SAND2020-6084C

Graduate Nuclear Security Education Program

Abstract:

Sandia National Laboratories (Sandia), through sponsorship from the National Nuclear Security Administration's Office of International Nuclear Security (NNSA/INS), has piloted the beginning of a graduate nuclear security program at the University of New Mexico (UNM) in Albuquerque, New Mexico. This program seeks to develop a focus on three key pillars to shape the next generation of nuclear security experts: education, research, and professional development. While the program is shaped around providing graduate credits and credentials in nuclear security to both traditional and non-traditional students, efforts to date include a pilot graduate course offered at UNM in the spring of 2020. The program also aims to establish an academic-research environment for the advancement of STEM-based and social-science based research to improve efforts in nuclear security domestically in the US and internationally. The program will also contain professional development programs, including a multi-week, in-residence course to be held at UNM. This course would allow for a codified professional development course for domestic and international professionals attend and potentially obtain Continuing Education Unit credits for course completion.

SAND2020-XXXX. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525

Introduction

Nuclear facilities are facing an evolving and dynamic threat environment, which creates an increasing and timely need for experts in the field. For example, the International Atomic Energy Agency has offered guidance on crafting educational programs in nuclear security since 2010(1). In response, Sandia National Laboratories (Sandia) has developed a framework by which to collaborate with a university (e.g., perhaps the University of New Mexico (UNM))—under primary sponsorship of NNSA's Office International Nuclear Security (INS)—to establish a formal academic program in nuclear security. From its origins, this program will create a pipeline of credentialed students into nuclear security professions; provide university-based options for onboarding or on-the-job training; advance technical and socio-technical solutions for nuclear security; and, each stakeholder in meeting their respective nuclear security missions.

Program Framework Overview

To achieve these goals, developing this academic program—based on the collective experience of the stakeholders in developing similar projects(2)—will be based on three key design principles: local, strategic, and collaborative. For this first design principle, ***local***, indicates that this program will focus on high-quality, in-residence education and professional development that best leverages close proximity to the technical and research capabilities of Sandia and the partner university. The second design principle, ***strategic***, indicates that this program will make decisions centered on ensuring that the program is "demand-driven" by students (and the nuclear security profession) and self-sustaining within five years. Lastly, the third design principles, ***collaborative***, indicates that initiating and shepherding program success is predicated on sharing financial, human capital, and intellectual content resource burdens to maximize strengths of each stakeholder. Taken together—based on previous experiences—these design principles provide a navigational guide to help orient and align the program with the needs of the nuclear security profession(3).

In addition, these design principles also help coordinate the objectives of the nascent program's stakeholders. To steer the program toward success, clear and coordinated roles and responsibilities have been identified for each stakeholder. For example, Sandia as a co-implementer, has such responsibilities as: providing dedicated staff for program management and development, developing curriculum, delivering courses, leading/supporting research, advising graduate students, negotiating engagement with/participation from U.S. government entities, and championing all elements of the program with various stakeholders (e.g., domestic and international agencies. Similarly, the partner university as a co-implementer, has such responsibilities: providing a dedicated faculty member for program management and development, developing curriculum, integrating this program other areas of study, delivering courses, leading/supporting research, advising graduate students, championing all elements of the program with various university-related groups (e.g., faculty and students), and exploring university-specific funding opportunities. Lastly, NNSA/INS as a primary sponsor, has such responsibilities as: providing sustained financial and programmatic support and advising on program development. In return, NNSA/INS gains tools to meet its engagement mission and internal staffing needs. If successfully conducted, these roles and responsibilities will provide clear benefits for each stakeholder.

This academic program is designed to be built on three pillars:

SAND2020-XXXX. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525

- ***Education Pillar***—This pillar will provide students with technical knowledge and intellectual skills related to nuclear security through offering a set of in-residence, graduate-level courses (e.g., nuclear security system design). Combinations of core and elective courses could lead to a degree concentration (for traditional students) or a graduate certificate (for non-traditional students).
- ***Research Pillar***—This pillar will provide opportunities to leverage both UNM and Sandia capabilities to support cutting-edge research and development related to nuclear security. Such research projects—with new technology development and advancements in analysis techniques as representative examples—can be based on current collaboration mechanisms between UNM and Sandia, as well as build long-term intellectual investment in nuclear security among students, faculty, and lab staff.
- ***Professional Development Pillar***—This pillar will provide additional opportunities for (current or future) nuclear security professionals to gain deeper technical knowledge across topics in the discipline. For example, the first major action under this pillar is to a three-week professional development course to be conducted over the summers as UNM and provide continuing education units for both domestic and international attendees.

Education Pillar

To date, the emphasis in developing this advanced nuclear security program has been on UNM and Sandia partnering to conduct an initial pilot course. The result was the seminar-style course "Nuclear Security: Theory and Practice" (NUEN 515.12) conducted during the 2020 spring semester.[1] This course served as an advanced, comprehensive overview to the principles, concepts, technologies and practices responsible for securing nuclear material and nuclear facilities. Due to the broad nature of securing nuclear facilities and nuclear material, this course brought together the diverse areas of expertise within nuclear to security to cover a wide variety of aspects including—but not limited to—physical protection systems, cybersecurity at nuclear facilities, unmanned aerial systems as well as counter unmanned aerial systems and the link between facility security, safety and safeguards.

Each meeting of this seminar-style course is divided equally into three sections. In the first section, one of the primary instructors provided a comprehensive overview of the weekly topic, which often included historical context, analytical foundations/assumptions, current capabilities/ applications, and gaps/areas for growth. In the second section, students actively discussed topical readings—which included relevant academic journal papers, laboratory publications, and open-source news articles which were read *before* class—which provided the students with insights into new and developing research in the weekly topic, advancements and current applications of the topic, and served to enhance the technical understanding of each weekly topic. In the final section of each class, a Subject Matter Expert (SME) provided a guest lecture on some element of the weekly topic. SMEs first described their role within the nuclear security profession and then discussed an aspect of the weekly topic in detail, often fielding questions from the students in throughout the presentation. Taken together, these three sections of each class meeting—comprehensive review by primary course authors, reading discussions, and SME guest lectures—mutually reinforced student learning opportunities across a wide range of nuclear security topics.

---

[1] As with the rest of the world, stay-at-home and self-quarantine efforts directly impacted our course. In short, the second half of the semester was delivered online (via Skype). Though a significant change in structure, the delivery of the context was not substantially impacted as primary lecturers, students, and guest lecturers were are flexible and able to adjust to online learning as best as possible.

SAND2020-XXXX. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525

In response, this course separated into five broad categories or themes, shown in Table 1. , Though designed for technical students with engineering or hard science majors, this course began by building a foundation for nuclear security based on historical connections to nuclear safety, different philosophies underlying security, and on understanding/assessing threats to nuclear facilities. Given the importance of non-technical aspects influencing technical security requirements, this seminar also introduced students to the international recommendations and domestic regulations that guide security design and operations at nuclear facilities. The course then transitioned into more traditional, technical approaches to nuclear security to help establish the current "state of the art." Once established, the conversation naturally turned toward what capabilities or operations aspects challenge the efficacy and efficiency of these current state of the art approaches. Finally, the course ended with several discussions on how options for evolving current state of the art of practices to better mitigate these new challenges.

Table 1: Nuclear Security Theory & Practice Topics.

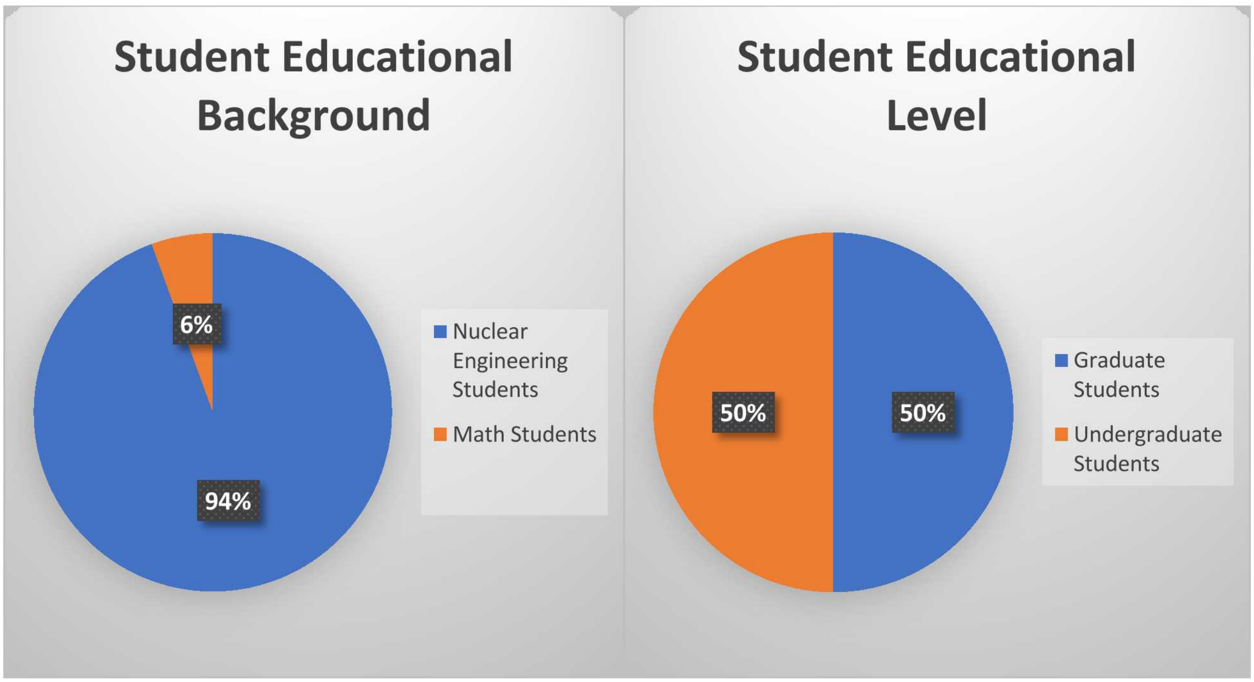
Course Theme	Class	Topic
Core Concepts for Nuclear Security	1	Introduction to Nuclear Security: From "theory" to practice
	2	Threats to Nuclear Security: The Identification, Assessment, Mitigation Loop
	3	Nuclear Security: Gates, Guards, & Guns
Policies & Best Practices in Nuclear Security	4	International Best Practices for Nuclear Security: Challenges & Opportunities
	5	US Best Practices for Nuclear Security: Comparing DOE & NRC perspectives
	6	Case Studies: Y-12 & Pelindaba
Current Context & Capabilities for Nuclear Security	7	Physical Protection System Design: A DEPO-Based Perspective
	8	Nuclear Material Accounting & Control: Support for Nuclear Security
	9	Modeling and Simulation
Challenges to Current Nuclear Security Approaches	10	Unmanned Aerial Systems
	11	Cyber & Digital Challenges
	12	The Role of Humans in Nuclear Security
Future Capabilities & Needs	13	Advancements in Vulnerability Assessments
	14	Physical Protection System Design: A "beyond-DEPO" perspective

Course Assignments

The assignments in this course were meant to solidify the information learned throughout the classes and pave the path for the second core course of the program. In the class four assignments were given to the students, assignments were decreased due to the transition to online learning during the COVID-19 timeframe. The first assignment in the class asked students to describe the similarities and differences between nuclear security and nuclear safety. This assignment was meant to capture the similarities in the mission space of ensuring safe operations of nuclear material and nuclear material and ensuring the safety and health of onsite workers and the environment. However, security defends sites against the intentionality of an adversary to a facility and safety ensures safe operations to natural or manmade accidents. The second assignment was a student debate where two teams were created to debate whether a nuclear newcomer country should adopt a recommendation or regulation-based approach to their nuclear security regime. This allowed students to weight the benefits and drawbacks of both national level recommendations and strict regulations to guide applications of security systems at a country's nuclear facilities. The third assignment was based on the students creating a scaled down version of a path analysis at a hypothetical nuclear power facility. This assignment gave students a predetermined adversary path and students had to define probabilities of detection and task time along the path and to define the cumulative probability of detection and adversary task time. Students were also asked to define one other pathway the adversary may take to reach the target objective and define probabilities of detection and task time at each step in the path and the cumulative probability of detection and task time. The fourth assignment focused on upgrading the physical security system at the hypothetical nuclear power facility in the third assignment. Students were asked to upgrade the security system of the facility to secure the facility against an updated DBT that was given to the students.

Student demographics

The first iteration of this course was compromised of 17 nuclear engineering students and one math major. Nine of the students were senior undergraduate students, and nine students were taking the class for graduate credits. These student demographics can be seen in Figure 1 below.



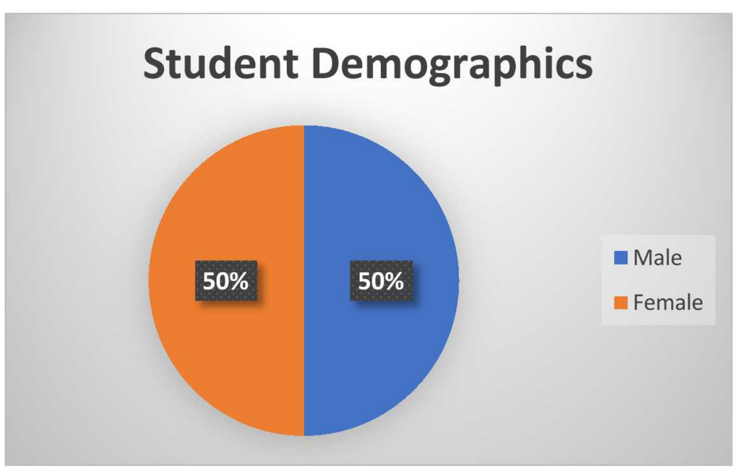


Figure 1: Student demographic breakdown.

SAND2020-XXXX. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525

Course Effectiveness

To evaluate the effectiveness of this “Nuclear Security: Theory & Practice” course, Sandia generated a specific course survey to gather student opinion on course delivery, appropriateness, and applicability. Of the 18 students registered in the course, nine students answered the survey given. Of the nine answers, four students were undergraduates, three were graduate, and two were non-traditional students. The table below highlights some of these results.

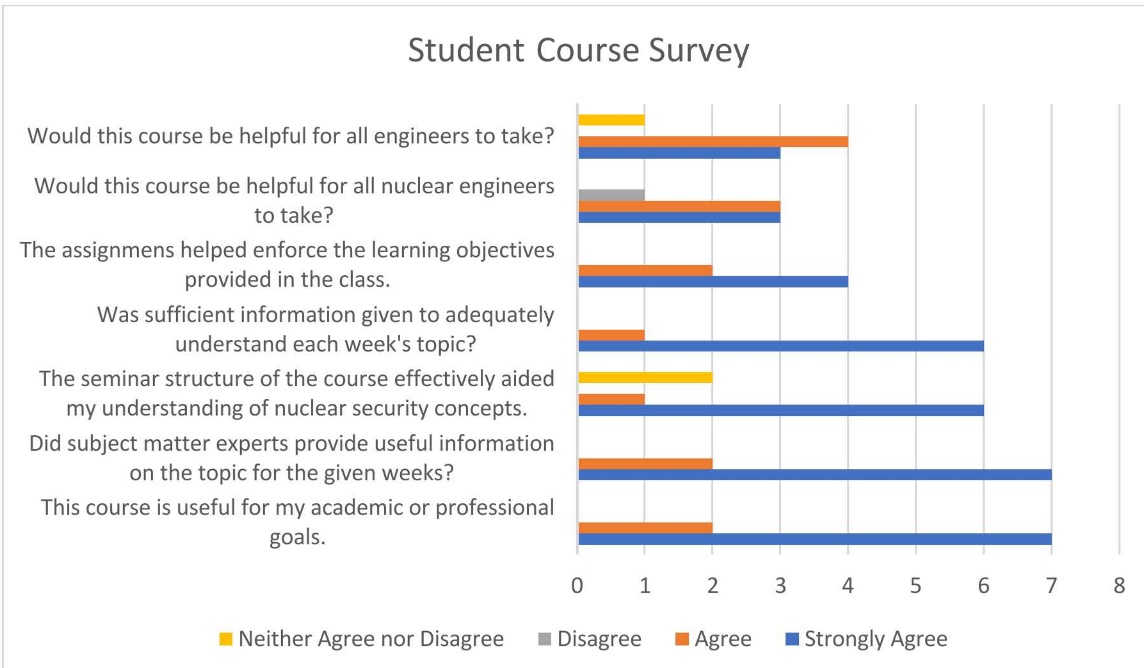


Figure 2: Student survey results.

Based on the results from the student surveys the students who took this class believed this course was beneficial to both their academic and professional goals. This shows the added benefit to students of improving their academic experience and created a course that lends to their success in their academic and professional careers. Students also tended to agree that both nuclear engineering students and other engineering discipline students would benefit from taking this course. Based on these results and the wide technological breadth of nuclear security, this course would be impactful to multiple engineering disciplines. Students also conveyed in their survey that the two primary instructors and the guest lecturers effectively delivered information and context that contributed to their understanding of the core nuclear concepts. Students conveyed through the survey that Modeling and Simulation and Physical Protection System Design: A “beyond-DEPO[2]” perspective were the two topics that the students would have liked more time spent on in class. In the Modeling and Simulation portion of the class, students were exposed to a variety of modeling and simulation methods and tools. Modeling and simulation tools were taught as design and analysis tools for physical protection systems. The and

[2] The “Design Evaluation Process Outline (DEPO)” is a security design framework developed by Sandia in the early 1980s [Mary Lynn Garcia Book]. DEPO is a globally accepted framework and serves as the de facto “standard” for nuclear security applications.

Physical Protection System Design: A “beyond-DEPO” perspective section was designed to create critical-thinking based on the new threats that nuclear facilities face and the potential gaps in the existing DEPO methodology. Students were exposed to some solutions and new iterations of the DEPO methodology that can lead to addressing the new threats and challenges that nuclear facilities face. From these student responses, students are very interested in learning more information on tools for design and analysis, solutions and methodologies for improving security system designs, and solutions and methodologies for securing facilities against new and advanced threats that nuclear facilities face.

Students were also asked if further courses in nuclear security, what topics they would like to be covered? The results can be seen in the figure below.

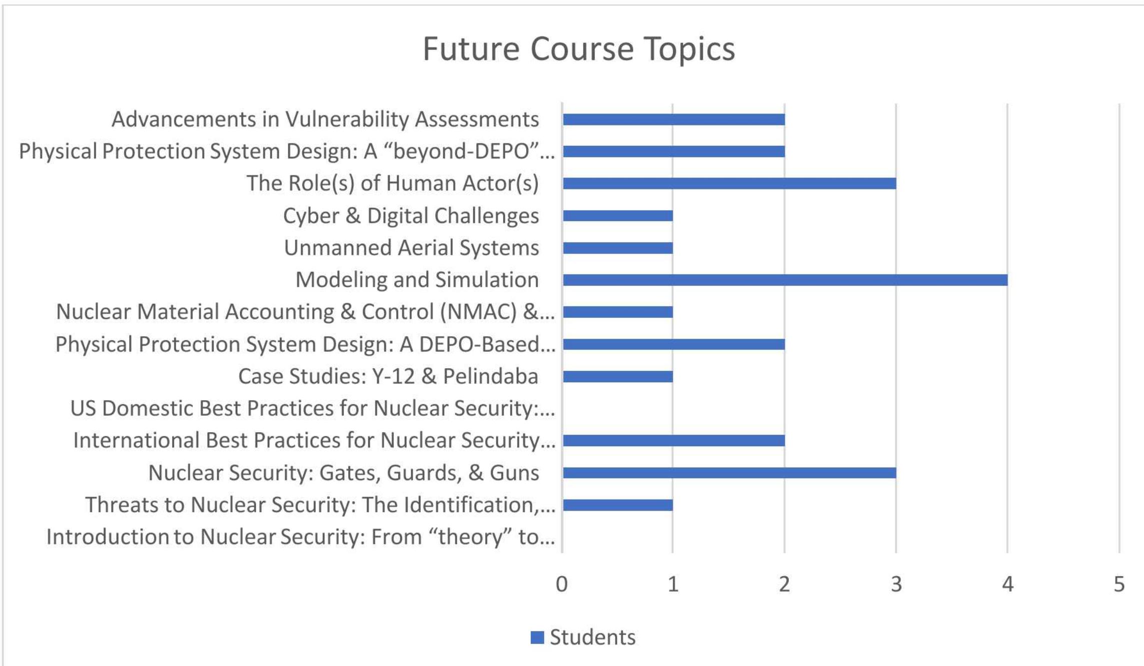


Figure 3: Additional nuclear security courses.

Through the survey students expressed that if further classes were offered in nuclear security, Modeling and Simulation was an area for creation of future classes within the nuclear security program. Students also expressed interest in the Gates, Guards & Guns and lecture for future classes. However, this section of the course was meant to put a historical perspective around nuclear security and how it has progressed in technological advancements and implementation. The other topic students were interested in expansion was The Role(s) of Human Actor(s). This course topic was on the relationship between humans and nuclear security technologies and the dynamics of the system that makes up nuclear security systems.

As part of our course effectiveness, guest lecturers were asked to provide feedback on this course. The guest lecturer on the US best practices of nuclear security, with over 20 years in domestic nuclear security, said “This is a good course preparing anyone going into commercial nuclear power. This provides a good understanding of the basis and importance of nuclear security that can get lost on a lot of people. The regulatory drivers and threats to the health and safety of the public need to be understood by all NPP employees. Security is everyone’s responsibility.” As a site security manager at multiple nuclear power plants over his 20 years also said “. I know people that worked for me that could have used it, would have liked it, and it would have made it easier for me." These remarks show that this course would be extremely valuable for those moving into nuclear security roles at nuclear power plants. The guest lecture who discussed the history and advancements in nuclear security, who has over 30 years of experience in domestic and international nuclear security, said "Very valuable. In the 1970s, the idea of treating security systems like any complex system began to gain traction. People made a strong case that a security system is an important, complex, human in the loop system no different than a reactor control system or a critical safety system for example. Designing a security system that performs effectively against a defined threat is an engineering problem." This course and program is based on effectively outlining the engineering aspects of creating a security system that defends against a defined threat.

In many respects, the full scale and scope for contextualizing nuclear security as an academic field is yet to be fully realized, but this course—as designed and delivered—begins to give direction to this pursuit.

Next Steps and Vision of Success

Based on the success of this inaugural pilot course, several short-term goals were identified to support successful development of this program. First—and perhaps the most obvious—goal is to conduct a follow-on course in the 2020 Fall semester. This second course—tentatively titled "Nuclear Security Design and Analysis"—will expand on the foundations established in the "Nuclear Security Theory & Practice" course. Fashioned after common engineering design courses, students will be exposed to the design and analysis of nuclear security systems using a capstone design project. In this class instructors will provide weekly instruction the various engineering concepts of nuclear security systems. Topics to be covered in this course include, but are not limited to, path analysis, vulnerability assessments, threat assessments, design basis threats, internal and external intrusion detection, developing delay systems, nuclear material accounting and control, and system effectiveness calculations. The primary objective of this course is to teach students different technical analysis techniques to support nuclear security system design, as well as frameworks for continually analyzing security system effectiveness.

A second short term goal focuses on codifying the efforts of creating a nuclear security educational program between Sandia and a partner university with a memorandum of understanding (MOU). This MOU would create an understanding between the host university and Sandia to create this nuclear security education program. This MOU will create equal investment between the host university and Sandia. Creating equal investment in the program will ensure that both the host university have equal to gain in the success of the nuclear security education program. Creating equal investment and equal opportunities will increase the likelihood of overall of creating a self-sustaining nuclear security education program.

A third short term goal relates to conducting a professional development pilot offering. More specifically, Sandia aims to host an Advanced Nuclear Security Summer Program at a host university. As the foundational tenant of the professional development program, this will be a multi-week program to educate both domestic and international students in the foundations of nuclear security. Leveraging existing curriculum created in the education pillar, students will be exposed to the theory and practice of nuclear security to create a foundational understanding of nuclear security and participate in hands-on exercises at Sandia. These exercises will include performance testing of sensors, cameras and other security system technologies, demonstrations of access delay technologies, counter unmanned aerial systems (CUAS) and other security related technologies. The final portion of the program will create an understanding of security system design and analysis using the foundational elements taught and their experience with security technologies. This program will be applicable for domestic and international students, including students and professionals pursuing careers in the nuclear security industry. This program is intended to be offered as an accredited program that offers continuing education credits to be used by professionals.

A fourth short term goal is to support the growth of the research pillar of this nuclear security education program. Research under this program would consist of STEM-based research and social science-based research that will contribute to the improvement of nuclear security domestically and internationally. STEM-based research may include advancements in nuclear security related technologies (sensors, cameras, access controls, access delay technologies, CUAS and cybersecurity), security system design, security system and analysis and modeling and simulation tools. This broad range of nuclear security related research projects will increase interest among university students and improve domestic and international nuclear security research and development. These research and development areas will lend to improved security technologies to be used in both domestic and international applications. For example, a recently hired UNM graduate student intern at Sandia will support ongoing R&D related to security systems for advanced reactor concepts and Small Modular Reactors.

Completion of these short-term goals will lead to the vision of success established for this program. Ultimately, this vision of success is a long-term plan aimed at ensuring a self-sustaining nuclear security program at the host university. Below is a list of medium and long-term goals that may ensure the success of a self-sustaining nuclear security education program. While not comprehensive, this list does outline key program attributes to support success of the nuclear security education program. For overall program development and evolution, success would include the university partner hiring a dedicated professor to manage the program, convening of the programs Advisory Council, and coordination with the nascent Nuclear Security Fellowship Program[3]. For the education pillar, success would include formal approval of the core courses (e.g., having official university course numbers), an average student population of 5-8 students per course, 3-5 students having already received their graduate credential, and an official process by which to develop/incorporate new elective courses. For the research pillar, success would include current (or completed) projects under each Sandia collaboration mechanism; 3-5 joint peer-reviewed publications, patent applications, or invited talks; and, initiation/evolution of a "Nuclear Security Laboratory" at the partner university. For the professional development pillar, success would include 2-3 successful offerings of the summer professional development course, summer program graduates from 4-6 different countries, and agreements with various stakeholders to meet onboarding and other on-the-job-training needs.

Even from these initial steps, this program allows students to gain knowledge, experience, and expertise across the wide-ranging topics within the nuclear security space. Once sustainable, this academic program can create a direct pipeline from the university partner—through experiences impacted directly by SNL and indirectly by NA211—to nuclear security missions across the NNSA lab complex, as well as the wider nuclear industry. Further, there is the potential for adapting and replicating this program to other universities, to grow the academic field of nuclear security and create a diverse field of

[3] The Nuclear Security Fellowship Program is aimed to provide a pipeline for technical students into nuclear security professions. For further information contact Alan Evans (aevans@sandia.gov).

graduate students who are comprehensively prepared to join—and advance—the nuclear security discipline.

References

1. https://www.iaea.org/publications/8363/educational-programme-in-nuclear-security
2. GNEII paper in JNMM (2020)
3. Crawford, C.E. and **A.D. Williams.** (2017) 'Human Capacity Building in Nuclear Security,' in International Atomic Energy Agency *International Conference on Physical Protection of Nuclear Material and Nuclear Facilities*, Vienna, Austria, November 13-17.

SAND2020-XXXX. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525