An International Nuclear Forensics Pipeline: Master's Students and Mentors

Greg Brennecka[1]*, Lisa Hudston[2], Andrew Tompson[1], Ruth Kips[1], Liz Dallas[3], Stephen LaMont[2], Adam Stratz[3]

[1] Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
[2] Los Alamos National Laboratory, Los Alamos, NM 87545, USA
[3] Office of Nuclear Smuggling Detection and Deterrence, US Department of Energy, National Nuclear Security Administration

Abstract
The number of technical experts in nuclear forensics has been systematically waning as many members trained in the nascent days of the science have begun entering retirement. This, combined with an ever-increasing worldwide demand for nuclear forensic practitioners is causing an acute need in training the next generation of nuclear forensic experts. As such, engaging and training students to enter the nuclear forensics "pipeline" is a worldwide focus. The Nuclear Smuggling Detection and Deterrence (NSDD) office is partnering DOE laboratories with master's students from select partner countries as a pilot program to help address this pipeline issue. NSDD has identified four master's students, one each from Tajikistan, Armenia, Serbia, and Moldova, to be paired with mentors in their respective field (e.g., gamma spectroscopy, mass spectrometry) at DOE laboratories. Mentors will periodically meet remotely with the student and the student's advisor at their home institutions to help guide the student's thesis. Importantly, following the student's successful completion of their MS degree, the student will have the opportunity to join the workforce of an already identified employer in their field of study. Here, we will discuss the details of NSDD's program that aims to increase the number of early career researchers joining the field of nuclear forensics.

Introduction and Background

The concept of nuclear forensics was born as a consequence of an increasing number of incidents in the 1990s where nuclear materials were discovered outside of regulatory control. While it is difficult to say when nuclear forensics went from a concept to a science, the need for nuclear forensics was acutely recognized following multiple high-profile radiologic interdictions after the fall of the Soviet Union. Since then, nuclear forensics has rapidly matured into a broad and dynamic discipline, often requiring skillsets used in disparate scientific subjects and an ability to communicate technical assessments to regulatory and law enforcement authorities. As such, a wide swath of scientists is often required to perform nuclear forensic examinations.

Nuclear forensics is broadly defined as a discipline that "seeks to identify the origin of nuclear materials found outside regulatory control" [Kristo et al., 2016]. Wrapped into this definition are a number of concepts, including the idea that national and international regulatory bodies are keeping track of a wide range of nuclear materials that span from mined uranium—the beginning of the fuel cycle—all the way to special nuclear materials, such as highly enriched uranium or weapons-grade plutonium that diverted from the fuel cycle at some point. Such "nuclear ledgers"

are maintained in different ways in different locations, but regardless, there is generally a high degree of scrutiny for material accountancy once it has entered the nuclear fuel cycle.

A second concept within the above definition of nuclear forensics implies that technical methodologies exist and are constantly evolving that enable a nuclear forensic investigation. For this second concept to remain true, practitioners of nuclear forensics must 1) stay engaged in scientific research on the subject and 2) must be replenished with new members of the workforce as members leave the field. The focus of this work is on the replenishment of talent in the international nuclear forensic workforce.

Traditionally, the classical disciplines such as geology, analytical chemistry, radiochemistry, microscopy, nuclear engineering, and physics have all provided crucial pipelines into the more nascent science of nuclear forensics. Whereas many of these classical disciplines contain and are producing high numbers of qualified graduates in their respective fields, recruiting these young researchers into the niche community of nuclear forensics remains a significant challenge. As experienced practitioners reach retirement age, it is becoming difficult to replace human capital and maintain institutional knowledge continuity. For this, we need a concerted effort from the nuclear forensic community to advertise and recruit to the field.

Methods

To specifically address this pipeline and knowledge transfer issue, the office of Nuclear Smuggling Detection and Deterrence (NSDD) is piloting a program to sponsor graduate work in for master's level students to gain the skills and credentials needed to directly enter the workforce and contribute to nuclear forensics. It is a specific goal to increase the number of students with interest and training in the field of nuclear forensics and capable of handling of radioactive materials. While the skills needed in the field are broad, some of the most acute needs reside in measurement techniques such as alpha and gamma spectrometry, scanning electron microscopy, radiochemistry, and mass spectrometry. As such, applications for the NSDD master's program were solicited from the chosen partner countries of Serbia, Tajikistan, Moldova, and Armenia and focused on recruiting students with interests in these techniques. Most of the recruiting and outreach about the opportunity was done through the International Science and Technology Center (ISTC) and Science and Technology Center of Ukraine (STCU).

The planned program, while unique to each student and degree granting institution in the four partner countries, follows a general pattern. Each student has a thesis supervisor at their home institution that has at least some expertise in the chosen topic. Additionally, each student is paired with an expert in their chosen field from the Department of Energy (DOE) national laboratory system. The students will take relevant classes and be supervised at their home institution in the respective countries, but, in addition, the student will have regular meetings with the DOE expert to help guide the research and the student's thesis. This arrangement leverages DOE expertise while leaving the primary mentoring responsibilities on the degree-granting institution in the student's home country.

Some of the additional benefits are that the students are funded to attend international conferences related to their topics. This will not only give the students greater exposure to the

community, but will aid student networking in nuclear forensics and provide experience communicating their scientific findings.

Lastly—and what we believe is one of the primary keys to success of the program—is the promise of an opportunity for employment in the field following the master's degree program. As part of the funding agreement, NSDD has partnered with companies and governmental institutions in the respective countries who pledge to hire the selected student following their graduation from the program. This mutually beneficial situation starts with NSDD providing the funding and expertise for education and training of students in relevant fields and continues with previously agreed upon partners providing an opportunity for at least two years of employment and on-the-job training.

Results and Discussion

Following a competitive application process, one student was selected each from Serbia, Tajikistan, Moldova, and Armenia as an NSDD master's fellow. The students hailing from Tajikistan, Moldova, and Armenia will pursue a master's degree focused on gamma spectrometry and radiation transport modeling and will be mentored by experts from both Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL). The student from Serbia will pursue work in mass spectrometry and will be mentored by an expert from LLNL. These assignments were not predetermined but were decided based on the interest and prior experience of the student and availability of in-country mentors.

As a specific example, the mass spectrometry student from Serbia has already been sponsored by NSDD to attend a workshop in Hungary to gain knowledge and experience working with mass spectrometry. The student's thesis will focus on making measurements of trace elements—specifically rare earth element patterns—in uranium ore concentrates. These patterns can be indicative of sample provenance and represent an important capability in nuclear forensic analyses.

In most instances, the master's degree programs last for two years. For the students, classwork in relevant areas is heavily weighted in the first year, with the second year focused more on the thesis and data collection. Similarly, international conference attendance for the first year will primarily provide broader educational and networking opportunities, while the second-year conferences will ensure the students are able to present their work and gain community feedback as they are making significant progress on finalizing their research.

Depending on the needs and the opportunities available for each student, short-courses and/or DOE laboratory visits are potential ways to provide targeted mentoring or experience that may not be available in the students' home institutions.

While still at a very early stage in its development, the NSDD fellowship program aims to provide an important service to the global nuclear forensic community and will greatly benefit individual students by providing them with opportunities they would not have otherwise. Even though the initial round of applications and student selection went well, one of the primary areas that can be improved going forward is our methods of recruiting applicants. While we were ultimately able to select attractive candidates interested in the fields of gamma spectroscopy and

mass spectrometry, having a better understanding of how undergraduate students in our partner countries search for jobs and graduate programs will be key to the continued success of the program. This should be addressed by interacting more with our colleagues at higher learning institutions in these respective countries, and by leveraging the current student's knowledge of how they and their peers search for opportunities in their fields.

Conclusion

The NSDD-sponsored pilot program for master's students in NSDD partner countries represents one way of addressing the global problem of a dwindling nuclear forensic capable workforce. We hope that this program can not only train students to be the next generation of nuclear forensic practitioners, but additionally raise awareness of the need for other organizations to address this important issue.

References

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