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Cover Page Footnote
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The Nuclear Security Science and Policy Institute at Texas A&M University

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Abstract

NSSPI is a multidisciplinary organization at Texas A&M University and the first U.S. academic institution focused on technical graduate education, research, and service related to the safeguarding of nuclear materials and the reduction of nuclear threats. NSSPI employs science, engineering, and policy expertise to: (1) conduct research and development to help detect, prevent, and reverse nuclear and radiological proliferation and to help guard against nuclear terrorism; (2) educate the next generation of nuclear security and nuclear nonproliferation leaders; (3) analyze the interrelationships between policy and technology in the field of nuclear security; and (4) serve as a public resource for the reduction of nuclear threats. Since 2006, Texas A&M awarded over 31 Doctoral and 73 Master degrees through NSSPI-sponsored research. Forty of those degrees are Master of Science in Nuclear Engineering with a specialization in Nuclear Nonproliferation and 16 are Doctorate of Philosophy degrees that specifically focus on nuclear nonproliferation. Over 200 students from both technical and policy backgrounds have taken classes provided by NSSPI at Texas A&M.

NSSPI faculty and staff at Texas A&M established a model for educating technical safeguards and security experts at the university level, which has been, in large part, replicated worldwide. In addition to conventional classroom lectures, NSSPI faculty: (1) provide practical experiences; (2) advise students on valuable research projects that contribute substantially to the nuclear nonproliferation, safeguards, and security arenas; and (3) engage with experts from several similar international academic and research institutes in activities and research that benefit Texas A&M students. NSSPI also helps international institutions develop their own programs in nuclear security and nonproliferation.

KEYWORDS: nuclear; safeguards; security; education; university

I. Introduction

It is in the general interest of humankind and the specific interests of the U.S. government to detect, prevent, and reverse the proliferation of nuclear weapons materials and technology as well as control existing nuclear arms stockpiles. In their Nuclear Security Plan for the period 2006-2009, the International Atomic Energy Agency (IAEA) emphasized the need to develop, educate,

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and train nuclear security workforces **[*1*]**. The communiqué from the first Nuclear Security Summit held in Washington, D.C. (2010) also echoed this need when it specifically called for the building of human capacity through "technology development, human resource development, education, and training" **[*2*]**. The U.S. has witnessed the growth of initiatives like the National Nuclear Security Administration's (NNSA) Global Threat Reduction Initiative (GTRI) Nuclear Security Education Program, the Next Generation Safeguards Initiative (NGSI), and the U.S. Department of Homeland Security Domestic Nuclear Detection Office's (DNDO) Nuclear Forensics Education Award and Academic Research Initiative (ARI) programs. These programs, sponsored by the U.S. government, encourage universities to participate in nuclear security education and research; the focus of these initiatives demonstrates the widely held perceived need for highly trained experts in these fields.

To help achieve these goals, NSSPI is educating future generations of nuclear nonproliferation, nuclear security, and nuclear safeguards experts through technical and policy education and research. NSSPI is administered as an academic research center under the Texas A&M Engineering Experiment Station (TEES), a component of the Texas A&M University System. NSSPI's programs support nuclear security education both internationally and at Texas A&M; these programs employ innovative approaches that combine theoretical and practical experiences. NSSPI faculty, students, and researchers are also committed to producing state-of-the-art research in several key areas of nuclear security and nonproliferation. Eight professional staff members, including four nuclear engineering faculty members and two research staff members, currently comprise the institute.[2]

In its nine years of existence, NSSPI's invaluable experiences in nuclear security education and research has enabled it to develop a multi-faceted program that models how to produce technical experts in this high-demand field.

II. Overview of the NSSPI Program

Since 2004, the Nuclear Engineering Department at Texas A&M has offered a Master of Science degree with a Nuclear Nonproliferation Specialization (MS-NNP). This degree responded to the growing demand for safeguards and security experts worldwide. At the time, Texas A&M was teaching some of the only engineering courses in the U.S. that addressed the technical aspects of nuclear nonproliferation **[*3*]**. As the program interacted with the U.S. national laboratories, it became evident that engagement in this critical area between technical experts in the labs and in academia would be beneficial for both parties. In particular, programs like the MS-NNP at Texas A&M alleviated some of the burdens of on-the-job training for the laboratories and offered cost-effective solutions for training individuals in nuclear safeguards and security **[*4*]**.

In March of 2006, NSSPI was formed as a joint center between Texas A&M and TEES, the engineering research agency of the Texas A&M University System. It was positioned to be a multidisciplinary institute whose leadership consisted of faculty from the Texas A&M Department of Nuclear Engineering working closely with faculty from the Texas A&M George Bush School of Government and Public Service (Bush School). In 2006 at the announcement of its founding, then NSSPI associate director Dr. Warren Miller remarked, "NSSPI will be the first campus-based entity, with a higher-education mission, focusing on the details of nuclear security science and the interface with national and international policy" **[*5*]**. Moreover, since faculty and staff designed NSSPI as a multidisciplinary institute, rather than as a program within a nuclear

[1] http://nsspi.tamu.edu/people/professional-staff

engineering department, it spans across several colleges at the university; thus, it brings the full capabilities of a large research university to bear on the complex problems of nuclear security.

The political and social science disciplines in academia already had strong programs focused on nuclear nonproliferation and nuclear security policies that well pre-dated NSSPI's formation. A notable example of these is the James Martin Center for Nonproliferation Studies at the Middlebury Institute of International Studies (MIIS) at Monterey, which formed in 1989 and offers a Master of Arts degree in nonproliferation studies.[3] To complement these policy-centered programs, the NSSPI program 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 technologies. Education of this kind can be achieved only through a combination of both theoretical and practical instruction with a heavy focus on technical research that addresses the policies of the safeguards and nonproliferation regimes.

NSSPI's research and education program has evolved in three stages. Originally NSSPI focused heavily on the safeguards and proliferation detection missions (mainly through support from the NNSA and the national laboratories). In 2008, NSSPI added significant programs in nuclear forensics and border monitoring (including support from the DNDO-ARI, the Nuclear Forensics Academic Award Program, and the Second Line of Defense Program). More recently, NSSPI increased its portfolio in nuclear security (including physical security and insider-threat analysis) and consequence management (through support from GTRI, the U.S. Department of State's Partnership for Nuclear Security (PNS), the Nuclear Regulatory Commission, and others). The changing needs of the nuclear security enterprise in the U.S. have shaped these evolutions, which have also resulted in a reasonably diverse portfolio in terms of both the NSSPI research programs and course offerings.

Strong interactions with the U.S. national laboratories and other academic institutions guided NSSPI's evolution. Initially, NSSPI worked closely with MIIS and Los Alamos and Lawrence Livermore National Laboratories on its safeguards education program. Later, through a grant from GTRI, NSSPI joined with the Pennsylvania State University (Penn State) and the Massachusetts Institute of Technology (MIT) to develop a nuclear security education program that the three universities could exchange and possibly share in the future with other academic institutes **[*6*]**.

NSSPI has also undertaken to support nuclear safety, security, and safeguards (3S) education around the world through partnerships with international organizations and universities. NSSPI faculty regularly present nuclear security workshops and training sessions for educators and students in other countries (such as India, Indonesia, and Malaysia) as well as provide other forms of outreach to the international nuclear security community (Russia, Nigeria, Jordan). Due to the maturity and success of its educational program, NSSPI is responding to ever-increasing requests to participate in the development of academic programs in nuclear security worldwide. The first of these requests grew out of interactions with the Moscow Engineering Physics Institute (MEPhI) and the Obninsk State Technical University (IATE) as part of the Russian Academic Program in Nonproliferation and International Security funded through the NNSA. NSSPI has since developed a close partnership with organizations like PNS and the IAEA in this area. NSSPI also helped to draft the IAEA's Technical Guidance publication on "Educational Programme in Nuclear Security," (2010), a publication that introduces how the agency prescribes human resource development for member States **[*7*]**.

[2] http://www.miis.edu/academics/programs/npts;

Texas A&M faculty and students have been conducting research in nuclear nonproliferation, nuclear material safeguards, and international security for many years. Their activities have included scientific and engineering research projects with Los Alamos, Sandia, Oak Ridge, Lawrence Livermore, Savannah River, Idaho, and Pacific Northwest National Laboratories. Among others areas, faculty and students have researched:

- Proliferation-resistant nuclear fuel designs
- Proliferation and terrorism risk assessments for fuel cycles
- Nuclear material safeguards development and analysis
- Development of portal monitors to detect the illicit trafficking of nuclear materials
- Modeling of nuclear smuggling routes
- Pre-detonation and post-detonation event nuclear material attribution
- Compilations of reactor data for international safeguards and safety purposes
- And nuclear terrorism pathways analysis

III. Nonproliferation Curriculum and Education at Texas A&M University

In the years since its inception, the MS-NNP program at Texas A&M has become one of the most robust technical nonproliferation and safeguards education programs in the U.S. The largest of its kind, the program's longevity and willingness to embrace new instructional technologies and models have resulted in a successful academic program. The program has seen a number of successes, and faculty have learned a number of lessons through trial and error. The following program elements have evolved from the most effective of the methods tried, providing an exceptional education experience for NSSPI students:

- Nuclear engineering core-discipline courses that provide the fundamental technical background
- Nonproliferation, safeguards, and security specific courses that provide technical details that directly relate to the mission area
- Elective courses that provide increased breadth of knowledge in several areas of application to the mission (e.g., courses on national security policy) or deep technical knowledge in a single area (e.g., a course on nuclear forensics inverse analyses)
- Technical research applied specifically to the mission area
- Practical experience via training sessions at national laboratories, summer internships at national laboratories and the Pentagon, and visits to commercial fuel cycle facilities
- Prerequisite course material via asynchronous distance learning modules
- Extracurricular learning opportunities via the Texas A&M student chapter of the Institute for Nuclear Materials Management (INMM), the very first student INMM chapter formed

In all, Texas A&M has graduated 31 Ph.D. students and 73 M.S. students through NSSPI-supported research. Of those 73 M.S. degrees, 40 graduates specialized in nuclear nonproliferation through the MS-NNP program, 11 graduates specialized in other areas of nuclear engineering, and 22 graduated with Master degrees from other departments* at Texas A&M. Of the 31 Ph.D. degrees, 16 were in nuclear engineering and 15 were from other departments. Thus, about 50% of the NSSPI graduates are from disciplines outside of nuclear engineering (including computer science, electrical engineering, industrial and systems engineering, chemical engineering, chemistry, mathematics, and international affairs). Figure 1 shows annual degree conferrals for students who specialized in nuclear nonproliferation. This data shows: how the NSSPI program has grown from 2006 to 2012; an equilibrium of graduates since 2012; and the general level of emphasis between Master and Doctoral students.

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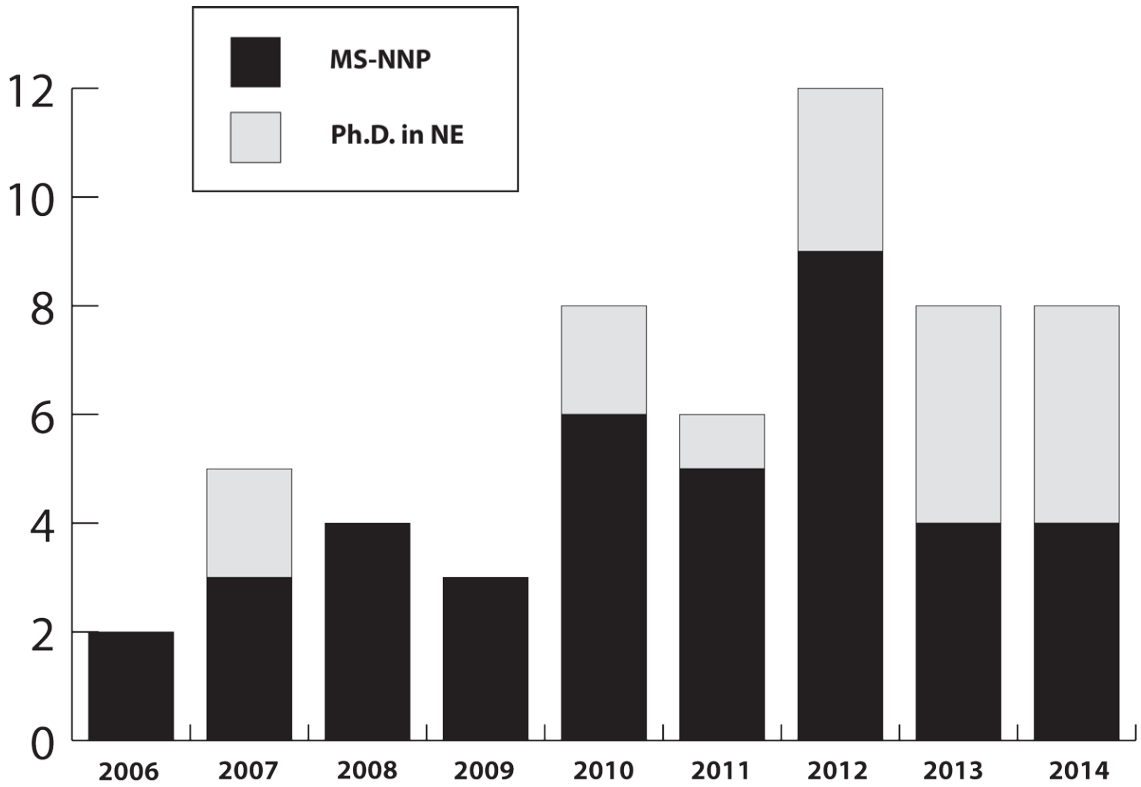

Figure 1. Number of M.S. and Ph.D. degrees with nuclear nonproliferation (NNP) specialization awarded on NSSPI-funded projects.

A. M.S. in Nuclear Nonproliferation Degree Program

The MS-NNP program is based on the M.S. degree in nuclear engineering. Several courses that are rooted in nuclear engineering basics are integral to the program, which provides students with a foundational technical knowledge so that they understand how professionals apply safeguards and nonproliferation to the broader nuclear fuel cycle. The program's research and classroom activities teach global nuclear security and, at the same time, they foster creativity to help students solve complex technical problems.

The 1½ to 2-year program consists of nine required courses that total 25 credit hours. The remaining 7 credit hours combine research hours and relevant elective courses. Candidates for the MS-NNP also research fundamental interests to the field; then they orally defend a written thesis that details their research. The outline of the MS-NNP is shown in Table 1.

Table 1. MS-NNP Degree Curriculum

	Course Title	Credit Hours
Year 1 Fall	Radiation Interactions and Shielding	3
	Radiation Detection and NM Measurement	3
	Nonproliferation and Arms Control	3
Year 1 Spring	Nuclear Reactor Theory	3
	Nuclear Reactor Analysis and Experimentation	4
	Nuclear Fuel Cycles and Materials Safeguards	3
Year 2 Fall	Design of Nuclear Reactors (Capstone)	4
	Seminar	2
As needed	Technical Electives and Research	7
	Total Hours	**32**

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 689 – Emergency Response Dose Assessment
- NUEN 451 – Nuclear Security Systems Design
- CHEM 681 – Radiochemistry & Nuclear Forensics (Chemistry Department)
- MATH 664 – Inverse Problems in Nuclear Forensics (Math 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.

B. Other Program Components

In addition to the traditional coursework and curriculum outlined in Section 3.1, students in the MS-NNP program conduct hands-on research for their M.S. theses. The program also fosters a well-rounded education through real-world opportunities that allow students to gain practical knowledge and experience that cannot be imparted in the classroom.

1. Graduate-Level Research

A rigorous research program in nuclear nonproliferation, safeguards, and security is paramount to effective education for graduate students in this field. NSSPI students are paired with or sponsored by project leads at various U.S. national laboratories, working in a myriad of areas that include nondestructive assay, containment and surveillance technologies, proliferation resistance analysis, physical security science, border security technologies, proliferation detection and latency analysis, attribution analysis and forensics, and other related topics. The students work in small groups that often include students who study disciplines that are outside of nuclear engineering—including international affairs students—and full-time members of the NSSPI research staff (Figure 2). Commonly, students conduct research at unique facilities at the sponsoring national laboratories as part of their research projects.

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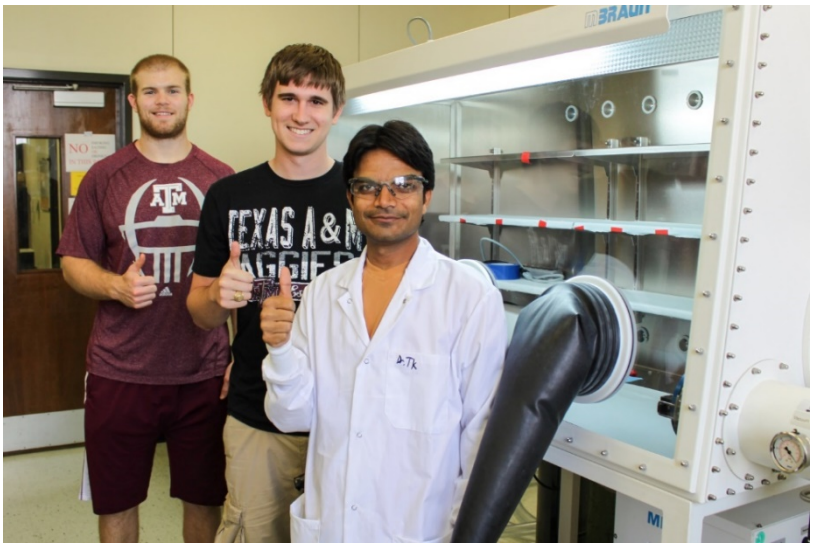

Figure 2. Texas A&M students work with NSSPI researcher Dr. T.K. Bhardwaj

NSSPI conducts research in five key areas: Proliferation Risk Analysis; Safeguards Systems and Instrument Development; Combatting Nuclear Terrorism; Nuclear Forensics and Attribution; and Arms Control.

a) Proliferation and Terrorism Risk Analysis

Robust and reliable quantitative proliferation assessment tools are critical to strengthening the nonproliferation regime and to the future deployment of nuclear fuel cycle technologies. NSSPI researchers and students have developed a number of these tools: the Proliferation Resistance Analysis and Evaluation Tool for Observed Risk **[*8*, *9*]** and a nuclear latency method for proliferation risk analysis **[*10*]**; an innovative N-terrorism pathways analysis to boost the efficacy of defense **[*11*, *12*]**; and a methodology to help nuclear experts determine which states will choose to develop nuclear energy. **[*13*, *14*]** NSSPI has also performed proliferation risk and safeguards analysis on the Fast Breeder Reactor fuel cycle **[*15*–*20*]**.

b) Safeguards Systems and Instrument Development

NSSPI researchers develop capabilities and technologies to support the safeguarding of nuclear and radiological materials. NSSPI worked with research staff at LANL to develop an effective non-destructive assay (NDA) method using Self-interrogation Neutron Resonance Densitometry. This method helps scientists verify spent fuel and recover continuity of knowledge in the event of a containment and surveillance systems failure **[*21*]**. NSSPI has also helped develop: remote unattended monitoring systems for spent fuel in dry cask storage **[*22*]**: the assessment of the fingerprinting method for verification of spent fuel in MACSTOR dry storage **[*23*]**: quantitative NDA measurement of advanced reprocessing product materials **[*24*]**: and Passive Neutron Albedo Reactivity measurement of Fugen reactor fuel **[*25*]**.

c) Combatting Nuclear Terrorism

NSSPI faculty and staff have developed a wide range of novel detection techniques and technologies that can be used to detect and respond to threats of nuclear terrorism. Research in this area includes: strategic analysis of smugglers; analysis of background signatures; analysis of environmental effects; detector systems development; and consequence management studies. Through funding from the DNDO, a multidisciplinary team led by NSSPI developed the SHIELD framework to interdict highly-enriched uranium at borders and ports **[*26*]**. As part of that project,

the NSSPI team became the first university research team to mount and record radiation data from a spreader-bar crane used in port operations **[*27*]**. NSSPI researchers also designed a portable gamma radiation portal monitor to scan livestock in the case of a radiological event **[*28*]**.

d) Nuclear Forensics and Attribution

One of the most serious dangers—with a potential for enormous societal consequences—is a terrorist who attacks using an improvised nuclear device. A State's capability to interdict special nuclear material smuggling and its forensics expertise to attribute the origin of the material (source attribution) are both highly desired deterrence features. These robust deterrence features not only help to curb a terrorist's malicious attempts, but they also help restrain rogue States from the illegal supply of special nuclear material due to the fear of retaliation. NSSPI researchers have conducted a set of experimental investigations on irradiated uranium dioxide surrogates to separate micrograms of plutonium in the newly set-up nuclear forensics and radiochemistry laboratory. These experiments were supported by high-fidelity Monte Carlo radiation transport simulations. The DNDO funded this project in collaboration with ORNL and Texas A&M's Cyclotron Institute. The objective of this study is to improve nuclear forensics capabilities for the source reactor attribution of weapons-grade plutonium **[*29*, *30*]**. NSSPI faculty and students also worked with ORNL to achieve the first quantitative measurements of plutonium in used nuclear fuel with the objective of strengthening safeguards measurements **[*31*]**.

e) Arms Control and Verification

As a unique contributor to arms control and verification research, NSSPI faculty and students have participated in cutting-edge research ranging from new detection techniques for weapons-usable materials to assisting others in evaluating the relationship between trust and confidence between host states and weapons inspection teams during arms inspection campaigns. For example, one NSSPI student developed a proof-of-principle technique for using fluorescence imaging to verify fissile material attributes of nuclear warheads relevant to current and future verification measures for arms control treaties **[*32*]**. One NSSPI student investigated a novel detection method that involved pulsed interrogation techniques to detect and quantify fissile material as applied to arms control **[*33*]**. NSSPI students also contributed to others' research endeavors (namely research conducted by King's College London and the Atomic Weapons Establishment) when they provided data from a trust/confidence weapons inspection simulated exercise conducted between American and Russian technical students in conjunction with Norway's Institute for Energy Technology **[*34*]**.

2. Short Courses at Oak Ridge National Laboratory

Once or twice per year, NSSPI joins with staff at Oak Ridge National Laboratory (ORNL) to provide the opportunity for graduate students within the MS-NNP program to complete a weeklong practical course in ORNL's Safeguards Laboratory (SL). The course alternately hosts undergraduate and graduate nuclear engineering students each semester. This activity helps the students understand and appreciate basic material control and accounting technologies focused specifically on detecting and measuring special nuclear material using NDA techniques. The weeklong class was first developed by Texas A&M and ORNL SL staff in the Spring 2007 semester. It borrowed heavily from the past experience of ORNL SL staff that had previously provided training courses on NDA techniques to professionals from various international institutions. Working closely with the ORNL staff, NSSPI designed this course to focus on topics the MS-NNP students learn as part of the Radiation Detection and Nuclear Material Measurements course.

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The time spent at the SL complements the students' theoretical knowledge gained in the classroom. Understandably, other universities have followed the example set forth by Texas A&M in this venue, and the ORNL staff has noted that these collaborations with universities within their region and beyond have been very successful **[*35*]**. In recent courses, students from the Bush School who are studying nonproliferation and international security and other foreign relations topics have also participated in the SL course at ORNL. This activity has provided policy students with opportunities to better understand the limitations and applications of various technologies as they apply to safeguards and nuclear security, fostering enhanced communication between future technical and policy experts. This integration of both policy students and technical students has been very productive for all who attended this course.[4] In the fall semesters of 2012 and 2014, the course included participants from Penn State and MIT, allowing Texas A&M students to interact with future nonproliferation professionals from other American institutions (Figure 3). Additionally, visiting Russian student interns from Tomsk Polytechnic University have also attended in an effort to combine various such activities occurring at Texas A&M with a shared goal to enhance the global nuclear security and safeguards culture.

Figure 3. Students from Texas A&M, Penn State, and MIT at ORNL in fall of 2012

3. Nuclear Facilities Experience

The MS-NNP program at Texas A&M provides the unique opportunity for students to travel to nuclear fuel cycle facilities in other countries to discuss safeguards applications and their effects on operations. Utilizing international inroads established by faculty and staff, NSSPI has conducted the Nuclear Facilities Experience (NFE) in several incarnations since 2007 in various countries with students from Texas A&M and from two Russian universities (MEPhI and IATE). Both MEPhI and IATE have established nonproliferation and international security education programs. The NFE is a series of visits to active nuclear fuel cycle facilities to examine operations and discuss applied safeguards and safety measures with experienced personnel. The opportunities for students to witness the magnitude of work that personnel conduct at these facilities and to talk with knowledgeable practitioners on operations, safety, and safeguards is essential to the students' growth as competent nuclear energy experts. Currently evolving into a unique opportunity for U.S. students, the NFE allows students to witness full-scale fuel facilities (ranging from reprocessing plants, fuel fabrication plants, and enrichment plants) and to gain real-

[3] This experience has since been replicated by students from the International Policy and International Affairs programs at the Center for International Trade and Security at the University of Georgia. http://cits.uga.edu/news/article/oak-ridge-national-laboratory-student-trip

world knowledge about topics they have studied in the nuclear nonproliferation educational programs at their respective universities.

Figure 4. Texas A&M Students at the U.S.'s Waste Isolation Pilot Plant in 2014

The NFE is conducted both domestically and internationally. The domestic NFE takes Texas A&M students on an organized series of visits to nuclear facilities in and around the state of Texas: the URENCO-USA uranium enrichment plant, the Waste Isolation Pilot Plant (Figure 4), the Pantex nuclear weapons assembly and disassembly facility, and the Comanche Peak Nuclear Power Plant. As a result of these visits, the participating undergraduate and graduate students gain a deeper understanding of the nuclear fuel cycle and dialogue with professionals about current responsible materials management techniques. Furthermore, these students continue to expand their knowledge into research areas relevant to material safeguards and security through visiting the research facilities at Sandia National Laboratories and Los Alamos during these domestic NFE events. Internationally, students from Texas A&M and other universities (through their contacts with NSSPI faculty) have the opportunity to visit advanced nuclear fuel cycle facilities such as reprocessing plants, enrichment plants, and waste facilities in Japan (Figure 5), the United Kingdom, Switzerland, and France **[*36*]**. At these facilities, students speak with practitioners about international and regional safeguards measures as well as how these types of facilities operate—opportunities not readily available within the U.S.

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Figure 5. Students and faculty from Texas A&M, the Tomsk Polytechnic University of Russia, and the Hanoi University of Science of the Vietnamese National University visiting a Hiroshima survivor Keijiro Matsushima during the NFE to Japan in 2013

4. Summer Internships and Summer Safeguards Courses

As noted in Section 3.2.1, students in the MS-NNP program are encouraged to participate in summer internships at the national laboratories, where they can continue their research under the direct guidance of their national laboratory sponsors/mentors and other subject matter experts. In this way, students gain additional knowledge beyond the expertise at Texas A&M and develop networks with possible future employers. The national labs gain: cost-effective research resources, enduring contacts with academia, and opportunities to evaluate potential future employees. Some NSSPI students have worked in the national laboratories for one year or more to complete their thesis/dissertation research work.

The Texas A&M MS-NNP students have prominently participated in the summer safeguards courses at the national laboratories sponsored by the NGSI. These courses provide students with enriching educational opportunities that would be difficult to find at the university. Students attend lectures by leading experts from national laboratories, and they participate in practical lab exercises using the advanced materials and technologies available throughout the Department of Energy (DOE) complex—materials and technologies unavailable at most universities.

5. Asynchronous Online Courses

Both policy and technical students at Texas A&M routinely use the Nuclear Safeguards Education Portal (NSEP) developed by NSSPI not only to gain basic knowledge of nuclear security, but also as a prerequisite to classroom instruction. The following section discusses this resource.

IV. Educational Support beyond Texas A&M

A. Nuclear Safeguards Education Portal

NSSPI launched NSEP in the spring of 2009 in their effort to provide introductory information to summer interns who are specifically interested in safeguards. The DOE, through the NGSI program, provided funding to NSSPI to develop NSEP, a series of instructional modules for students who are unfamiliar with the technical aspects of safeguards. Students who participated in the NGSI summer internship programs across the laboratory complex arrived with varying

degrees of technical expertise, making the instructional modules necessary. In 2009, NSSPI faculty and staff developed the first courses, which were used by students from around the country. The initial modules were:

- Basic Nuclear and Atomic Physics
- The Nuclear Fuel Cycle
- Basics of Radiation Detection

NSEP now consists of eight independent modules and two reference units for educating next generation safeguards and nonproliferation experts around the world. The additional modules are:

- Statistics as Applied to Nuclear Safeguards
- Nuclear Material Accountancy
- Physical Protection
- Containment and Surveillance
- Threats to Nuclear Security

While all of these modules were specifically designed for use in the summer seminars, they have also provided educational resources for students with interests in nuclear safeguards and the security of nuclear materials anywhere in the world. The current modules are available to the general public regardless of enrollment at Texas A&M. Each module consists of reading materials, video lectures, links to additional resources, and assessments. Typically, students complete a module in a few hours. The online, asynchronous nature of the modules provides students with the opportunity to complete the modules at their own pace.

Since the education program developed at NSSPI is largely based on the idea of hands-on education, asynchronous online learning through NSEP is not intended to be used in place of a fully developed program. These online modules are designed to deliver introductory materials that support nuclear security education. At Texas A&M, they are used as prerequisite materials for certain nuclear engineering courses. They also provide consistent background information to workshop and seminar participants.

651 users from around the world have registered with NSEP. These individuals create an account on NSEP in order to complete the assessments for credit in their courses. In 2014 alone, NSEP received 21,700 unique visitors the site, and the NSEP analytics data indicates that users spent a meaningful amount of time reading and engaging the course material **[*37*]**.

In comparison, a typical graduate-level course that covers any of these topics may have 10-20 students. Asynchronous distance education offers opportunities to reach a considerably larger audience. While many of these users are concentrated around the U.S. national laboratories and DOE HQ, university programs beyond Texas A&M's NSSPI program and other international training organizations have also used these modules **[*13*, *37*]**. A significant body of international users has accessed these courses as well.

NSSPI is currently in the final stages of developing four more NSEP modules on the following topics:

- Nuclear Security Culture
- Insider Threat Analysis and Mitigation
- Spent Nuclear Fuel Safeguards

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- Uranium Enrichment Safeguards

B. Nuclear Security Training Programs at Texas A&M

Under sponsorship from PNS, NSSPI has conducted a number of nuclear security training programs at Texas A&M and abroad for international students and professionals. These dynamic programs use Texas A&M resources to offer education and training through: courses, seminars, tours, experiments, hands-on activities, group projects, and cultural experiences. In the past, NSSPI has hosted groups from Japan, Brazil, Indonesia, Jordan, Nigeria, and India, as well as several multi-national groups. A select number of these sessions are detailed below.

1. Summer Certificate Program in Nuclear Security

In the summer of 2014, the first PNS Summer Certificate Program in Nuclear Security was held at Texas A&M. The eight-week certificate program is an intensive course designed to produce nuclear professionals who will lead efforts in their home countries to reduce the security risks associated with nuclear and radiological materials, ensuring the peaceful use of nuclear energy is available to all. Students completed three summer session courses, earning formal graduate credits from Texas A&M. Nuclear security faculty from Texas A&M's nuclear engineering department taught two courses, and a global terrorism/security expert on the faculty of the International Affairs Department at the Bush School taught a third course.

In addition to these formal graduate-level courses, the intense program immersed students in nuclear security education. They attended workshops and executive seminars that addressed specialized nuclear security topics. They also completed online learning modules on their own to ensure their knowledge of basic nuclear physics and nuclear security fundamentals. They participated in in-depth tours of various nuclear facilities that emphasized real-world security methods and procedures. These students also took part in simulation exercises that demonstrate how to apply the academic security principles covered in class. At the end of the program, students were encouraged to participate in the annual meeting of the INMM.

The participants in the inaugural class included professionals from the Nigerian Nuclear Regulatory Authority, the National Atomic Energy Commission in Yemen, the Jordan Atomic Energy Commission, the Indonesia Nuclear Energy Agency, and Pandit Deendayal Petroleum University in India.

2. Nuclear Security Training Series for Indian Universities

In 2014, NSSPI hosted the first part of the Nuclear Security Training Series (NSTS), sponsored by PNS. Participants included 24 students and 6 faculty members from three Indian Universities as shown in Figure 6: Anna University (Chennai); the Indian Institute of Technology (Kanpur); and Pandit Deendayal Petroleum University (Gandhinagar).

While in College Station, these participants attended lectures on nuclear security and nuclear security culture, visited Texas A&M's research reactors and the nuclear fuel cycle lab, took part in an outdoor radiation source recovery exercise at the Texas A&M Engineering Extension Service's "Disaster City" facility, and toured NASA and the George H. W. Bush Library and Museum. The program was supported by 17 different subject matter experts, including many Texas A&M M.S. and Ph.D. graduates who served as lecturers and guides for the tours. The participants also attended lectures that were part of the PNS Summer Nuclear Security Certificate Program. With the help of faculty mentoring sessions, NSTS students wrote group papers on nuclear security and nonproliferation to demonstrate their knowledge.

After their time at Texas A&M, the group continued the NSTS at Sandia and Oak Ridge National Laboratories. At the end of this series, NSTS participants attended the 55th annual meeting of the INMM held in Atlanta, Georgia. In the summer of 2015, nine different Indian University students and faculty will attend NSTS at Texas A&M.

Figure 6. Students and faculty from Indian Universities during the Nuclear Security Training Series at Texas A&M in the summer of 2014

C. The Gulf Nuclear Infrastructure Institute

One of NSSPI's missions is to encourage the peaceful use of nuclear energy throughout the world. During 2010-2011, NSSPI supported the establishment of the Gulf Nuclear Energy Infrastructure Institute (GNEII) at Khalifa University in Abu Dhabi, United Arab Emirates (UAE) **[*13*]**. GNEII is a semester-long professional development program that offers both classroom instruction and hands-on experience with nuclear energy safety, security, safeguards, and nonproliferation. GNEII strives to promote nuclear energy security and safety culture in countries in the Gulf region that are considering implementing nuclear energy programs. The U.S. Departments of Energy and State sponsored the start-up of GNEII. NSSPI worked with Sandia National Laboratories to develop the curriculum and supply the instructors for these classroom modules. GNEII has graduated 82 "Fellows" since 2011 (Figure 7 features the 2013 graduate class).

While most of the GNEII Fellows come from the UAE, the program is designed to serve the wider region as interest in nuclear energy grows. Accordingly, GNEII has also graduated students from Saudi Arabia, Kuwait, Qatar, and Jordan. As originally planned, GNEII is transitioning into an autonomous, regionally-supported institution staffed by Khalifa University and subject matter experts from regional nuclear energy organizations.

Figure 7. Group photo from GNEII graduation ceremony in 2013

D. International Engagement

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 the global nuclear security culture. NSSPI faculty frequently present lecture series and workshops at universities in other countries. They also offer curriculum development help to professionals from other universities who want to incorporate nuclear security topics in their courses. Since 2013, through NSSPI faculty and staff, Texas A&M has been collaborating with the Tokyo Institute of Technology (TiTech) as part of the DOJO Nuclear Security Program. Every year, TiTech invites Texas A&M students to attend a 2-week-long symposium in Japan focused on nuclear security, safety, and safeguards. In exchange, each fall TiTech students participate in a weeklong security and incident response exercise at the Texas A&M Engineering Extension Service (TEEX) Disaster City facility (Figure 8). NSSPI also hosted a group of Nigerian professors who wanted to add nuclear security curricula to their current traditional nuclear engineering undergraduate degree plans (Figure 9). Faculty from the Brazilian Federal University of Rio de Janeiro also recently took advantage of Texas A&M's support in this area. These activities allow NSSPI to respond powerfully to the call for the global issue of human resource development in nuclear security science.


Figure 8. Students from TiTech taking part in an incident response exercise at the TEEX Disaster City facility

Through formal agreements, NSSPI collaborates on research and educational endeavors with like-minded faculty members from a range of academic institutions that include: Khalifa University (UAE), Mangalore University (India), Pandit Deendayal Petroleum University (India), the Indian Institute of Technology-Kanpur (India), the University of Gadja-Mata (Indonesia), and Tomsk Polytechnic University (Russia). Furthermore, NSSPI has also worked with international organizations such as: the IAEA, the International Nuclear Security Education Network, the Japan Atomic Energy Agency, the European Safeguards Research & Development Association, the Institute for Energy Technology in Norway, and the Integrated Support Center for Nuclear Nonproliferation & Nuclear Security in Japan. Activities have ranged from providing guest lecturers to contributing to myriad research projects on nuclear security, safeguards, and arms control.

Figure 9. Nigerian faculty visit to Texas A&M in December 2014 for nuclear security curriculum development

V. Trajectories of NSSPI Graduates

The most important products of the NSSPI program are its graduates. NSSPI graduates enter the workforce with a comprehensive understanding of the nonproliferation regime. Their special combination of technical proficiency and policy acumen makes them highly sought after for careers in the U.S. national laboratories and federal agencies. When she was a NSSPI Ph.D. student, surveying her career options, Dr. Karen Miller remarked, "I have found that employers actively recruit NSSPI students because of the reputation it has built for producing highly-qualified young professionals." Currently, Miller is employed as an R&D Scientist at the Los Alamos National Laboratory, and is working on detector development for international safeguards. Miller received the 2014 Early Career Award from INMM. NSSPI Ph.D. graduate Dr. Alexander Solodov commented, "Although I was primarily interested in the technical side, getting to know relevant policy issues and approaches provided me with a broader outlook and helped me out a lot in advancing my career." Assistant professor Solodov currently teaches

nuclear engineering at Khalifa University and serves as the faculty coordinator for the GNEII program there.

Of the students who have graduated from Texas A&M with MS-NNP degrees or Ph.D. degrees in nuclear engineering with a nonproliferation focus, 39% are currently working in U.S. national laboratories. Another 18% work in the nuclear industry and 14% have careers in government. 8% are graduates from the MS-NNP program who are currently pursuing Ph.D. degrees at Texas A&M. Other career trajectories for NSSPI students include academia, the military, and non-governmental organizations.

Former students often cite the variety and uniqueness of the experiences they were afforded at NSSPI as being key to their development as nuclear security professionals. Mr. Grant Ford, a graduate of the MS-NNP program, wrote, "NSSPI is capable of producing world-class caliber graduates in the fields of nuclear security, safeguards, and nonproliferation because it offers them opportunities outside of the classroom that are second to none. What is truly unique about the education is the breadth of opportunity that never sacrifices depth of understanding." As a researcher for the Department of Defense's Defense Threat Reduction Agency, Ford is now leading cooperative efforts in threat reduction and arms control implementation in the Russian Federation. Dr. Braden Goddard, a NSSPI Ph.D. graduate works as a postdoctoral research fellow at Khalifa University. He remarked, "Without being part of NSSPI I would never have been able to be part of the nonproliferation community or have such wide knowledge of its activities. NSSPI also helped me obtain internships, educational tours, research trips, conferences travel, professional organization participation, and my first job."

Among the many experiences former students have as part of the NSSPI education, they often emphasize the intangible benefits of the international travel opportunities and interactions with nuclear security professionals from around the world. NSSPI Ph.D. graduate Dr. Grant Spence wrote, "One of the highlights of my time at NSSPI was a trip to Oslo, Norway to participate in a weapons verification simulation. It not only allowed me to visit another country but forced me out of my comfort zone of engineering and into a diplomatic and policy-focused scenario." Spence is currently on a post-doctoral fellowship—through NSSPI—at the Vienna Center for Disarmament and Nonproliferation, sponsored in conjunction with the Carnegie Corporation of New York.

Through internships, research projects, and academic courses, NSSPI has also worked closely with a number of students from the Bush School, many of whom are poised to go on to leadership positions in the public and nonprofit sectors. NSSPI has traditionally maintained a Bush School student or recent graduate as a research assistant on staff. Kate Putman Spence, one such Bush School graduate in International Affairs who worked as a NSSPI research assistant, is now a Junior Professional Officer at the IAEA. When asked about her relationship with NSSPI, she wrote, "As a graduate of the Bush School, most, if not all, of my technical skills were developed through the many projects, classes, and interactions I had through NSSPI. In addition to the research projects for various sponsors, I was afforded the opportunity to travel abroad to Russia, Norway, and the UK to meet other like-minded students and explore nuclear sciences in different cultures." The relationship between NSSPI and these policy "interns" has been one of mutual exchange and influence. Other former NSSPI research assistants from the Bush School have gone on to careers at the U.S. State Department, the Central Intelligence Agency, the White House, the NNSA, and private consulting companies.

VI. Future of NSSPI

In the past nine years, a large number of highly competent NSSPI graduates and professionals and a large body of its research has contributed to the field of nuclear security. NSSPI continues to develop its relationships with both existing and new sponsors (including the U.S. Departments of Defense, Energy, State, Homeland Security, and Agriculture as well as non-governmental organizations such as the Carnegie Corporation of New York and the Nuclear Threat Initiative). Furthermore, in recent years, more universities have followed NSSPI's leading example by forming similar academic research institutes for nuclear nonproliferation, safeguards, and security. As the number of potential university partners grows, NSSPI seeks to increase its network of like-minded researchers for the benefit of the community. Small research programs, often led by one or two faculty members at smaller universities, are also joining the nuclear nonproliferation research community. NSSPI is currently reaching out to several small universities including Prairie View A&M University, Texas A&M – Kingsville, and the University of Texas at Dallas.

Internationally, NSSPI's reach continues to grow. Developments with some universities outside the U.S. are creating inroads into regions that would not otherwise have existed for current sponsors. NSSPI's global reach continues to expand by utilizing the connections of its staff and faculty members for the benefit of the nuclear nonproliferation community.

In addition to current research projects and educational activities, NSSPI will make new calls to collaborate with others to address perceived future issues. NSSPI research remains state-of-the-art through involvement with experts in various fields, building teams of researchers from across the campus to solve complex problems in nuclear security. NSSPI also stays current in its focus by maintaining its connections in the U.S. government, the U.S. laboratory complex, and international organizations.

VII. Conclusions

The Nuclear Security Science and Policy Institute at Texas A&M is the first academic institute in the U.S. created to advance technical education and research in nuclear nonproliferation, safeguards, and security. In recent years, about 70 program graduates went to work throughout the national and international nuclear nonproliferation complex. Programs of this size in other industries influence their respective growing cultures, and NSSPI is no different. A balance between technology and policy is essential to best meet the needs of industry, government, and national labs. At NSSPI, students not only receive a practical technical education, but they also appreciate that solving today's nonproliferation and nuclear security problems requires the integration of both technology and policy factors.

The highlighted successes of this program speak to the commitment of Texas A&M and NSSPI, as well as to the growing interest in nuclear security by college-level students wanting to use their unique skills to make a difference in society. With recent developments across the globe in matters of nuclear security and safeguards, students are seeing the potential of these areas to grow into meaningful career opportunities. The NSSPI program will continue to develop in the future with continual feedback from its primary customers: the national laboratories, government agencies, and the IAEA. Embracing state-of-the-art educational technologies is paramount for maintaining a successful educational program in the ever-evolving areas of nuclear nonproliferation, safeguards, and security.

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