Proceedings of the INMM & ESARDA Joint Annual Meeting
May 22-26, 2023

A GROWING PARTNERSHIP: THE GRADUATE CERTIFICATE IN NUCLEAR SECURITY ENGINEERING AT THE UNIVERSITY OF NEW MEXICO

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ABSTRACT

Several dynamics and trends are driving the need for a dedicated program to educate the next generation of nuclear security experts and expand engineering design principles applied to the design and implementation of nuclear security systems. There are also ongoing discussions on a more time-sensitive need to build sustainable pipelines for experts across the aspects of nuclear security engineering—including to meet both the anticipated demand from advanced and small modular reactor (A/SMR) markets and forecasted personnel needs across the U.S. National Nuclear Security Administration (NNSA) complex.

In response, the University of New Mexico (UNM) has partnered with Sandia National Laboratories (Sandia) over the last three years to conceptualize, develop, and operationalize the Nuclear Security Engineering Program. This program consists of three pillars. First, the education pillar consists of traditional academic courses designed to meet the rigors of a graduate engineering curriculum. Second, the professional development pillar provides comparable levels of knowledge transfers in mechanisms more flexible for working professionals. Third, the research pillar consists of a range of joint and collaborative projects between Sandia researchers and UNM faculty and staff. The program has shown steady evolution over this period—as demonstrated by an increasing number of courses offered, inclusion of Los Alamos National Laboratory, leveraging a hybrid environment to host out-of-state students, and initiating research projects with UNM faculty. And the program recently took a significant step forward with the successful submission of an application to establish the graduate certificate in nuclear security engineering (as of the writing of this abstract).

After briefly summarizing the history and evolution of UNM's NSP program, this paper will describe the structure and elements of the overall program. Next, this paper will discuss the accomplishments of the program to date and provide additional details on the graduate certificate in nuclear security engineering. Lastly, this paper will review conclusions and insights from developing this graduate certificate, as well as highlight implications for continuing to advance the state-of-the-art in nuclear security as an academic discipline.

* **SAND2023-02875C**, 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

Several dynamics and trends are driving the need for a dedicated program to educate the next generation of nuclear security experts. Consider, first, increasing interest—across both established nuclear energy programs and nuclear newcomers—in advanced reactor technologies to meet new demands for clean electricity generation. Second, the potential combinations of advanced reactor technologies (e.g., pebble bed or molten salt), implementation modalities (e.g., floating platforms or highly mobile microreactors), and deployment environments (e.g., arctic or remote locations) introduce new challenges to developing effective security solutions. Lastly, emerging and disruptive technologies continue to drive an evolving and dynamic threat environment. Taken together, these trends suggest a time-sensitive need to build sustainable pipelines for preparing the next generation of nuclear security experts.

Efforts to address this need have been spearheaded by work by the International Atomic Energy Agency (IAEA), which has offered guidance on crafting nuclear security educational programs since 2010 [1] and leads a global dialogue on educational best practices in the International Nuclear Security Engineering Network (INSEN) [2]. These efforts have produced a range of professional development and educational programs. As a representative example, Table 1 illustrates a range of nuclear security education options across universities in the United States.

Table 1. Summary of nuclear security-related programs at universities in the United States, adapted from [3].

U.S. University	Academic Department	Scope
Texas A&M University	Nuclear Engineering	● Masters of Science **Concentration** in Nuclear Nonproliferation ● Graduate **Certificate** in Nuclear Security
University of Tennessee	Nuclear Engineering	● Graduate **Certificate** in Nuclear Science and Analysis
University of Nevada, Reno	Mechanical Engineering	● Graduate **Certificate** in Packaging and Transportation ● Graduate **Certificate** in Transportation Safeguards and Security
Purdue University	Nuclear Engineering, Health Physics, Political Science	● Nuclear Security **Concentration** for Health Physics/Public Policy degrees ● **Major** in Nuclear Security for Nuclear Engineering degree ● Graduate **Certificate** in Nuclear Security (online)
Multiple universities	Various	● Pennsylvania State University (individual **courses** like *nuclear security threat analysis and assessments*) ● Massachusetts Institute of Technology (e.g., individual **courses** like *principles of nuclear radiation measurement & protection*) ● Oregon State University (individual **courses** like *nuclear security science*)

HISTORY, EVOLUTION, AND STRUCTURE OF UNM's NUCLEAR SECURITY PROGRAM

Building upon these developments, the University of New Mexico (UNM) has partnered with Sandia National Laboratories (Sandia) and Los Alamos National Laboratory (LANL) to conceptualize, develop, and operationalize a unique, advanced program in nuclear security education. From its inception, this contribution to nuclear security education has been developed around three key design principles. The first principle focused on keeping the program ***local.*** The goal of this principle is to provide one-of-a-kind opportunities for high-quality, in-residence education and professional development that best leverages proximity to the technical and research capabilities of neighboring Sandia and LANL. The second principle emphasizes a ***strategic*** design. The goal of this principle is to make decisions centered on sustainability by ensuring that the program is "demand-driven" by students and nuclear security professionals as well as meets needs for next-generation security solutions. The third design principle accentuates ***collaboration.*** The goal of this principle is to concentrate program success on sharing financial, human-capital, and intellectual-content resource burdens to maximize strengths of each stakeholder. Taken together, these design principles provide a navigational guide to help orient and align this joint UNM and Sandia educational opportunity with the evolving needs of the nuclear security profession.

Table 2. Descriptive list of how academic domains (and related departments) map to needed skills in the nuclear security professional arena, adapted from [3].

Academic Domain	Related Academic Departments	Applicable Skills in Nuclear Security
Hard sciences	● Physics ● Chemistry ● Health Physics	● Non-destructive/Destructive assay for nuclear materials accounting ● Reactor Modeling and Simulation ● Nuclear forensics
Engineering	● Nuclear ● Electrical ● Mechanical ● Systems ● Computer science	● Physical protection systems design, operation, and maintenance ● Physical protections technical component design and development ● "Cyber security" = f(all aspects of digital hardware, software, and operations related to the protection of nuclear materials) ● Integrating security solutions in nuclear facility design(s)
Social Sciences	● Psychology ● Sociology ● International affairs ● International/Public Policy	● Human reliability/trustworthiness programs ● Nuclear security culture programs ● Threat assessment development ● State-level security policy development ● International engagement
Business	● Administration ● Management	● Security/Program management ● State-level security regulation
Mathematics	● Statistics ● Ops Research	● Uncertainty analysis and quality control for security performance ● System effectiveness, risk management & vulnerability assessment

During early discussions on the curriculum-basis for this program, UNM and Sandia reviewed other university programs (Table 1) and tracked international dialogues on the breadth of skills necessary to apply within the nuclear security profession. Despite misconceptions that security is

just “gates, guards, and guns,” Table 2 describes the gamut of traditional academic departments that connect to applicable nuclear security skills.

In response, UNM and Sandia decided to focus their collaborative educational program on engineering nuclear security solutions. Given the existence of peer programs (like those listed in Table 1), the partners wanted to create an educational program aimed at connecting traditional security course content with real-world engineering. Pedagogically, UNM and Sandia believe that this emphasis on practical solutions will encourage participants to navigate the relationships between cutting-edge possibilities (e.g., uncrewed aerial systems or machine learning) and operational realities (e.g., budgets or regulations). Invoking the three design principles described above, UNM and Sandia invited LANL to coordinate on this program. Ultimately, with support from the National Nuclear Security Administration’s (NNSA) Office of International Nuclear Security (INS), UNM and Sandia signed a *Memorandum of Understanding* in 2020 to establish a Nuclear Security Program that aims to “advance technical and socio-technical solutions for nuclear security” and “create a pipeline of credentialed students into nuclear security professions.”

To date, the UNM Nuclear Security Program is structured on three pillars: education, research, and professional development (Figure 1). Under the ***education*** pillar, the Nuclear Security Program provides in-residence (and hybrid) graduate-level courses that give students the technical knowledge and intellectual skills necessary for success in nuclear security. To date, three courses have been developed specifically for this program (Table 3).

Table 3. Summary of graduate courses created for UNM’s Nuclear Security Program

Course Name	Course Description	Semesters Offered	# Students Completed
Nuclear Security Theory & Practice	A seminar-style course that explores the philosophical, technical, historical, and practical foundations of nuclear security in order to better contextualize next generation solutions	Spr. 2020	19
Advanced Nuclear Security System Design & Analysis	A comprehensive overview and application of interdisciplinary engineering methods to develop nuclear security designs aligned to key technical, geopolitical, social, and economic aspects	Fall 2020 Fall 2021	26
Nuclear Material Accounting & Control	A deep technical dive across the range of standard and cutting-edge approaches available to monitor nuclear materials in operating facilities for security purposes	Fall 2021 Fall 2022	15

Combinations of these core courses and related elective courses are being explored for various types of academic credentials—including but not limited to a degree concentration (for traditional students) or a graduate certificate (for non-traditional students).

Similarly, the ***research*** pillar of the program seeks to build off the strong academic foundation of the education pillar to push the intellectual boundaries of nuclear security. In its pursuit of cutting-edge advances in nuclear security solutions, this pillar will leverage opportunities to collaborate across relevant laboratories and facilities at Sandia (e.g., the Nuclear Security

Technology Complex) and LANL. An early mini-research symposium illustrated an array of potential areas of mutual interest—including new technology development and advancements in analysis techniques. Ensuing efforts under this pillar include increased collaboration on project proposals (e.g., including UNM staff on Laboratory-Directed R&D proposals), facilitating a UNM visiting research scholar to spend time in-residence at Sandia in summer 2023 and in coordinating dissertation research related to nuclear security for UNM graduate students. Successful by-products of this pillar will build long-term intellectual investment in nuclear security among students, faculty, and national laboratory staff.

The third pillar—***professional development***—offers the last element of nuclear security knowledge transfer envisioned for the program. Directly augmenting the other two pillars, options provided in this pillar are aimed at (current or future) nuclear security professionals interested in gaining deeper technical knowledge outside of formal academic mechanisms. For example, each of the academic courses described above is also offered as a continuing education option, wherein professional students have a lighter workload and receive continuing education units (versus academic credits). Offered in 2021 and 2023, the cornerstone opportunity in this pillar is the *UNM Nuclear Security Summer School*, a multi-week course the collapses vital elements of academic curriculum into an accelerated agenda to better align with the schedules of professional students.

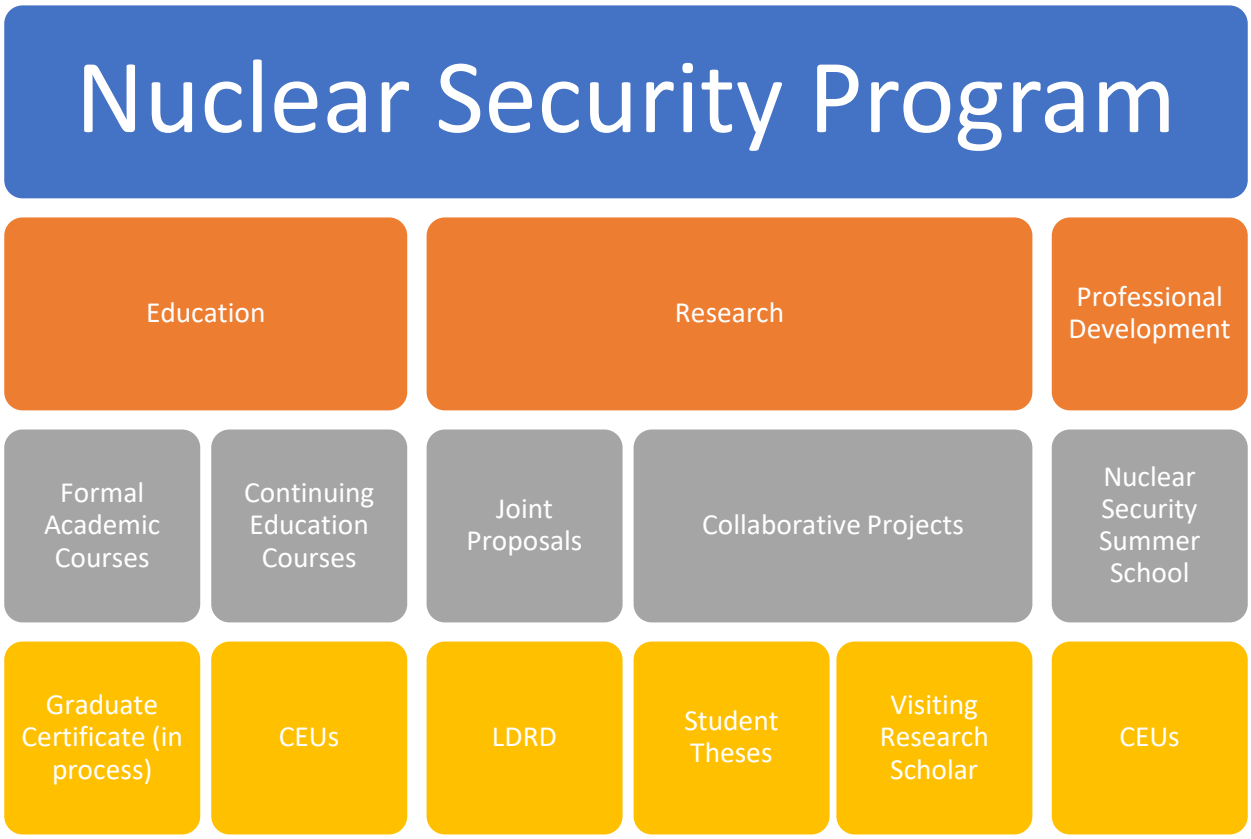

Figure 1. Illustrative summary of the "3-pillar" structure of the UNM Nuclear Security Program

A PROPOSED UNM GRADUATE CERTIFICATE IN NUCLEAR SECURITY ENGINEERING

Based on the successes the Nuclear Security Program has experienced to date, UNM and Sandia recently completed and submitted the paperwork to formally request the creation of a *Graduate Certificate in Nuclear Security Engineering* at the university. The request for the creation of the certification program is based on the need of national laboratories and the NNSA to develop an experienced workforce for the nuclear security enterprise—in part driven by the knowledge that over one-third of the cadre of employees in the NNSA are currently eligible to retire.

The structure of the proposed graduate certificate requires completion of 12 graduate-level credit hours—or typically four semester-length courses. The core requirements for the certificate are 9 credit hours that consist of three courses—two created for this program (the first two rows in Table 3) and UNM's NE/POLS 515 *Weapons of Mass Destruction Nonproliferation Science & Policy*. With the focus of the Nuclear Security Program on interdisciplinary engineering methods, the fourth course can be selected from a set of technical elective courses related to nuclear security (Table 2). Figure 2, below, illustrates the proposed certificate structure.

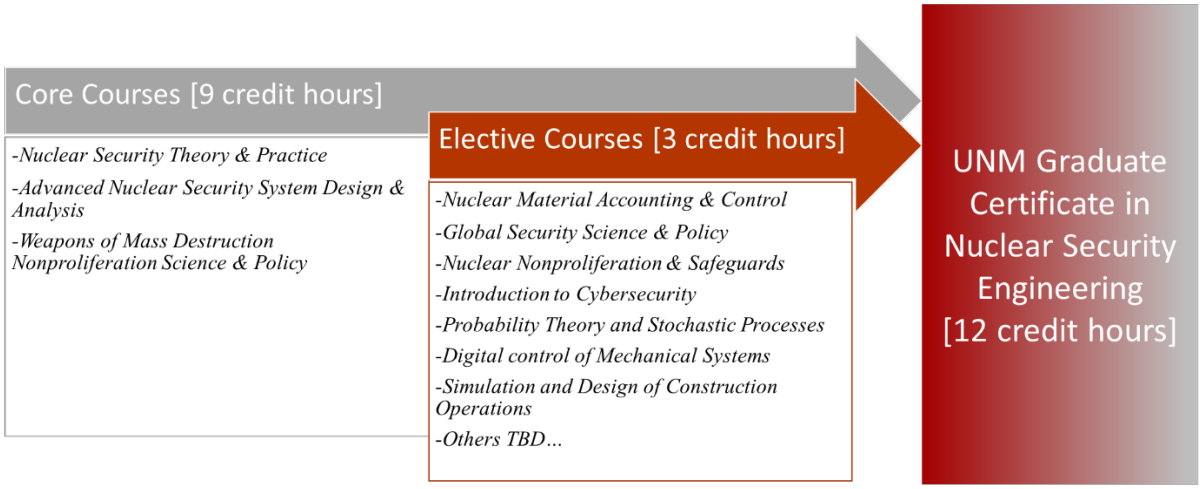

Figure 2. Graphical depiction of the proposed UNM Graduate Certificate in Nuclear Security Engineering

As an exciting prospect, there are several key benefits UNM can expect should this graduate certificate come to fruition. First, it would help advance the nuclear engineering department's academic missions of education and research by offering additional opportunities for professors to collaborate with the neighboring Sandia and Los Alamos National Laboratories. Second, it would provide increased opportunities to UNM students in terms of a new academic specialization, new laboratory-supported research projects, and additional internship options. Third, the certificate would introduce and encourage more interdisciplinary elements across departments whose courses might support the certificate. Lastly, the structure of a graduate certificate would likely be more flexible—and thereby more attractive to non-traditional students to improve the economies of scale.

After submission in late 2022, the certificate is currently in review by higher-level management and Faculty Senate at UNM.

CONCLUSIONS, INSIGHTS & IMPLICATIONS

Overall, efforts to create and establish a graduate-level Nuclear Security Program at the University of New Mexico have been successful. Executing several iterations of core courses and bespoke elective classes has both strengthened the status of the program and provided valuable lessons learned. For example, Nuclear Security Program courses were conducted before, during, and after New Mexico's precautions against COVID-19. These experiences indicated that while hybrid versions of these courses can be implemented effectively, the design principle of locality suggests the program does not want overly to rely on hybrid offerings. Another lesson relates to increased benefits for a common interdisciplinary perspective of nuclear security that emerged from Sandia staff serving as adjunct UNM faculty and UNM professors participating as visiting research scholars onsite at Sandia. Lastly, the importance of formal educational credentials for program sustainability, credibility, marketing, and clarity is demonstrated in the work put into submitting the proposal for the Graduate Certificate in Nuclear Security Engineering.

The evolution of this Nuclear Security Program is predicated on near-, intermediate-, and far-term visions of success. Operationally, these objectives could include UNM hiring a professor dedicated to managing the current courses and growing the overall nuclear security program. For the education pillar, success could involve an average annual enrollment of five to eight students per core course and a future steady state of three to five students receiving academic credentials per academic year (e.g., either a concentration on a formal degree or a graduate certificate). Success within the research pillar could consist of one to three joint research proposals submitted per year, a future steady state of three to five joint peer-reviewed publications or invited talks per year, or a stretch goal of building a "National Security Laboratory" at UNM. Lastly, success for the professional development pillar could encompass a well-established Nuclear Summer School with an annual attendance of 12–15 domestic and international participants as well as formal agreements to provide nuclear security onboarding and on-the-job training needs for domestic and international stakeholders.

The lessons learned and progress towards visions of success imply that the joint effort by UNM and Sandia to craft this program is timely and relevant. Moving forward, UNM and Sandia will grow this partnership toward ensuring that the Nuclear Security Program continues to advance the state-of-the-art in nuclear security as an academic discipline. Yet, the ultimate goal of this Nuclear Security Program is to help create a sustainable and adaptable knowledge transfer pipeline to mitigate the anticipated demand for next-generation nuclear security expertise to meet obligations for both domestic and international nuclear security enterprises.

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