

Roadmap for a Sustainable Professional Pipeline: The Nuclear Security Education Program at the Center for Nuclear Security Science and Policy Initiatives (NSSPI) at Texas A&M University

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Abstract:

NSSPI is the first U.S. academic institution focused on technical graduate education, research, and workforce development related to the safeguarding of nuclear materials and the reduction of nuclear threats. Since its inception in 2006, NSSPI has established itself as a center of excellence in nuclear security, safeguards, and nonproliferation (NSSN), and its educational initiatives have created a robust pipeline of career-ready graduates for U.S. national laboratories, relevant government agencies, and industry. NSSPI's graduate curriculum combines policy and technical aspects of NSSN, and its innovative program gives students a variety of experiences, from hands-on national laboratory training and internships to international facilities study tours, to enhance their understanding and improve their readiness to perform in the workforce. NSSPI faculty engage students in research, principally in the areas of detector system design and deployment, nuclear forensics and attribution, nuclear security and proliferation risk analysis, nuclear proliferation detection, and nuclear safeguards analysis. NSSPI has also become one of only two organizations to host Stanton Foundation Nuclear Security fellows engaging in policy-informed technical nuclear security research. Texas A&M is home to the first student chapter of INMM. As a pioneer organization in NSSN education, NSSPI's program has become a model to similar programs around the U.S. and the world. As such, NSSPI has engaged with academic institutions worldwide to support nuclear security curriculum development and regularly conducts in-person training for an international audience, supported by the US Department of State, Department of Education, and Department of Energy. NSSPI conducts asynchronous online training through its Nuclear Security and Safeguards Education Portal and offers two professional certificates to professionals and students around the world. NSSPI faculty support the online graduate nuclear security certificate as well as the online Master of Engineering degree. NSSPI faculty serve on domestic and international consultancies as experts including the International Atomic Energy Agency (IAEA). This paper describes the past and current efforts of NSSPI in strengthening human resource capacity in NSSN, both domestically and internationally, and the lessons learned from these efforts. These NSSPI efforts were supported by numerous U.S. federal agencies and national laboratories, as well as the IAEA.

1. Introduction

The Center for Nuclear Security Science and Policy Initiatives (NSSPI) at Texas A&M University is the first U.S. academic institution focused on technical graduate education, research, and workforce development related to the safeguarding of nuclear materials and the reduction of nuclear threats. The political and social science disciplines in academia already had strong programs focused on nuclear nonproliferation and nuclear security policy that well pre-dated NSSPI's formation. To complement these policy-centered programs, NSSPI focused primarily on a technical orientation in the nuclear security sciences with policy as a supporting element to help students understand the policy implications of new sensitive technologies based on nuclear science and engineering.

In addition to developing and teaching nuclear security and nonproliferation courses, NSSPI was instrumental in promoting innovative technical research with the involvement of students interested in the study of nuclear security, safeguards, and nonproliferation. NSSPI has conducted collaborative R&D starting with Los Alamos National Laboratory (LANL), and subsequently with other national laboratories, which allowed students to respond directly to real-life engineering problems being studied in nuclear security and nonproliferation. Through these collaborations, Texas A&M provided a critical service of

feeding the pipeline with career-ready graduates in the area of nuclear security and nonproliferation to the national laboratories.

The NSSPI model for nuclear nonproliferation and security education is largely based on the idea that training professionals to enter careers in this domain requires experiences and expertise beyond the nuclear engineering classroom curriculum. Five main categories support NSSPI student education: academic classes in nuclear security and policy; experiential learning; research; networking; and professional development. These additional elements of the NSSPI program serve to support the professional development of our graduates and their readiness to enter U.S. national laboratories, relevant government agencies, and industry.

2. Trajectories of NSSPI Graduates

Since its inception in 2006, NSSPI has produced 127 graduates specializing in nuclear security and nonproliferation research (see Figure 1). NSSPI’s unique formula of providing a multidisciplinary education that occurs both inside the classroom and through meaningful experiences has produced an entire generation of new leaders in nuclear security and nonproliferation.

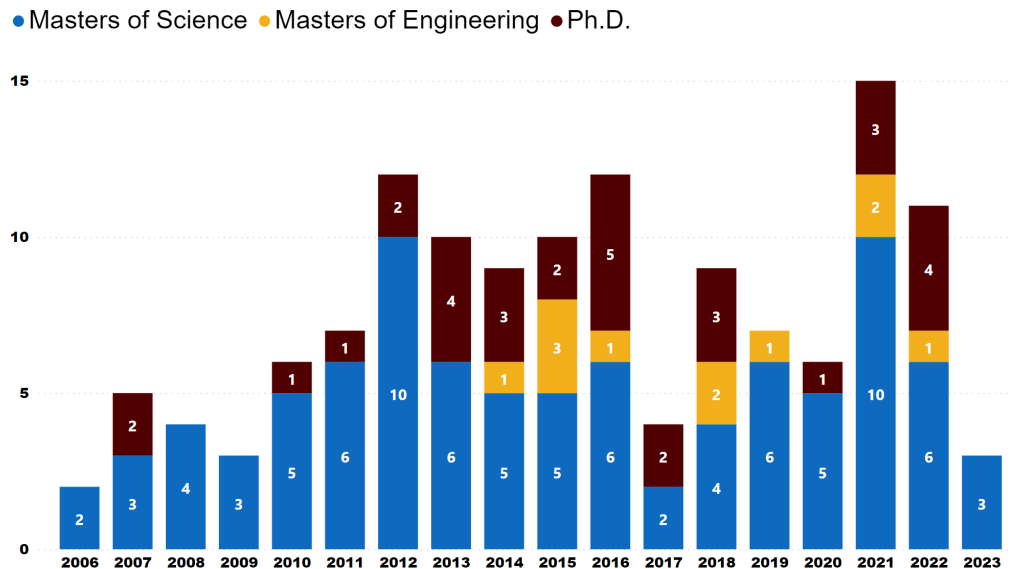


Figure 1. Degrees Earned by NSSPI Students by Year. NSSPI students are students who were advised by NSSPI faculty members and who completed coursework in the nuclear nonproliferation academic track. NSSPI has supported students in many other research groups and departments, as is partly reflected in the list of theses and dissertations.

The majority of NSSPI graduates (58%) go on to careers in government or national laboratories. Other destinations for NSSPI graduates include the nuclear industry (14%), the military (10%), academia (5.5%), and continued graduate studies (5.5%). See Figure 2.

NSSPI Graduate Trajectories

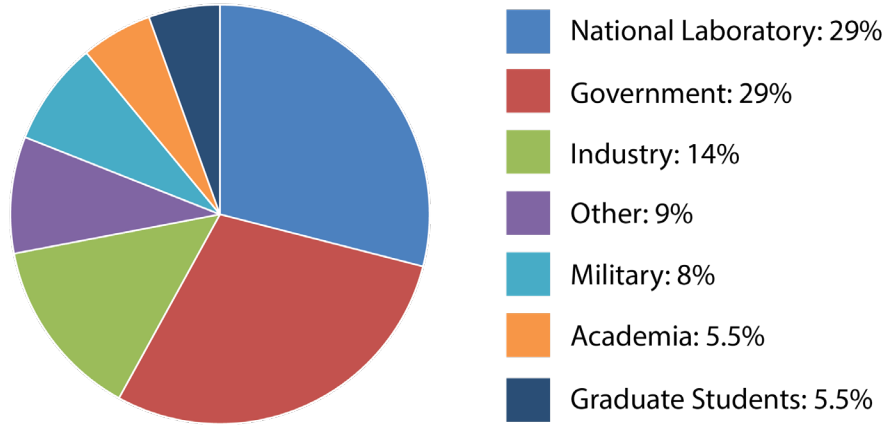


Figure 2. Trajectories of NSSPI graduates. Fifty-eight percent of NSSPI graduates are working in the government or in national laboratories.

3. Educational Initiatives at NSSPI

(a) Master’s Degree with Nuclear Nonproliferation Specialization

The Master’s degree with a specialization in nuclear nonproliferation offered by the Texas A&M Department of Nuclear Engineering is designed as a 1½ to 2-year program consisting of nine formal courses. Of these formal courses, seven are required courses and two must be selected from a set of possible electives. As a Master of Science degree, the students will also complete research of fundamental interest to the field and write a corresponding thesis detailing their research. The Master of Engineering (ME) Degree in nuclear engineering does not require the completion of a thesis and, since the development of the remote detection laboratory, can be completed completely online. The outline of the Master’s degree in Nuclear Engineering with Nuclear Nonproliferation Specialization is shown in Table I [1].

Table 1. M.S./M.E. Degree with a Specialization in Nuclear Nonproliferation Curriculum

	Course Title	Credit Hours
Year 1: Fall	NUEN 604 – Radiation Interactions and Shielding	3
	NUEN 605 – Radiation Detection and NM Measurement	3
	NUEN 650 – Nonproliferation and Arms Control	3
Year 1: Spring	NUEN 601 – Nuclear Reactor Theory	3
	NUEN 606 – Nuclear Reactor Analysis and Experimentation	4
	NUEN 651 – Nuclear Fuel Cycles and Materials Safeguards	3
Year 2: Fall	NUEN 610 – Design of Nuclear Reactors (capstone)	4
	Seminar	2
As Needed	Technical Electives and Research	7

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Students select electives from a set of relevant elective courses, some being provided by faculty in other Texas A&M departments:

- NUEN 630 – Monte Carlo Methods for Particle Transport
- NUEN 657 – Emergency Response Dose Assessment
- NUEN 451 – Nuclear Security Systems Design
- CHEM 681 – Radiochemistry & Nuclear Forensics (Chemistry Department)
- INTA 617 – Deterrence and Coercion (Bush School)
- INTA 620 – International Security (Bush School)
- INTA 652 – The Role of Intelligence in Security Affairs (Bush School)

These electives are designed to enrich students' educations by focusing their attention on issues that are key to the field; these electives also bring some diversity to the degree program.

(b) Academic Certificate in Nuclear Security

NSSPI faculty also support a Certificate in Nuclear Security, which is an official Texas A&M University certificate program open to both degree-seeking and non-degree-seeking students that focuses on providing students with a solid understanding of the policy and technical aspects behind nuclear security, safeguards, and nonproliferation. This multidisciplinary program has courses both in the Department of Nuclear Engineering and at the Bush School of Government and Public Service. To qualify for this certificate, students must complete 12 semester credit hours (SCH) of coursework selected from the following list:

- NUEN 451 - Nuclear Security System Design (3 SCH)
- NUEN 605 - Radiation Detection and Nuclear Materials Measurement (3 SCH)
- NUEN 650 - Nuclear Nonproliferation and Arms Control (3 SCH)
- NUEN 651 - Nuclear Fuel Cycles and Nuclear Material Safeguards (3 SCH)
- INTA 669 - Nuclear Terrorism Threat Assessment and Analysis (3 SCH)
- INTA 617 - Deterrence and Coercion (3 SCH)

The graduate programs in nuclear nonproliferation and the academic certificate in nuclear security offer multiple pathways for students to gain expertise in this area.



Figure 3. The 2022 International Nuclear Facilities Experience took students and early career professionals from the national laboratories to various sites in the UK. This is a photo of the group at the URENCO-UK uranium enrichment facility.

4. Experiential Learning

The nonproliferation specialization Master's degree provides an academic underpinning to the education of the students involved with NSSPI. Inside the classroom, students in these courses participate in tabletop exercises, simulations, and hands-on detection labs (both in person and remotely) to augment the theoretical content of the courses in the nonproliferation specialization.

However, from the beginning, NSSPI faculty and staff have also worked to provide enriching experiences for students in addition to their classroom education. From annual trips for students to the national laboratories to participate in hands-on safeguards training sessions to student exchanges that give them opportunities to travel internationally and grow their knowledge base, NSSPI students receive the sort of multi-faceted education required to produce quality nuclear security professionals.

The International Nuclear Facilities Experience (INFE), jointly organized by NSSPI and Argonne National Laboratory and sponsored by the NNSA, represents one of the defining experiences for many NSSPI students. As part of the INFE, NSSPI students join with nuclear security and nonproliferation students from other U.S. universities and early career professionals from the national laboratories to participate in technical visits to nuclear fuel cycle facilities in foreign countries. Over the past thirteen years, NSSPI has sponsored international trips for 87 students, eight faculty members, and 38 early-career staff members to visit fuel cycle facilities in Japan, the UK, and Europe. In FY23, NSSPI conducted INFES to the UK and Japan with a third INFE to take place in Europe in May 2023. These trips allow students and early career professionals access to facilities not found in the US and interactions with professionals responsible for safeguarding materials in those facilities. NSSPI also organizes Domestic Nuclear Facilities Experiences to tour nuclear facilities and national laboratories in Texas and New Mexico.



Figure 4. Participants in the 2023 INFE to Japan pose with a Hiroshima bombing survivor. Visits to sites like Hiroshima give young professionals in nuclear security and nonproliferation international perspective for their studies and future work.



Figure 5. NSSPI research facilities, clockwise from top left: the Nuclear Forensics and Radiochemistry Laboratory; the Remote Detection Laboratory used for remote classroom experiments; the Radiation Detection and Measurements Laboratory; and the Nuclear Security and Emergency Response Laboratory.

5. Research in Nuclear Security and Nonproliferation

Research undertaken by NSSPI faculty and students supports in tandem two of its missions: (a) to conduct policy-informed technical research in collaboration with national laboratories and other partners to develop and apply science and technology to detect, prevent, and reverse the proliferation of nuclear and radiological weapons and (b) to educate the next generation of leaders in the field of nuclear security and nonproliferation. To meet these twin missions of research and education, NSSPI utilized its NNSA seed funding, as well as resources garnered from other research projects sponsored by various federal agencies, such as the Department of Homeland Security and the Department of Defense, to develop experimental laboratories at Texas A&M with the needed equipment to conduct research in its focus areas. The research facilities under NSSPI's purview include the Nuclear Forensics and Radiochemistry Laboratory, the Nuclear Security and Emergency Response Laboratory, and the Radiation Detection and Measurements Laboratory. (see Figure 5).

Some of NSSPI's key research projects have focused on nuclear safeguards instrumentation, nuclear forensics methods, neutron detector design, radiation detector simulation, proliferation pathways analysis, plutonium source attribution, advanced reactor safeguards, nuclear weapons latency, advanced safeguards

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measurement techniques, border monitoring methods to prevent nuclear material smuggling, anti-neutrino measurements, proliferation resistance analysis for advanced reactor types, and consequence management. Most of NSSPI's research endeavors are policy-informed through collaboration with the Bush School and the Texas A&M Department of Political Science. Research partners include relevant federal agencies, national laboratories, the IAEA, universities, and non-governmental organizations.

Every year NSSPI also advises one to two Stanton Nuclear Security fellows to conduct policy-relevant nuclear security research with NSSPI and Texas A&M political science faculty. Past Stanton fellows have done work on assessing the proliferation risk of pyro-processing, estimating the extent of the HEU stockpile in North Korea, evaluating the effects of the US withdrawal from the Joint Comprehensive Plan of Action with Iran, forecasting the proliferation risk of the growth of nuclear power programs, developing a two-PMT directional detector for radiation source localization, assessing radioactive dispersion from a terrorist attack on a nuclear power plant, and evaluating the proliferation and security risks of nuclear trade for nuclear newcomer countries seeking to implement small modular reactors. NSSPI Stanton fellows present their research and interact with the other technical and policy fellows at the annual Stanton fellows conference in Washington, D.C.

One NSSPI faculty member is part of the DOE-NNSA-sponsored consortium for monitoring, technology, and verification (MTV) led by the University of Michigan. The MTV's mission is to develop new technologies that detect and deter nuclear nonproliferation activities and to train the next generation of nuclear professionals. NSSPI team contributes to the research thrust area on signals and source terms for nuclear nonproliferation.



Figure 6. NSSPI regularly organizes meetings and seminars with distinguished speakers for students.

6. Networking

Participation in NSSPI allows students ample opportunities for meeting with both peers and leaders in the discipline. NSSPI faculty and staff organize biweekly meetings with technical presentations that run the gamut from student research to distinguished visitors. NSSPI draws on its immense network of contacts from the government, academia, industry, and national laboratories to give NSSPI students the greatest exposure to experts and other students both domestically and internationally. “The network and connections that NSSPI provides are invaluable,” NSSPI graduate Dr. Sean Martinson explains. “They have allowed me to intern with fantastic laboratories and meet peers from across the country and even the world.” The INFE is another example of a successful networking program for students and young professionals,

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with around 125 alumni now occupying positions throughout the nuclear nonproliferation mission space in the US.

Furthermore, Texas A&M became the first university to host a student chapter of the Institute for Nuclear Materials Management (INMM) in 2005, providing students with additional opportunities to connect with professionals through organizing seminars, workshops, and social events for Texas A&M students interested in nuclear nonproliferation. In coordination with NSSPI faculty members and professional staff, the Texas A&M INMM student chapter also promotes participation in the larger professional society and has inspired the establishment of more student chapters at universities in the U.S. and around the world. According to NSSPI graduate Dr. Robert Zedric, “Through the connections and support of our faculty, [the Texas A&M] INMM [student chapter] brought in numerous speakers and visitors who delivered presentations on and fostered discussion about the most pressing issues in our field.”



Figure 7. NSSPI hosted the 2023 IAEA Regional School of Radiation Emergency Management for the Caribbean Community.

7. Professional Development and International Cooperation

As part of its mission to serve as a public resource for knowledge and skills to reduce nuclear threats, NSSPI partners with countries and organizations around the world to help develop safeguards capabilities and enhance global nuclear security culture. NSSPI faculty frequently present lecture series and workshops at universities in other countries and serve as experts for IAEA training activities. Some of the countries that have benefitted from NSSPI-led training include Brazil, the Czech Republic, Ghana, India, Indonesia, Japan, Jordan, Kenya, Malaysia, Nigeria, South Africa, Thailand, Ukraine, and the United Arab Emirates.

NSSPI holds observer status with the IAEA and became one of the founding members of the International Nuclear Security Education Network (INSEN). NSSPI faculty also participated in the drafting of the IAEA’s Nuclear Security Series No. 12 and includes members of Working Group B of the International

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Network for Education and Training on Emergency Preparedness and Response (iNET-EPR), which addresses EPR education and academics and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) working group. NSSPI has recently hosted the IAEA multi-regional School of Nuclear Knowledge Management, along with the Regional School of Radiation Emergency Management and Train-the-Trainer Workshop in Radiation Detection for the Caribbean Community.

NSSPI has also worked with the National Institute of Advanced Studies (NIAS) in Bengaluru, India to organize a series of meetings on human reliability programs in industries of national importance between subject matter experts from the US and participants from Indian industries, government, universities, research institutes, and other stakeholders (see Figure 8).



Figure 8. NSSPI Director Dr. Sunil Chirayath helped organize a series of meetings on human reliability programs in industries of national importance in India.

Over the past couple of years, NSSPI has worked with Oak Ridge National Laboratory (ORNL) to develop and provide the equipment for a new radiation detection and nuclear security instructional laboratory at the Amity Institute of Nuclear Science and Technology (AINST) on the campus of Amity University in Noida, India. As part of this project, NSSPI faculty and students worked with Amity faculty to conduct training in the use of specialized radiation detection equipment and provided exercises to demonstrate how this equipment is utilized for nuclear security for university faculty from all over India as well as some professionals from the nuclear industry.

NSSPI conducts asynchronous online training through its Nuclear Security and Safeguards Education Portal (NSSEP) to disseminate knowledge in nuclear and radiological sciences, security, and safeguards to a large number of professionals and students across the globe. Developed with support from the NNSA and the Department of State's Office of Cooperative Threat Reduction, this resource has the capacity to reach an audience greater than is possible through face-to-face training. In FY2022, NSSEP delivered more than 1500 courses to over 500 registrants. NSSEP modules have also been the basis for two professional certificates offered by the Texas A&M Engineering Experiment Station (Nuclear Security Fundamentals

and Nuclear Safeguards Fundamentals), as well as four INMM workshops on the “Technical and Policy Fundamentals of International Safeguards” in 2018, 2020, 2021, and 2023 [3].

Students in the NSSPI education program participate in various professional development opportunities provided by NSSPI (such as NSSEP and workshops), but they are also involved in the delivery of training. For example, NSSPI students regularly help with radiation detection field exercises for training in emergency preparedness and response at the Texas A&M Engineering Extension Agency’s Disaster City facility (see Figure 9). NSSPI graduate Alexis Ash, who was part of a team that led an emergency response training exercise conducted at Disaster City, describes, “It was a very unique experience to witness, and getting to explore Disaster City was definitely memorable. This experience allowed me to witness emergency response in an in-person learning environment rather than just through textbooks and lectures.”

8. Conclusion

Throughout its 17-year history, NSSPI has produced 127 graduates specializing in nuclear nonproliferation and security and trained many individuals globally in nuclear security and nonproliferation. Key elements of NSSPI’s program—education, experiential learning, research, networking, and professional development—are focused on giving students the tools they need to become leaders in the field. The unique experiences provided by NSSPI give Texas A&M graduate students specializing in nuclear nonproliferation a substantial foundation on which to build a successful career in this area.

9. Acknowledgement

The authors would like to express their deep gratitude to the sponsors that have supported NSSPI throughout its history. The staff and faculty at NSSPI that have led these efforts have received substantial financial and moral support from various agencies and organizations: the U.S. Departments of Energy, State, Defense, Education, and Agriculture; the U.S. National Nuclear Security Administration; the U.S. Nuclear Regulatory Commission; the U.S. National Science Foundation; various U.S. national laboratories, the IAEA; the Carnegie Endowment for International Peace; Carnegie Corp. of New York; the Stanton Foundation; and nuclear industry partners. For the continued success of all elements of NSSPI’s educational, research, and outreach programs, the authors extend their gratitude for all past and continued support.

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Figure 9. NSSPI faculty and students lead a radioactive source recovery field exercise at Disaster City for an IAEA Train-the-Trainer event for the Caribbean Community.