

**THE CENTER FOR NUCLEAR SECURITY SCIENCE AND POLICY INITIATIVES
(NSSPI) AT TEXAS A&M UNIVERSITY: FIFTEEN YEARS OF EXCELLENCE IN
EDUCATION, RESEARCH, AND WORKFORCE DEVELOPMENT**

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ABSTRACT

NSSPI is celebrating its 15th year of operation in 2021. 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. NSSPI has established itself as a center of excellence in nuclear security, safeguards, and nonproliferation (NSSN) in the three aforementioned focus areas. NSSPI's educational initiatives have created a robust pipeline of career-ready graduates for the U.S. national laboratories, relevant government agencies, and industry. Its anniversary coincides with the 100th graduate (MS/ME/PhD) from the program. NSSPI's graduate curriculum combines policy and technical aspects of NSSN, and its innovative program gives students a variety of experiences, from hands on laboratory training and internships to international facilities tours, to enhance their understanding and improve their readiness to perform in the workforce. NSSPI faculty members manage laboratories of nuclear security and safeguards, nuclear forensics and radiochemistry, and neutron sensing. NSSPI conducts state-of-the-art 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. Texas A&M is the home of 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. NSSPI has engaged with academic institutions worldwide (Brazil, Ghana, India, Indonesia, Japan, Jordan, Nigeria, South Africa, South Korea, Thailand, and UAE) to support nuclear security curriculum development and regularly conducts in person training for an international audience. To disseminate knowledge in NSSN to professionals and students around the world, NSSPI conducts asynchronous online training through its Nuclear Security and Safeguards Education Portal. NSSPI faculty members serve on domestic and international consultancies as experts including the International Atomic Energy Agency (IAEA). This paper describes the past and current efforts NSSPI at Texas A&M have undertaken 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.

INTRODUCTION

The Center for Nuclear Security Science and Policy Initiatives (NSSPI), a joint center of Texas A&M University and the Texas A&M Engineering Experiment Station (TEES), is celebrating its 15th anniversary this year. NSSPI continues to contribute to the pipeline of nuclear security professionals through its educational, research, and workforce development activities focused on nuclear security science and its interface with national and international policy. At every step of its development, NSSPI has managed to expand its activities and scope to serve students, other universities, national laboratories, international organizations, U.S. government agencies, and industry. This has created a strong, sustainable academic group at Texas A&M with links to all of these stakeholders.

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THE FOUNDING OF NSSPI

The vision of Drs. William S. Charlton, Kenneth L. Peddicord, and Warren F. Miller, Jr. led to the creation of NSSPI at Texas A&M as a collaborative effort between its Department of Nuclear Engineering and the George Bush School of Government and Public Service. The leadership and dedication of Prof. (Dr.) Charlton, its founding director, took NSSPI from an idea to a dynamic program. He spearheaded the addition of a nuclear nonproliferation specialization track to the Master of Science (MS-NNP) nuclear engineering degree program in 2004, the first technical nuclear nonproliferation-focused MS degree of its type in the United States. This newly created nonproliferation education and research track was further developed and nurtured by NSSPI beginning with its inception in March 2006. The degree required students to learn core and nonproliferation specialization courses in nuclear engineering while also participating in international affairs courses offered by the Bush School.

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 innovative technical research with the involvement of students interested in the study of nuclear security, safeguards, and nonproliferation. NSSPI 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 work-ready graduates in this area to the national laboratories.

With the help of local U.S. Representative Chet Edwards, NSSPI obtained seed funding of about \$2 million per year for three years from the Department of Energy's National Nuclear Security Administration (NNSA) to realize its vision. In the past 15 years, NSSPI was able to successfully garner resources from multiple federal agencies, industry, and national laboratories for continuing and enhancing their multidisciplinary research, education, and workforce development programs in nuclear security and nonproliferation by utilizing the full capabilities of the university. NSSPI's average annual research expenditure for the past 15 years has been \$2.38 million, out of which \$1.54 million per year was utilized for multi-disciplinary research.

By the end of FY2009, NSSPI had grown to include faculty members Prof. (Dr.) David Boyle (nuclear weapons test monitoring), Prof. (Dr.) Paul Nelson (transport theory, computational methods), Prof. (Dr.) Sunil Chirayath (nuclear fuel cycle, safeguards approaches development, nuclear forensics, Monte Carlo radiation transport simulations), and Prof. (Dr.) Craig Marianno (nuclear instrumentation development, physical protection system design, radiological consequence management), each of whom brought their unique expertise to the center and expanded the scope of NSSPI's education and research capabilities. In that same period, NSSPI also added professional staff members Dr. Claudio Gariazzo, David Grant Ford, Kelley Ragusa, Lana Wilson, and Gayle Rodgers to support its mission.

EDUCATIONAL INITIATIVES AT NSSPI

(1) Master's and PhD Degrees with Nuclear Nonproliferation Specialization and Nuclear Security Certificate Programs

The Master's degree with a specialization in nuclear nonproliferation 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

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corresponding thesis detailing their research. The Master of Engineering Degree does not require the completion of a master's thesis and could potentially be completed online with some lab requirements done onsite over a short period. 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
Year2: Fall	NUEN 610 – Design of Nuclear Reactors (capstone)	4
	Seminar	2
As Needed	Technical Electives and Research	7

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 689 – Radiochemistry & Nuclear Forensics (Chemistry Department)
- MATH 664 – Inverse Problems in Nuclear Forensics (Mathematics 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)
- INTA 669 – Nuclear Terrorism Threat Assessment and Analysis (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 students' degree program. PhD degree course work will include a set of elective courses from the above list in addition to the dissertation research and core nuclear engineering courses.

NSSPI also supports a Graduate Certificate in Nuclear Security, which is an official Texas A&M University graduate certificate program open to both degree-seeking and non-degree-seeking students that focuses on providing students 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)

(2) Education Beyond the Classroom

The nonproliferation specialization Master's degree provided an academic underpinning to the education of the students involved with NSSPI. However, from the beginning, NSSPI faculty and staff worked to provide enriching experiences for students in addition to their classroom

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education. From annual trips for students to the national laboratories to participate in hands-on safeguards training sessions to other training opportunities and student exchanges that give them opportunities to travel internationally and grow their network, NSSPI students receive the sort of multi-faceted education required to produce quality nuclear security professionals.

The International Nuclear Facilities Experience (INFE), 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 tour nuclear fuel cycle facilities in foreign countries. Past INFEs have taken students to Japan, the UK, and Europe. NSSPI also organizes Domestic Nuclear Facilities Experiences to tour nuclear facilities and national laboratories in Texas and New Mexico.



Figure 1. The 2019 International Nuclear Facilities Experience took students and early career professionals from the national laboratories to various sites in Europe.

With Prof. (Dr.) Charlton as the first faculty advisor, Texas A&M became the first university to host a student chapter of the Institute for Nuclear Materials Management (INMM) in 2005. The INMM student chapter sponsors seminars, workshops, and social events for Texas A&M students interested in nuclear nonproliferation. In coordination with NSSPI faculty members and professional staff, it 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.

(3) Trajectories of NSSPI Graduates

Since its inception in 2006, NSSPI has produced 110 graduates specializing in nuclear security and nonproliferation research (see Figure 2). 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. The majority of NSSPI graduates (54%) go on to careers in government or the national laboratories. Other destinations for NSSPI graduates include the nuclear industry (20%), the military (8.5%), academia (3.5%), and the International Atomic Energy Agency (IAEA) (2%). See Figure 3.

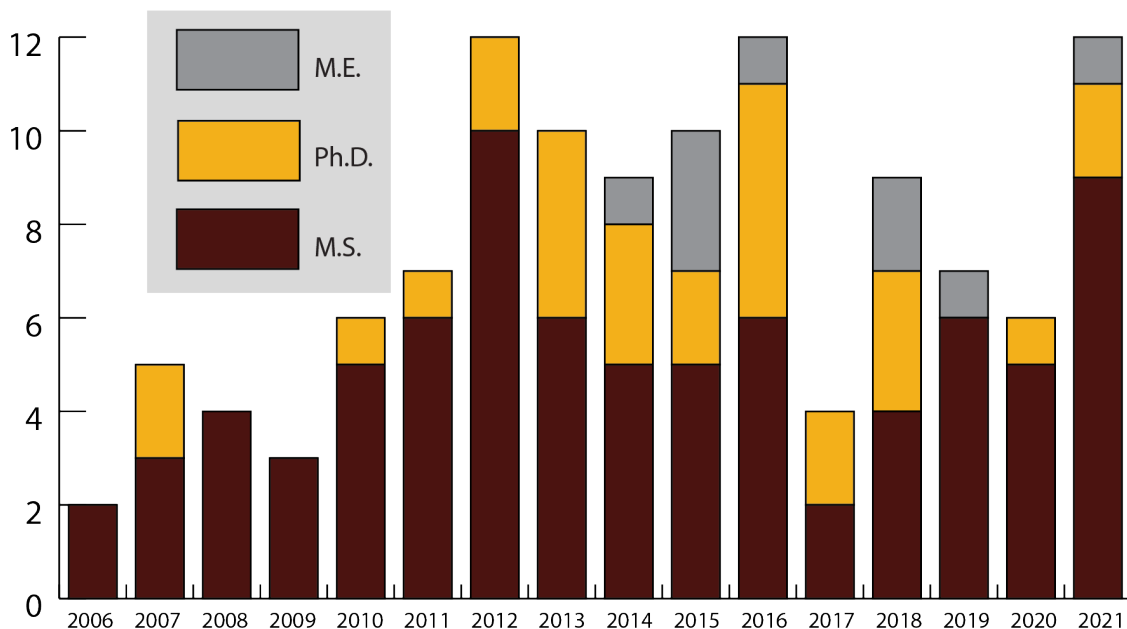


Figure 2. Degrees conferred to NSSPI students by year from Spring 2006 to Summer 2021. NSSPI students take classes in the nuclear nonproliferation specialization degree plan and have NSSPI faculty for advisers. NSSPI has produced 110 graduates from its degree programs.

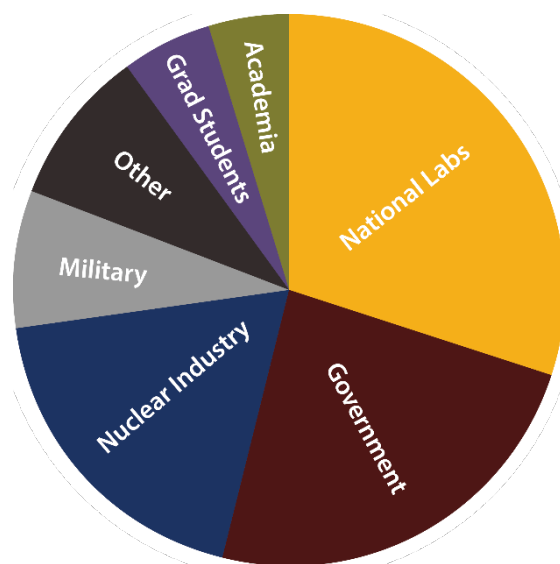


Figure 3. Trajectories of NSSPI graduates. The majority of NSSPI graduates (54%) go on to careers in government or the national laboratories.

EXPERIENTIAL EDUCATION THROUGH RESEARCH

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, the Radiation Detection and Measurements Laboratory, and the Neutron Sensing Laboratory (see Figure 4).



Figure 4. NSSPI research facilities, clockwise from top left: anti-neutrino detection setup at the Texas A&M University research reactor; the Nuclear Security and Emergency Response Laboratory; the Remote Detection Laboratory used for remote classroom experiments; the Nuclear Forensics and Radiochemistry Laboratory; and the Neutron Sensing Laboratory.

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 measurement techniques, border monitoring methods to prevent nuclear material smuggling, anti-neutrino measurements, 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.

The following is a list of some of NSSPI's major research accomplishments:

(a) became the first university research team to mount and record radiation data from a crane used in port operations [2]; (b) designed the Self-Interrogation Neutron Resonance Densitometry (SINRD) detector for nuclear safeguards measurements with Los Alamos National Laboratory for

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testing by the IAEA [3]; (c) developed the SHIELD framework to interdict HEU at borders [4]; (d) made the first quantitative measurement of Pu in used nuclear fuel with Oak Ridge National Laboratory [5]; (f) developed the PRAETOR tool [6] and performed proliferation risk analysis of various fuel cycles [7]; (g) developed a nuclear weapons latency method [8] and performed analysis for the case of Iran [9]; (h) performed nuclear forensics analysis on weapons-grade plutonium samples employing PUREX combined with ICPMS and gamma spectrometry [10]; (i) devised a safeguards system concept for pebble-fueled high temperature gas-cooled reactors [11]; (j) developed a new technique for analyzing Pu K x-rays for nuclear forensics applications using a bent-crystal spectrometer [12]; (k) performed proliferation resistance / safeguards analysis of the Fast Breeder Reactor fuel cycle [13]; (l) developed a portable gamma radiation portal monitor specifically designed for the scanning of livestock [14]; (m) developed dynamic agent-based modeling using the Bayesian framework for addressing intelligent adaptive nuclear nonproliferation analysis [15]; (n) devised and analyzed a safeguards approach for spent nuclear fuel in dry cask storage using remote monitoring systems [16]; (o) developed nuclear safeguards approach for Molten Salt Reactors [17]; (p) created an environmental chamber to study the deterioration of portal monitor detectors [18]; (q) developed safeguard measures for neptunium-237 [19]; (r) evaluated radiation protection of transport vehicles in a radiological incident [20]; (s) developed method using advanced semiconductor detectors to measure reactor antineutrinos [21]; (t) developed a Nuclear Material Control system for Pebble Bed Reactors.

SERVING THE WORLD

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, Czech Republic, Ghana, India, Indonesia, Japan, Jordan, Kenya, Malaysia, Nigeria, South Africa, Thailand, Ukraine, and the United Arab Emirates.

In fall of 2009, NSSPI brought in Dr. Paulo Barretto, former IAEA Director for Technical Cooperation programs for Europe, Latin America and West Asia, to broadcast his very popular widely respected daily e-mail news digest for those following nuclear policy and technology throughout the world. Paulo's Corner continued until 2016 and was followed by subscribers from 54 different countries. According to subscribers, the information from Paulo's Corner was so relevant and timely as to be of utmost utility to those asked to analyze and comment on nuclear matters. As such, it was influential in spreading information to help promote an informed security culture throughout the world.

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

NSSEP currently offers the following modules [22]:

(a) Introduction to Nuclear Safeguards and Security, (b) Basic Nuclear and Atomic Physics, (c) Introduction to the Nuclear Fuel Cycle, (d) Basic Radiation Detection, (e) Introduction to

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Statistics, (f) Threats to Nuclear Security, (g) Nuclear Security Culture, (h) Physical Protection Systems, (i) Insider Threats, (j) Applied Statistics for Safeguards, (k) Containment and Surveillance, (l) Nuclear Material Accountancy, (m) Spent Nuclear Fuel Safeguards, and (n) Uranium Enrichment Safeguards.

In FY2020, NSSEP delivered more than 1400 courses to 500 registrants. During the COVID-19 pandemic, NSSEP courses were promoted extensively by the U.S. National Laboratory complex as suitable training for their employees to complete while working from home. 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 two workshops on the “Technical and Policy Fundamentals of International Safeguards” held on the sidelines of the INMM annual meetings in 2018 and 2020 [23].

NSSPI TODAY

Today, NSSPI continues to support a large number of students—approximately thirty graduate students and at least 5 undergraduate students at any given time—to study and conduct research in the nuclear security and nonproliferation field. In addition to Prof. (Dr.) Sunil Chirayath (Director), NSSPI core faculty consist of its Deputy Director Prof. (Dr.) Craig Marianno and faculty fellows Prof. (Dr.) Shaheen Dewji and Prof. (Dr.) Shikha Prasad. Professional staff members Oscar Acuna and Kelley Ragusa lead efforts in training and outreach. NSSPI has kept its core faculty and staff to a minimum and draws from the wealth of intra-departmental and intra-university researchers based on the type of multi-disciplinary research at hand.

Given the global expansion of nuclear energy with growing interest in advanced reactor technologies, NSSPI looks to play a role in supporting technical education, research, and workforce development to safeguard nuclear materials and reduce nuclear threats in response to a changing landscape. As it has in the past, NSSPI will evolve to provide the best possible education to its students to prepare them to take on leadership roles in the future.

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