulations. The Philippines will present on their use of the tool at the IAEA's International Conference on Nuclear Security in May 2024. They will describe how the tool can be helpful to member states seeking to implement the Convention and plan on encouraging others to use the tool.

ICNL Self Assessment

Patricia O'Brien is a Senior Advisor with the Office of International Nuclear Security and leads engagement with multilateral organizations, including the International Atomic Energy Agency.

Taylor Hart-McGonigle is the Deputy Program Director of Bilateral Cooperation with the Office of International Nuclear Security. In this role, she collaborates with international partners to build their capacity to prevent the theft and sabotage of nuclear materials and facilities and leads the Nuclear Security Women initiative.

Twenty Years of Nuclear Material Removal and Elimination: From GTRI to M3

By Jessica Lillo and Flora Lethbridge-Cejku

Introduction

In May 2004, then-Secretary of Energy Spencer Abraham announced the creation of the Global Threat Reduction Initiative (GTRI) at the International Atomic Energy Agency (IAEA) headquarters in Vienna. For the 20th anniversary of that announcement, the National Nuclear Security Administration (NNSA)'s Office of Nuclear Material Removal and Elimination is reflecting on the historical context of the launch of GTRI, its catalyzing role accelerating the removal and elimination of weapons-usable nuclear materials, and the continued efforts and challenges to permanently reducing nuclear threats.

IAEA Director General Mohamed ElBaradei (left), U.S. Secretary Spencer Abraham (center), and U.S. Ambassador Kenneth Brill at the press conference following the announcement of the GTRI initiative on May 26, 2004 in Vienna, Austria.

Following the September 11, 2001, terrorist attacks, concern about the spread and potential use of weapons of mass destruction became a key driver of U.S. national security policy. As the lead U.S. government agency responsible for nuclear security, the U.S. Department of Energy and the newly formed NNSA responded to these concerns by creating GTRI, an organization dedicated to addressing the threat of non-state actors obtaining weapons-usable nuclear and radiological materials and using these materials to cause harm at home or abroad. GTRI accelerated and expanded existing DOE nuclear material efforts to remove and/or secure high-risk weapon-usable materials around the world; convert research reactors from highly enriched uranium (HEU) to low-enriched uranium fuels; and enhance the security of high-risk radiological materials globally.

While GTRI made tremendous progress, these missions are enduring, and DNN offices continue this important work still today. NNSA's Office of Nuclear Material Removal and Elimination—part of the Office of Material Management and Minimization (M3) since 2015—maintains and deploys NNSA's one-of-a-kind capabilities to eliminate excess inventories of HEU and plutonium around the world.

Addressing the Threat

When GTRI launched, the global threat landscape comprised increasingly capable non-state actors and significant stockpiles of vulnerable weapons-usable nuclear material. To advance and better coordinate its nuclear material removal and elimination efforts, NNSA brought the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program (also referred to as "U.S.-origin program") under the GTRI program umbrella, integrating it with other existing programs, such as the Russian Research Reactor Fuel Return program (also referred to as "Russian-origin program") and new efforts to address unirradiated HEU and separated plutonium, referred to as "gap" materials that had previously been left unaddressed.

These programs have been incredibly successful. Over the last 20, the U.S.-origin program has repatriated HEU from 18 countries and Taiwan to the United States for downblending and/or disposition. Meanwhile, since May 2004, the Russian-origin program has repatriated or downblended Russian-origin fresh and spent HEU from 15 countries. The newly created "gap" program first worked to eliminate inventories of unirradiated HEU and later broadened its scope to irradiated HEU, regardless of origin and in forms beyond those that the U.S.-origin program returned. Finally, the U.S.-origin program expanded to work with partner

continued on page 11

International Nuclear Forensics Capacity Building: Characterization to Support Nuclear Security

Erica Wolf (NSDD), Greg Brennecka (LLNL), Adam Stratz (SNL), and Jodi Canaday (ANL)

The identification and characterization of nuclear and other radioactive materials are central to the Office of Nuclear Smuggling Detection and Deterrence (NSDD) mission to build global capability to detect, disrupt, and investigate the smuggling of nuclear and radioactive material before it can be used in an act of terrorism. To that end, NSDD collaborates with international partners to enhance their radiation detection capabilities at border checkpoints, frontier regions, and interior locations. Further, NSDD teaches nuclear forensic methodologies as a deterrence measure to help partners identify, and in some cases characterize, radioactive or nuclear materials after they are detected—either through a detection instrument alarm or an information alert (informant tip to law enforcement, for example). "Nuclear forensics not only provides information critical to the immediate disposition of radioactive material, it is also essential to any subsequent investigation of a criminal act", according to Erica Wolf, who leads NSDD's International Nuclear Forensics (INF) group. Nuclear forensics contributes objective information toward criminal investigations and can also be used to assign attribution (material history or origin) which can be a powerful deterrent to nuclear smuggling.

Greg and Ilijana (student from Serbia) analyzing nuclear materials at LLNL as part of her NSDD mentorship.

NSDD INF conducts two types of collaborations with international partners: capacity building activities and advanced scientific exchanges. NSDD leverages scientists and engineers from the DOE/NNSA laboratories Argonne National Laboratory (ANL), Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory, Pacific Northwest National Laboratory, and Sandia National Laboratories as the subject matter experts (SMEs) and instructors for these collaborations. Capacity building activities include training, workshops, tailored engagements, and promotion of a human capital pipeline for new international nuclear forensics SMEs. Scientific exchanges are designed as scientist-to-scientist collaborations with international partners that advance the science of nuclear forensic analysis, the results of which can be published for use by the broader nuclear forensics community worldwide.

INF collaborations have expanded significantly over the past few years, including new strategic partnerships with Sri Lanka, Czechia, Thailand, Latvia, Italy, Lithuania, Ghana, Nigeria, Djibouti, Iraq, Tunisia, and Taiwan. Training topics have covered topics ranging from radiological/nuclear collection and chain of custody at radiological crime scenes to nuclear forensic analysis, investigation, and support for prosecutorial proceedings.

As part of a new national nuclear forensics library (NNFL) initiative, radiological and nuclear material library SMEs at LLNL and ANL developed a new field-deployable NNFL kit to aid first-time NNFL development in INF partner countries. The first version of the kit includes a SQL database backbone to incorporate into radiological and nuclear material library databases query capabilities, NNFL guidance documents, mock sources, an artificial database for testing library implementation, and guidance on implementing the kit. The second version of the kit will include a user interface for partners with minimal expertise in implementing SQL code. "We hope this provides partners an easy on-ramp to the NNFL highway, as determining whether an interdicted material originated from within your country or from somewhere else is important for nuclear security", says Jodi Canaday (ANL).

Additionally, the INF group recently conceptualized and implemented a two-year pilot program in partnership with Science and Technology Center in Ukraine with the aim of bringing more young talent to the field of nuclear forensics in countries around

the world. The pilot resulted in graduate student fellowships in Tajikistan, Moldova, Armenia, and Serbia to put four students through a graduate program relevant to nuclear forensic science and to provide mentorship from U.S. nuclear forensics experts and travel funding for multiple conferences. New funding was secured to continue this program following its success, and the first cohort of four students will graduate in the summer of 2024.

Adam and Jodi preparing to deliver NNFL kit to Morocco partners.

"It really does take a village", says Adam Stratz, "NSDD's impact on nuclear security through the international nuclear forensics partner collaborations is amplified by effectual coordination within the USG interagency." As NSDD continues to work directly with partner countries, the office also maintains strong ties with U.S. interagency stakeholders. Whether with interagency bodies such as the Forensics Engagement Working Group and Nuclear Forensics Steering Committee, or with the NNSA Office of Nuclear Forensics, Department of State, FBI, or others, NSDD remains heavily involved in U.S. nuclear forensics policy to help enhance nuclear security messaging and training around the globe.

Dr. Erica Wolf is a Foreign Affairs Specialist in the Office of Nuclear Smuggling Detection and Deterrence (NSDD) and leads efforts in international nuclear forensics as well as projects in the Asia region.

Dr. Greg Brennecka has a background in mass spectrometry and works half-time as a space geologist and half-time on international nuclear forensics at Lawrence Livermore National Laboratory.

Dr. Adam Stratz is a trained nuclear engineer and a nuclear forensics subject matter expert leading capacity building and peer-level nuclear forensics initiatives across several NSDD partner portfolios.

Jodi Canaday is a radiological sealed source expert supporting NSDD, the Office of Radiological Security, and several other programs at Argonne National Laboratory.

Nuclear Material Removal– *Continued from page 9*

nations to identify vulnerable inventories of separated weapons-usable plutonium that could be removed to the United States for disposition. Since 2004 alone, 6,336 kilograms of HEU and plutonium have been removed or confirmed as disposed, bringing the total inventory of weapons-usable nuclear material addressed by NNSA to more than 7,347 kilograms, enough for more than 300 nuclear weapons.

Moving Forward

GTRI, later boosted by the 2012-2016 Nuclear Security Summits, created an increased sense of urgency that propelled the elimination of HEU and plutonium to be a worldwide priority. M3, the follow-on organization to GTRI created in 2015, continues to advance the mission of reducing vulnerable inventories of excess weapons-usable nuclear material around the world. M3 and its Office of Nuclear Material Removal and Elimination have devised unique ways to address the technical and logistical challenges of different types of material, including finding creative solutions to transportation and other logistics; improving package and cask designs; and creating modular facilities capable of characterizing, stabilizing, packaging, and now—following construction of the Mobile Melt-Consolidate system—treating nuclear materials overseas.

For the fourth International Conference on Nuclear Security (ICONS), it's worth reflecting on Secretary Abraham's May 2004 call—in the same IAEA venue almost exactly 20 years later—to "secure, remove, relocate or dispose of these materials and equipment—whatever the most appropriate circumstance may be—as quickly and expeditiously as possible". Despite the successes described above, some hard cases remain. Over the last two decades, civilian plutonium stockpiles have continued to rise; HEU minimization cooperation with the Russian Federation came to a halt in February 2022; and political, economic, and technical challenges limit M3's ability to eliminate remaining inventories of excess weapons-usable nuclear material around the world. M3's Office of Nuclear Material Removal and Elimination is committed to facing these challenges head on, building on its legacy and continuing to adapt to identify new pathways to remove or eliminate additional inventories of HEU and plutonium

Jessica Lillo is the Deputy Director for the Office of Nuclear Material Removal and Elimination. For nearly 10 years, her work has focused on minimizing and, when possible, eliminating weapons-usable nuclear material from civilian applications in support of U.S. Government nonproliferation objectives.

Flora Lethbridge-Çejku is a project manager supporting the Office of Nuclear Material Removal and Elimination's Mobile Packaging program and is leading the office's newest effort to work with international partners to address sensitive nuclear infrastructure at research reactors' end of life.

Staying PROACTIVE: Addressing Future Arms Control Challenges

By Riad Manaa, LLNL, Venture Manager; Elizabeth Heckmaier, LLNL, DNN R&D Technical Advisor; David Matters, Senior Program Manager, DNN R&D

The arms control landscape is evolving as new capabilities (such as hypersonic vehicles) and domains (such as contested space) create new challenges in an increasingly multipolar threat environment. As we look toward future nuclear arms control treaties and agreements, we will need improved monitoring and verification (M&V) technology to assess treaty compliance.

PROACTIVE team members perform a gamma-ray measurement to determine the absence of special nuclear material in a simulated weapons part, as part of a larger verification system exercise at ORNL in August 2023. During the experiment, a building was configured as a mock materials storage facility and outfitted with a variety of sensors including door switches, motion detectors, spectroscopic portal monitors, and cameras. The intent of the experiment was to test and validate a framework for collecting data from a variety of different sensor types, then confirming, storing, and analyzing that data to inform a picture of the facility and identify potential vulnerabilities in the verification process.

The U.S. Government's 2022 Nuclear Posture Review (NPR) stressed, "Mutual, verifiable nuclear arms control offers the most effective, durable and responsible path to reduce the role of nuclear weapons in our strategy and prevent their use" and recognized that "successfully enforcing future arms control agreements will require new technical capabilities for verification and monitoring." As such, potential arms control treaties of the future should include discussions of verification technologies that can discern between different types of warheads and their readiness levels. They should also tackle monitoring capabilities that reduce the burden of on-site inspections while providing verifiable data to support treaty compliance. Any new M&V technology must also include information protection measures to prevent the disclosure of sensitive information.

The Priority Research Objectives for Arms Control Technology Innovation, Verification, and Evaluation (PROACTIVE) venture is a multi-laboratory, multi-disciplinary project sponsored by NNSA's Office of Defense Nuclear Nonproliferation Research and Development (DNN R&D). The PROACTIVE venture began in FY23 with the goal of enabling the negotiation and implementation of future nuclear arms control treaties through verification at the individual-warhead level by advancing M&V technologies.

R&D efforts include contributions from nine national laboratories/sites from across the DOE complex, focused on providing systems of nuclear warheads verification and monitoring tools. Test and evaluation activities are an important part of PROACTIVE as well. In partnership with the DNN R&D-funded Testbed for Research Evaluation and Test Integration (TREATI) for test and evaluation support, the performance and relevant risks associated with each technology developed will be demonstrated and evaluated.

These capabilities would support various arms control treaty scenarios and address the following:

- developing and demonstrating new M&V technologies that increase transparency among partners;
- addressing concerns about sensitive information protection, authenticating to ensure equipment and data have not been tampered with, and certifying equipment for use in nuclear sites and facilities;
- developing methods to evaluate the performance of M&V options at scales ranging from individual technologies to facility-scale monitoring systems to verification systems over an entire enterprise;
- developing a workforce with expertise in nuclear arms control.

One focus area the PROACTIVE venture is investigating how various technologies and verification activities interplay from an enterprise perspective. This system-focused approach is designed to provide credible verification that minimizes operational burdens, provide information security, and maximize confidence in results.

continued on page 15

Replacing Cesium Irradiators with X-Ray at Home and Abroad

By Jordan Niehoff, Nan Wise

Radioactive materials play an important role in commercial, medical, and research industries. Yet if these materials fall into the wrong hands, there could be devastating consequences, especially if used in a radiological dispersion device, or "dirty bomb". The Office of Radiological Security (ORS) seeks to prevent high-activity radioactive materials from being used in acts of terrorism and employs several strategies to do so at home and abroad. One key strategy is to permanently reduce risk by promoting the adoption of alternative technologies that use machine-based radiation instead of radioactive materials. Depending on the application, machine-based radiation, such as X-rays or electron beams, can deliver results that are equivalent or better than those from gamma-emitting materials such as cesium-137 or cobalt-60. When the radioactive material is removed, the risk is eliminated.

Removal of a cesium irradiator through CIRP.

X-ray irradiator in use in South Africa.

The Cesium Irradiator Replacement Project (CIRP) is ORS's flagship initiative promoting alternatives to permanently reduce risk in the United States. Since 2015, ORS has assisted hundreds of organizations in replacing irradiators that use cesium-137 with X-ray devices through CIRP. Congress explicitly supported CIRP in the John S. McCain National Defense Authorization Act of Fiscal Year 2019 by setting the goal for NNSA to replace, on a voluntary basis, all cesium irradiators used to treat blood in the United States by the end of 2027. As a result, replacing cesium blood irradiators in the United States is one of three Agency Priority Goals for NNSA. Thanks to continued support from Congress and DOE/NNSA leadership, ORS is making strong progress toward this goal. As of January 31, 2024, 80 percent of all cesium blood irradiators in the United States have been pledged, contracted, removed, or replaced.

The risks posed by reliance on cesium irradiators extend beyond the United States, as cesium remains the preference for blood irradiation globally. ORS partners around the world are also achieving permanent risk reduction by replacing cesium irradiators. Uruguay was the first government to partner with ORS to completely replace their inventory of cesium blood irradiators with X-ray technology. More recently, the Kingdom of Jordan's Energy and Minerals Regulatory Commission concluded an effort with ORS to replace Jordan's entire inventory of cesium irradiators with X-ray technology—the culmination of 20 years of cooperation between the organizations.

Thanks to CIRP, cesium blood irradiators are increasingly rare in the United States; yet cesium remains popular for other medical and commercial research requiring irradiation. ORS is engaging with research institutions around the country to demonstrate and document the effectiveness of X-ray irradiators in place of cesium through webinars, workshops, conferences, and comparison studies between the two technologies. Internationally, ORS continues to expand partnerships and assist countries with replacing and removing their cesium devices and the adoption of machine-based radiation technology, both for blood irradiation and an ever-growing range of other applications.

In 2023, ORS held a workshop with the Malaysian Ministry of Health to discuss transitioning to X-ray technology for blood irradiation. Malaysia has the largest inventory of cesium blood irradiators in the Pacific region, and this workshop initiated the first replacement project in Malaysia. ORS held a similar workshop on the Iberian Peninsula in March. Engagements like these are critical to build the relationships necessary to replace cesium devices.

An ongoing partnership with the government of Albania to explore the use of X-ray to induce genetic mutations in plants, for example, seeks to facilitate the development of new crop varieties to promote food security in the region. Thanks to the willingness and ability of these licensees and countries to foster alternatives, they can achieve permanent risk reduction by limiting reliance on radioactive materials while still promoting the benefits of radiation for society.

Niehoff and Wise are contractors for the Office of Radiological Security (ORS) supporting the alternative technology portfolio.

DNN Initiative Supports Women in Nuclear Security

By Taylor Hart-McGonigle

The Office of International Nuclear Security (INS) envisions a world in which effective nuclear security prevents nuclear theft, sabotage, and terrorism. The Nuclear Security Women (NSW) Initiative supports a key U.S. mission by promoting a diverse and inclusive workforce, which will lead to greater effectiveness in meeting today's challenges and produce more resilience and sustainability in the field.

INS established the NSW initiative in 2020. NSW's efforts focus on women, men, and gender diverse individuals who seek to attain gender equality in the nuclear security field. NSW goals are to increase visibility and representation of women in nuclear security by:

- promoting the importance of their roles and contributions;
- delivering education, training, research, and other professional development opportunities for women in the field;
- raising awareness about the importance of gender equality and intersectional approaches to diversity, equity, and inclusion;
- influencing structural, programmatic, and policy changes that promote gender equality in nuclear security; and
- building relationships with organizations and individuals who share common goals to support and amplify their efforts.

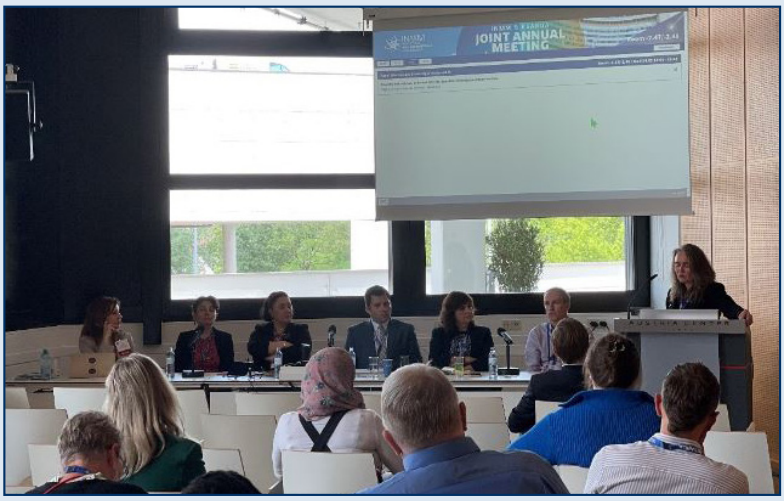
To increase the visibility and representation of women in nuclear security, NSW conducts outreach and engagement with the international community, holds virtual and in-person meetings with international partners, hosts bilateral and regional events, promotes and provides professional development opportunities, and conducts research pertaining to the challenges of women in nuclear security. These activities build a community, identify the challenges of women in nuclear security, and raise awareness of the issue.

Black Sea Network "Lunch and Learn" at the Institute of Nuclear Materials Management and the European Safeguards Research and Development Association Annual Meeting in May 2023

NSW established the Black Sea Women in Nuclear Network to establish and sustain a professional network for women among nuclear security experts in the Black Sea region. The Network's activities include workshops and webinars with regional partners on nuclear security and nonproliferation issues, discussions of gender equality, regional issues pertaining to women in this field, mentoring, and conducting surveys on perceptions of women in nuclear security in the region. Building off the success of the Black Sea Network, NSW sup-

During the International Atomic Energy Agency 2023 General Conference, NNSA Administrator Hruby opened a side event on women in nuclear security. "When it comes to addressing the ever-evolving challenges and risks we face in our work every day, we need to have the best talent and most diverse perspectives on our team. By achieving gender parity, we open the door to bringing innovative ideas and fresh perspectives to the table. NNSA has launched the Nuclear Security Women's Initiative (NSW) to increase women's representation in all aspects of nuclear security worldwide."

– NNSA Administrator Jill Hruby



Women in nuclear security side event at the Institute of Nuclear Materials Management and the European Safeguards Research and Development Association Annual Meeting in May 2023

ported the development of Women in Nuclear in Central Asia. This network held its first annual meeting in 2023 and the leadership of both networks developed a relationship to share lessons learned and good practices.

"Nuclear security is more than just technical measures: the most important part of the nuclear system is people. People thrive in organizations where they feel included and valued. Therefore, promoting a diverse and inclusive nuclear security workforce will lead to greater effectiveness in meeting today's nuclear security challenges and produce more resilience and sustainability in the nuclear security field."

– Christine Bent, International Journal of Nuclear Security, Vol. 8, No. 2, 2023 – IJNS and NSW Special Issues: Women in Nuclear Security, pg. xiii.

NSW participants served as guest editors of the International Journal of Nuclear Security. This provided women and gender diverse authors on nuclear security research an additional forum to publish their technical work and receive recognition for their contributions to the community. The Journal received a high volume of quality abstract submissions demonstrating an appetite for this type of opportunity.

Since its inception in 2020, NSW has expanded initiatives, communities, and partnerships to address the under-representation of women in the nuclear security workforce. NSW will continue to grow its community, form relationships with like-minded groups, and support research to identify the challenges of women in nuclear security to better address gender inequality in nuclear security globally.

Taylor Hart-McGonigle is the Deputy Program Director of Bilateral Cooperation with the Office of International Nuclear Security. In this role, she collaborates with international partners to build their capacity to prevent the theft and sabotage of nuclear materials and facilities and leads the Nuclear Security Women initiative.

PROACTIVE– *Continued from page 12*

Last summer, PROACTIVE conducted an exercise at Oak Ridge National Laboratory (figure), performing six experiments varying in complexity of verification measurements of a mock treaty requirement. The exercise outcomes confirmed that the team achieved their goals by demonstrating a working verification system (see Figure caption).

"The goals of this set of exercises are to design a scalable enterprise model in a Discrete Event Simulator, develop inputs to the simulator for the verification system, and use results for assessment of the verification system," said Dan Archer, the ORNL scientist who led the exercise.

A major milestone for the PROACTIVE venture was the execution of an integrated experiment in March 2024 at Lawrence Livermore National Laboratory's Dome facility. This experiment incorporated M&V capabilities such as radio-frequency readers, gamma-ray spectrometers with information barriers, and neutron detectors for template-based measurements, to confirm the count of specified treaty-covered items in a storage facility and to confirm dismantlement of specified items in another. Activities like these are an important way to showcase different M&V technologies developed under PROACTIVE, test interoperability, and obtain stakeholder feedback to improve implementation of potential future arms control treaties. With PROACTIVE planned to continue through FY27, there is ample opportunity for further R&D under the venture.

Dr. Riad Manaa has been a staff scientist at Lawrence Livermore National Laboratory for over 26 years, leading sponsored projects for defense programs and nuclear nonproliferation.

Dr. Elizabeth Heckmaier is a nuclear diagnostician and the Deputy Group Leader for Global Security Applications within the Nondestructive Evaluation Group at Lawrence Livermore National Laboratory. She is currently on detail as a Technical Advisor in DNN R&D (NA-221), supporting the Arms Control (Warhead M&V), Nuclear Data, and Emergency Response R&D portfolios.

Lt. Col. David Matters, Ph.D., is a U.S. Army Functional Area 52 (Nuclear and Countering WMD) officer assigned to DNN R&D as the Senior Program Manager for the Nuclear Data and Arms Control Monitoring & Verification portfolios.