

Oak Ridge National Laboratory Next-Generation Safeguards Initiative: Human Capital Development



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Kimberly V. Gilligan

November 2015

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Nuclear Security and Isotope Technology Division

**OAK RIDGE NATIONAL LABORATORY NEXT-GENERATION SAFEGUARDS
INITIATIVE: HUMAN CAPITAL DEVELOPMENT**

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ACRONYMS

ANL	Argonne National Laboratory
AWCC	active well coincidence counter
BNL	Brookhaven National Laboratory
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization
DIQ	design information questionnaire
DIV	design information verification
DOE	US Department of Energy
FY	fiscal year
GCEP	gas centrifuge enrichment plant
GW	George Washington University
HBCU	Historically Black College or University
HCD	human capital development
HFIR	High Flux Isotope Reactor
IAEA	International Atomic Energy Agency
INL	Idaho National Laboratory
INMM	Institute of Nuclear Materials Management
INSEP	International Nuclear Safeguards Engagement Program
ISOCS	in situ object characterization
JPO	Junior Professional Officer
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
M&S	modeling and simulation
NCSU	North Carolina State University
NDA	nondestructive analysis
NESLS	Nuclear Engineering Science Laboratory Synthesis
NGSI	Next Generation Safeguards Initiative
NGSPN	Next Generation Safeguards Professional Network
NNIS	Nuclear Nonproliferation International Safeguards
NNSA	National Nuclear Security Administration
NPAC	NNSA Office of Nonproliferation and Arms Control
NSITD	Nuclear Security and Isotope Technology Division (ORNL)
OLEM	on-line enrichment monitor
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
PSU	Pennsylvania State University
REDC	Radiochemical Engineering Development Center
SME	subject matter expert
SNL	Sandia National Laboratories
SNM	special nuclear material
SNS	Spallation Neutron Source
SRS	System Requirements Specification
TISS	Triangle Institute for Security Studies
UF	University of Florida
UM	University of Michigan
UT	University of Tennessee
UTK	University of Tennessee, Knoxville
VTC	video teleconference

WG
Y-12

working group
Y-12 National Security Complex

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The continued success of the education outreach is also dependent on the following individuals who serve on the 2015 Nuclear Science and Engineering Directorate Education Outreach Committee. These individuals have donated hours of work to ensure the success of the program, particularly Julie Ezold, Denise Lee, Adam Aaron, and Barbara Snow.

1. INTRODUCTION

In 2007, the U.S. Department of Energy National Nuclear Security Administration (DOE NNSA) Office of Nonproliferation and Arms Control (NPAC) completed a comprehensive review of the current and potential future challenges facing the international safeguards system. The review examined

- trends and events that have an effect on the mission of international safeguards,
- the implications of expanding and evolving mission requirements of the legal authorities and institutions that serve as the foundation of the international safeguards system, and
- the technological, financial, and human resources required for effective safeguards implementation.

The review's findings and recommendations were summarized in the report *International Safeguards: Challenges and Opportunities for the 21st Century* (NNSA, 2007). The executive summary of this report is available at http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/NGSI_Report.pdf.

One of the report's key recommendations was for DOE NNSA to launch a major new program to revitalize the international safeguards technology and human resource base. In 2007, at the International Atomic Energy Agency (IAEA) General Conference, then Secretary of Energy Samuel W. Bodman announced the newly created Next Generation Safeguards Initiative (NGSI). NGSI consists of five program elements:

- policy development and outreach,
- concepts and approaches,
- technology and analytical methodologies,
- human capital development (HCD), and
- infrastructure development.

This report addresses the HCD component of NGSI. The goal of the HCD component as defined in the *NNSA Program Plan* is "to revitalize and expand the international safeguards human capital base by attracting and training a new generation of talent." The major objectives listed in the HCD goal include education and training, outreach to universities and professional societies, postdoctoral appointments, and summer internships at national laboratories.

Oak Ridge National Laboratory (ORNL) is a participant in the NGSI program, together with several other DOE laboratories, such as Pacific Northwest National Laboratory (PNNL), Lawrence Livermore National Laboratory (LLNL), Brookhaven National Laboratory (BNL), and Los Alamos National Laboratory (LANL). ORNL's participation specifically encompasses student internships, postdoctoral appointments, collaboration with universities in safeguards curriculum development, workshops, and outreach to professional societies through career fairs.

2. ORNL NEXT GENERATION SAFEGUARDS INITIATIVE INTERNS

ORNL hosted three NGSi interns in FY 2015, mostly during the summertime. Many ORNL interns come under the Nuclear Engineering Science Laboratory Synthesis (NESLS) internship program, which is geared toward students in scientific disciplines who have an interest in nuclear science and engineering. Internships are typically fulltime for 10 weeks in the summer. Some interns are then invited to stay on during the school year.

Students from The University of Tennessee, Knoxville (UTK) and Portland Community College participated in the FY 2015 internship program.

The student breakdown included

- Rachel Gaudet, a rising senior in nuclear engineering (UTK),
- Mark Carringer, a 2015 graduate in computer science (UTK) about to begin a Masters degree in computer science at Portland State University, and
- Liliy Sobolev, a Portland Community College student.

2.1 ORNL SUMMER INTERN PROJECTS

ORNL did an internal call for intern project proposals and submitted the consolidated list to NPAC for review. ORNL staff submitted requests for 12 nonproliferation projects that could benefit from intern support. Of these projects, the following were selected to be supported with NGSi funds for FY 2015. One project was moved to the fall (and therefore FY 2016).

- Human Capital Development Roadmap (one part time intern during the school year and one intern in the summer) – During the school year, **Rachel Gaudet**, a senior nuclear engineering major at The University of Tennessee, wrote a paper assessing the core competencies in nuclear safeguards. She identified core competencies that may be necessary for nuclear safeguards and matched them to subject matter experts in those fields. Gaudet also supported the Cloud-based Training Delivery for Safeguards project with Jim Younkin and Jeremy Townsend. During the summer, **Mark Carringer** joined the HCD Roadmap team. Carringer graduated with a Bachelor degree in computer science in May 2015. Carringer was responsible for transferring existing data related to the HCD Roadmap to a single location accessible by ORNL stakeholders and NNSA sponsors. He also drafted the initial requirements document for a possible future knowledge portal.
- During the summer, **Rachel Gaudet** transitioned from the HCD Roadmap project to international safeguards. She supported Don Kovacic on International Safeguards Engagement Program (INSEP) projects. This gave Gaudet an opportunity to learn about safeguards while supporting international visits and workshops.
- NGSi Nonproliferation Workbook - **Liliy Sobolev** worked with mentor Angie Lousteau to develop a training aid for NGSi nonproliferation workshops. Her focus was writing procedures for the operation and calibration of nondestructive analysis (NDA) instruments and systems used in support of nuclear safeguards, as well researching nonproliferation policy and history for the opening sections.

Summer interns are required to participate in the annual ORNL-wide end-of-summer poster competition. Below are NGSi summer interns and their mentors (Figs. 1–3).



Fig. 1. NGSi summer intern Rachel Gaudet with mentor Don Kovacic.



Fig. 2. Summer intern Liliy Sobolev and mentor Angie Lousteau.



Fig. 3. Summer Intern Mark Carringer with mentor Jessica White-Horton.

2.2 INTERN PROGRAM

ORNL offered the following tours for the interns during the summer of 2015:

- Spallation Neutron Source (SNS),
- Consortium for Advanced Simulation of Light Water Reactors,
- High Flux Isotope Reactor (HFIR) and Radiochemical Engineering Development Center (REDC),
- Manufacturing Demonstration Facility,
- Carbon Fiber Technology Facility, and
- Robotics and Remote Systems laboratory.

Interns also attended the following NGS Summer Seminar Series via Webinar.

- | | |
|---------|--|
| July 6 | Yana Feldman, LLNL, “Overview: IAEA and International Safeguards” |
| July 8 | Sarah Frazer, PNNL, “Safeguards Infrastructure Development” |
| July 13 | Karen Miller, LANL, “Technology Development for Safeguards Applications” |
| July 15 | Ruth Kips, LLNL, “The Life of a Safeguards Inspector” |
| July 20 | Shirley Johnson, PNNL, “Safeguards at Reprocessing Facilities” |
| July 22 | Justin Reed, Argonne National Laboratory (ANL), “Experience of a Safeguards Information Analyst” |

- July 27 Helly Diaz-Marcano, Savannah River National Laboratory, “Safeguarding CANDU Reactors”
- July 29 Michael Whitaker, ORNL, “Safeguards at Enrichment Facilities”
- August 3 George Anzelon, LLNL, “Investigating Undeclared Activities”
- August 5 Ray Diaz and Tanya Collins, BNL/International Safeguards Project Office and Steve Amundson, ANL, “Job Opportunities at the IAEA”
- August 10 Kory Budlong-Sylvester, LANL, “Acquisition Path Analysis and the State-Level Approach”
- August 12 Heidi Smartt, Sandia National Laboratories, “Containment and Surveillance Technologies”

2.3 INTERN RECRUITMENT

Career fairs are an important complementary effort to the NGSi-HCD program at ORNL. ORNL staff participated in several career fairs. NGSi funds were not used to support their participation, but the NGSi internships and fellowships are emphasized at these events.

3. ORNL NGSi SUPPORTED POSTGRADUATE APPOINTMENTS

In FY 2015, NGSi postgraduate funds contributed to supporting six postgraduate positions at ORNL. The following section summarizes each postgraduate's contribution to nonproliferation and safeguards during his or her time at ORNL.

3.1 SCOTT STEWART

Scott Stewart is an Oak Ridge Associated Universities (ORAU) post-master's research associate supporting Jim Garner and Michael Whitaker in the International Safeguards Group of the Nuclear Security and Isotope Technology Division (Fig. 4). He works with Jim Garner on the Unattended Cylinder Verification Station project, and as part of that effort is working on camera surveillance image encryption and verification. Stewart also supports Garner's work with the General Advanced Review Software, or GARS product, from Canberra for surveillance imagery review, as well as other work with the Genetec software package, which is essentially commercial off-the-shelf security software. Stewart's participation has been renewed for a second year.



Fig. 4. Scott Stewart works on calibrating new equipment.

3.2 PHILIP MAKAREWICZ

Philip Makarewicz joined the International Safeguards group of the Nuclear Security and Isotope Technology Division as a post-master's research associate in August 2014, having worked most recently as an NNSA Graduate Program Fellow within the NNSA Production Office in Amarillo, Texas. Makarewicz is mentored by Jim Garner and since joining the team has primarily focused on safeguards efforts at gas centrifuge enrichment plants (GCEPs). Makarewicz's work to date has included current safeguards techniques at GCEPs and the political environment surrounding development of new supplemental techniques for safeguards. His work has included a literature review of the methodology for counting GCEP feed cylinder throughput from load cell data, and the use of commercial products in an experimental surrogate flow loop located at ORNL to test these methodologies. Makarewicz left ORNL in April for a staff position with the Kansas City Plant.



Fig. 5. Philip Makarewicz is collaborating with ORNL staff to strengthen safeguards at GCEPs.

3.3 MARIANNE GILLOGLY

Marianne Gillogly transitioned to ORNL as a research associate after a year at the NNSA as a Nonproliferation Graduate Fellow. Since August 2013, as a follow-on to her work at headquarters, she splits her time between two programs at ORNL: International Safeguards and Nuclear Security/Export Controls.

With the International Safeguards Group, Gillogly worked closely with the Regional Lead for Sub-Saharan Africa engagement. This work supported a fairly recent regional mission for INSEP, and Gillogly focused on developing workshops and training covering a myriad nuclear safeguards activities in Africa. With the Nuclear Security/Export Control team, Gillogly participated in licensing reviews for NNSA to provide to the United States government interagency for approval/denial of export control licenses. She was the moderator for the NGSi-supported Nuclear Export Controls course at UTK and participated in professional-level export control training sessions. Gillogly also collaborated on developing an analysis tool for license reviews. Gillogly left ORNL in December for a position as Advisor to the Director General of the Nuclear Energy Agency.

3.4 KATY SNOW

During her appointment in the ORNL Post-Master's Research Participation Program, Katy Snow worked in the International Safeguards Group of the Nuclear Security and Isotope Technology Division under the supervision of Michael Whitaker. Given that Snow no longer lives near a national laboratory, she has established her own consulting business to continue to pursue her passion for nonproliferation and safeguards issues. ORNL continues to call on her as needed to support international safeguards and international meetings.

3.5 ANN PEDERSON

Ann Pederson works part-time as an ORAU research associate in the International Safeguards Group while attending UTK law school fulltime (Fig. 6). She assists in research and writing on NGS-related topics. She primarily works on nuclear safeguards reporting systems and on a system requirements specification document that provides software developers with discrete and verifiable requirements for comprehensive safeguards nuclear material accountability reporting and additional protocol reporting. She also received a prestigious summer clerkship with DOE.



Fig. 6. Research Associate Ann Pederson.

3.6 KAARA PATTON

Kaara Patton is working as an ORAU research associate for the Process Engineering Research group of the Nuclear Security and Isotope Technology Division. She worked hands-on with a variety of fuel-cycle-related processes, including many uranium processes such as solvent extraction, uranium hexafluoride reduction, uranium tetrafluoride reduction, and uranium metal production. She helped to make uranium microspheres for possible use as fuel for National Aeronautics and Space Administration spacecraft, which require a compact, long-lasting, standalone source of power. When not in the laboratory, Patton compiled and reported on the results of these studies (Fig. 7). Patton left ORNL for a permanent position with the Y-12 National Security Complex (Y-12) in September 2015.

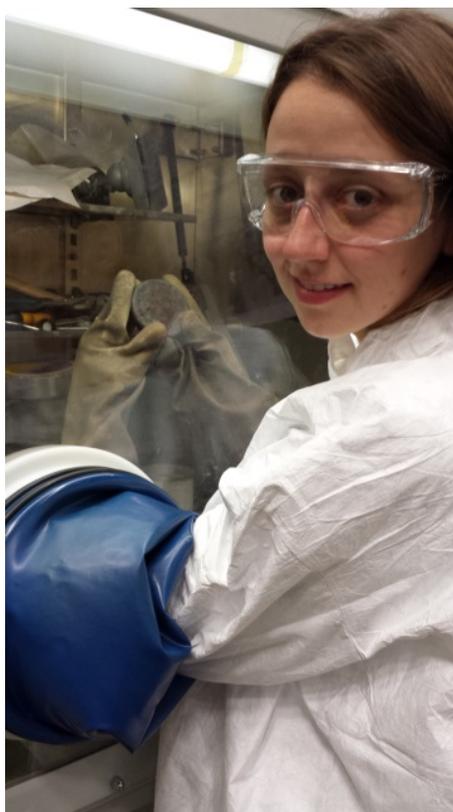


Fig. 7. Research Associate Kaara Patton.

4. NGS-HCD PROGRAM SUPPORT

4.1 NUCLEAR NONPROLIFERATION INTERNATIONAL SAFEGUARDS EVALUATION AND SUPPORT

Kim Gilligan and Michael Whitaker reviewed applications for the 2015 Nuclear Nonproliferation International Safeguards (NNIS) Graduate Fellowship Program. ORNL NGS-HCD partner universities were well represented in the applicant pool. The applicants selected for the fellowship this year were both from the University of Tennessee.

NNIS Fellow and University of Michigan Ph.D. student Aaron Bevill worked with Reactor and Nuclear Systems Division's Keith Bledsoe. Bevill's research time at ORNL fulfilled the practicum requirement of his fellowship. Bevill worked closely with ORNL staff on inverse analysis and uncertainty quantification for quantitative radiation imaging (Fig. 8).



Fig. 8. NNIS Fellow Aaron Bevill with mentor Keith Bledsoe.

5. UNIVERSITY ENGAGEMENT

In addition to the NGSi nonproliferation workshops (Section 6), ORNL works with universities to enhance their programs, and worked with several universities in FY 2015 to introduce safeguards concepts into their curricula. The following sections summarize the safeguards university engagement with North Carolina State University (NCSU), University of Florida (UF), and University of Michigan (UM).

5.1 UNIVERSITY OF FLORIDA

The University of Florida worked to improve the “Introduction to Safeguards” course content and execution, based on student feedback and instructor and key ORNL personnel observations. UF also began development of an Advanced Safeguards course with the help of ORNL and Y-12’s Jill Cooley. The instructor for the safeguards course left UF in the summer. The transition was started during the spring class, and it is expected to be smooth.

This year there was an opportunity for INSEP to expand upon the work done by HCD with UF. INSEP supported a two-week workshop on nuclear safeguards curriculum development between ORNL and the nuclear engineering programs at UF and Hacettepe University (in Ankara, Turkey). The engagement involved two professors from UF and three professors from Hacettepe visiting UF and ORNL, January 9 through 20, 2015. The INSEP workshop included a week at UF for a knowledge transfer of the NGSi supported curriculum to Hacettepe. This included lectures and exercises within four areas: policy, detection, predication (simulations), and practical exercises. Hacettepe plans to develop undergraduate and graduate versions of the safeguards course for its nuclear engineering students.

UF came to ORNL for an NGSi nonproliferation workshop in the spring (see Section 6, University Engagement). Upon returning to UF, the students prepared reports summarizing their experiences and lessons learned. The final exercise was directed by ORNL’s Gilligan and Scott Stewart when they visited UF from April 12 to 13, 2015. During their visit, Gilligan conducted a mock Complementary Access of the UF subcritical assembly facility. Prior to the inspection, the students had prepared the required mock design information questionnaire (DIQ) paperwork to provide their inspector (Gilligan). While playing the part of an IAEA inspector, she instructed the students about what an inspector looks for and what equipment the instructor brings along in the field. The students played the role of site and government representatives during the exercise.

While at UF, both Gilligan and Stewart met with students from the American Nuclear Society and Women In Nuclear student chapters for an “Ask Me Anything” session. The event was very well received and gave the students who had been unable to attend the ORNL workshop exposure to some of the difficulties associated with nuclear safeguards. Stewart also shared his NGFP experience and his thoughts on transitioning from academia to the workforce.

Stewart and Gilligan also met with the Criticality Safety class to discuss the synergies between safeguards and safety. Finally, they held discussions with the NGSi-supported professors about past and future work, as well as exploring collaboration potential with the research reactor faculty.

5.2 NORTH CAROLINA STATE UNIVERSITY

Previously, ORNL NGSi-HCD created a series of taped lectures of safeguards and nonproliferation experts that are still used in university courses. In NCSU’s “Nuclear Nonproliferation and Safeguards Technology and Policy” course, students watch the lectures and then develop questions for the subject

matter experts. Professor John Mattingly collects these questions and submits them to the subject matter experts at ORNL. The students are then able to have a live video teleconference with these experts at their next class session. This year, NCSU also requested three new lectures and updates to two existing lectures. A list of NGSi taped lectures and teleconferences with ORNL subject matter experts is provided as follows (with the new and revised topics indicated).

NGSI Taped Lectures of ORNL Subject Matter Experts

- Nuclear Fuel Cycle – Back End (updated)
- International Safeguards (new)
- Physical Security (updated)
- Transportation Security (new)
- Nuclear Forensics (new)
- Spent Fuel Safeguards
- Environmental Sampling
- IAEA Safeguards
- Safeguards for Uranium Enrichment
- Containment and Surveillance Technologies for Safeguards
- Second Line of Defense
- Nuclear Export Controls

Live Q&A via Video Teleconference (VTC) with ORNL Subject Matter Expert (SME)

- State System of Accounting for and Control of Nuclear Material and Safeguards
- Nuclear Fuel Cycle: Back End
- Safeguards Implementation at ORNL
- Physical Security
- Uranium Enrichment
- Safeguards for Spent Fuel
- Containment and Surveillance
- Nuclear Export Controls
- Nuclear Forensics
- Transportation Security

5.3 GEORGE WASHINGTON UNIVERSITY

ORNL is forming a new partnership with George Washington University (GW). GW is incorporating ORNL expert lectures (from the NCSU series) into a two-semester course on nuclear safeguards. This is the same class that was to attend an NGSi Nonproliferation Workshop at ORNL but had to cancel when travel funds were not provided.

ORNL researcher Vince Jodoin spoke at GW on April 1, 2015. Jodoin was in Washington, D.C. for another meeting but took advantage of the close proximity to respond to GW's needs. He gave a talk on nuclear forensics to Professor Chris Cahill's Nuclear Safeguards and Forensics course. Cahill requested this talk by Jodoin because he was present when it was given at the NGSi Modeling and Simulation for Safeguards and Nonproliferation workshop at ORNL in December 2014.

5.4 MOREHOUSE COLLEGE

In addition to the NGSi Nonproliferation Workshop discussed in the following section, ORNL had an engagement with Morehouse College. ORNL's Kim Gilligan and Channa Palmer held a VTC with Morehouse College physics students in December 2014 (Fig. 9). Gilligan gave a talk on nonproliferation and safeguards, and Palmer gave a talk on student opportunities at ORNL.

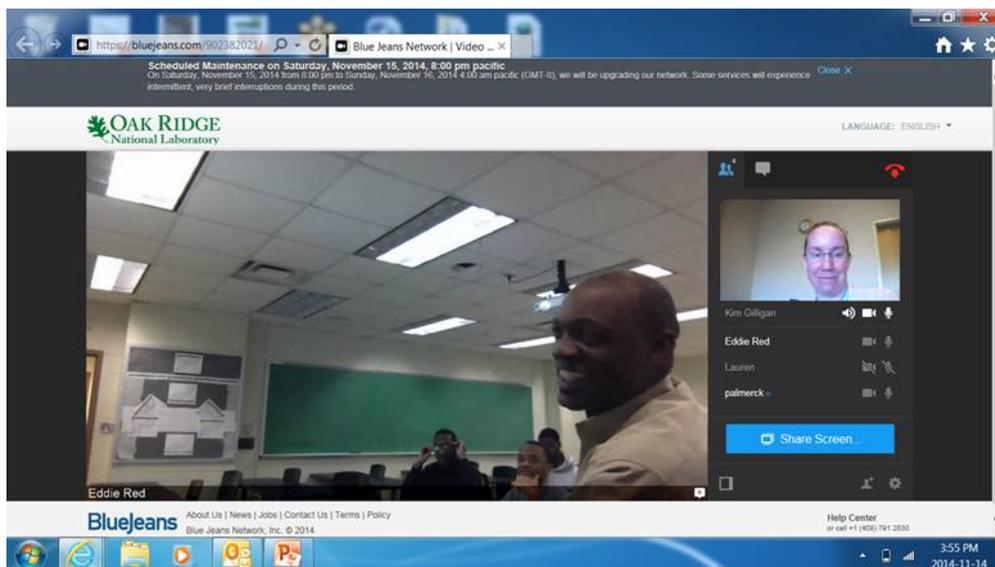


Fig. 9. Webinar between ORNL and Morehouse College

5.5 THE UNIVERSITY OF TENNESSEE, KNOXVILLE

5.5.1 Arms Control, Nonproliferation, and Nuclear Safeguards and Security Course

This year ORNL NGSi-HCD worked with UTK political science professor Brandon Prins to support the Arms Control, Non-Proliferation, and Nuclear Safeguards & Security course. This year the course was only offered to undergraduates. Both political science and nuclear engineering students take this course. ORNL and Dr. Prins arranged for guest SMEs from ORNL to lecture on a variety of topics as part of the course. The SMEs discussed a wide range of topics, including safeguards, the IAEA, the nuclear black market, nuclear weapons, and nuclear power in the Middle East and North Korea. This gave the students a unique opportunity to interact with researchers and practitioners involved in the topics they were learning about in the course.

- February 4: Allyn Milojevich, “Nonproliferation and IAEA Safeguards” (cancelled)
- February 11: Krystee Ervin and Len Philips, “Export Control”
- February 25: Pat Lynch, “Nonproliferation and the Middle East” (Fig. 10)
- March 11: John Begovich, “Experience in DPRK”
- March 25: Vince Jodoin, “Nuclear Forensics”
- April 1: Bill Toth, “Nuclear Nonproliferation Programs Overview”



Fig. 10. Pat Lynch discussing nonproliferation with a class at UT.

5.5.2 Nuclear Politics of the Middle East Course

This year ORNL NGSi-HCD worked with a second UTK political science professor, Matt Buehler. Buehler is a new professor at UTK and offers a course on Nuclear Politics of the Middle East. The course is part of the Global Security Studies certificate, and students from political science and nuclear engineering enroll in the course. ORNL and Dr. Buehler arranged for guest SMEs from ORNL to lecture on nonproliferation topics relevant to the region. Once again, this gave the students a unique opportunity to interact with researchers and practitioners involved in the topics they were learning about in the course.

- August 20: Allyn Milojevich, “Intro to Nonproliferation and ORNL”
- September 3: Pat Lynch, “Nuclear Issues in the Middle East”
- September 24: Karen Kaldenbach, “Nonproliferation and Nuclear Security in Morocco (and Elsewhere)”
- September 24: Kim Gilligan, “Safeguards and the IAEA”
- November 12: Jim Radle, “Nonproliferation and Disarmament in Iraq” (planned)

5.5.3 Export Control and Nonproliferation Course

During the fall of 2014, the ORNL NGSi-HCD program supported ORNL staff members in delivering the second iteration of this class for students earning a Master’s degree in nuclear engineering at UTK. The class, NE536, Export Control and Nonproliferation, focused on the principles and regulatory framework for controlling sensitive nuclear commodities and technology. Various case studies were discussed relevant to export control violations and nuclear proliferation issues. The class was facilitated by an NGSi postgraduate student to reduce the expense, and lectures were given by ORNL staff. This class featured a number of guest speakers who covered a wide variety of proliferation-related topics, including export enforcement, the IAEA, the nuclear fuel cycle, and various types of reactor designs. The detailed infrastructure of the U.S. export control system was studied along with impending changes resulting from President Obama’s Export Reform Effort. Hands-on exercises challenged students to examine proliferation-sensitive equipment and to determine the associated export controls. Students were assigned a topic and required to give a 15 minute presentation on the export control and nuclear nonproliferation aspects of their topic. The class was well received, students were engaged and attentive, and the goal of understanding the importance of nonproliferation efforts was accomplished.

Class Topics Covered via Lecture and Exercises:

- International Regimes and U.S. Controls
- WMD Processes Control List
- Export Control Basics
- Enforcement
- Nuclear Island
- Reese Roth Case
- Trigger List
- Dual-Use List
- A.Q. Khan
- Fuel Cycle
- End-Use/End-User
- Export Controlled Information
- Small Modular Reactors
- Publically Available Information

6. NGSi NONPROLIFERATION WORKSHOPS

6.1 NGSi UNIVERSITY WORKSHOPS

ORNL is pleased to host several NGSi nonproliferation/safeguards workshops throughout the year, the focus of which can vary depending on the group. Attendance in FY 2015 was 138 students and faculty from 12 universities. The students were evenly divided between undergraduate and graduate degree programs and were predominantly nuclear engineers. In FY 2015, ORNL continued to reach beyond nuclear engineers to those policy students interested in the science of nonproliferation as well.

In the summer and fall, Angie Lousteau undertook developing a workbook to support the NGSi University Workshops. She was supported by NGSi summer intern Liliy Sobolev. The workbook is intended to aid the participants throughout the workshop as well as to be a reference when they return to their universities. The workbook includes topics such as:

- International Safeguards,
- Nuclear Physics and Measurement Fundamentals,
- Handheld Detectors,
- Uranium Enrichment Measurements,
- Radiation Portal Monitors,
- In-situ Object Counting System (ISOCS),
- Active Well Coincidence Counters (AWCC), and
- Uranium Holdup Measurements.

6.1.1 The University of Tennessee

Staff from ORNL's Safeguards and Security Technology Group conducted four laboratory hands-on classes for the spring semester UTK nuclear engineering course Radiation Measurements Laboratory (NE550). The class had 14 nuclear engineering students, the professor, and a visiting Nigerian faculty member. The activities in the laboratory included ISOCS, basic NDA, and holdup measurements. The application for safeguards was discussed in conjunction with the hands-on activities. Safeguards instrumentation and software provided the students with a practical understanding of a number of NDA techniques used for analyzing special nuclear material (SNM). The exercise culminated in the analysis of an unknown nuclear sample, which forced the students to assimilate all the information they garnered in the previous sessions. The professor for the class is Dr. Steve Skutnik, a former Nuclear Nonproliferation International Safeguards Fellow.

6.1.2 Morehouse College

In April, Morehouse College sent 12 undergraduate physics students and two physics professors to ORNL for a two-day workshop on nonproliferation NDA training. The students were given lectures on nuclear nonproliferation and the role that the IAEA plays in ensuring nonproliferation. They participated in several exercises in the Safeguards Laboratory that included the use of handheld detectors and a radiation portal monitor. They also participated in tours of the HFIR and the REDC and a design information verification (DIV) exercise with the Surveillance and Containment Laboratory. This and future workshops with historically black colleges and universities will encourage minority students to pursue nonproliferation- and safeguards-related careers (Fig. 11).



Fig. 11. Morehouse College Students at ORNL for an NGSi Nonproliferation Workshop.

6.1.3 The University of Florida and North Carolina State University

In 2015, UF and NCSU met several days for an NGSi Nonproliferation Workshop (Fig. 12). This can be very beneficial for students to meet their peers from another school. The four-day class consisted of both lectures and valuable hands-on experience with safeguards instrumentation and software that provided the students with an introduction to numerous NDA techniques used for analyzing nuclear material. In addition, as part of the class, students attended several technical tours including the SNS, Hybrid K-edge, the HFIR, and the Graphite Reactor.

Topics covered during the class included the following:

- Nuclear nonproliferation and the IAEA
- Uranium enrichment measurements using an HM5 with NaIGEM, WINU235, and uranium/plutonium detection system
- Uranium holdup measurements
- Neutron coincidence counting using an AWCC
- ISOCS measurements
- Radiation portal monitors
- Portable NDA instrumentation operation, including
 - the FLIR Interceptor and HM5 (Identifinder)
 - the Canberra InSpector 1000
 - the Ortec Detective

The UF participants also participated in the Institute for Nuclear Materials Management (INMM) Central Regional Chapter spring meeting, 70 Years of Managing Nuclear Materials/Weapons: the Nuclear Fuel Cycle. The UF students also extended their stay in Tennessee to take an opportunity to tour Nuclear Fuel Services, Inc., in Erwin, Tennessee. Both events provided valuable opportunities to meet professionals in the field and to gain a better understanding of operations.



Fig. 12. NCSU and UF students taking measurements at ORNL.

6.1.4 Clemson University

Staff from the Safeguards and Security Technology Group and the International Safeguards Group hosted a Clemson University workshop (March 23–25, 2015) entitled Nonproliferation NDA Training Workshop for a group of 13 nuclear engineering graduate students and two faculty members. The three-day class consisted of both lectures and valuable hands-on experience with safeguards instrumentation and software that provided the students with an introduction to numerous NDA techniques used for analyzing SNM.

Topics covered during the class included the following:

- Uranium enrichment measurements using an HM5 with NaIGEM, WINU235, and uranium/plutonium detection system
- Uranium holdup measurements
- Neutron coincidence counting using an AWCC
- ISOCS measurements
- Radiation portal monitors
- Portable NDA instrumentation operation, including
 - the FLIR Interceptor and HM5 (Identifinder)
 - the Canberra InSpector 1000
 - the Ortec Detective

In addition, as a part of the class, the students attended several technical tours including Y-12, HFIR, REDC, and the Graphite Reactor.

6.1.5 The University of Georgia

Based on the success of the previous year, students from the University of Georgia returned to ORNL for another NGSi Nonproliferation Workshop. ORNL hosted the group of 15 students from March 30 to April 1, 2015. The workshop portion at ORNL began with a discussion of nuclear nonproliferation and the important role played by IAEA in attaining nonproliferation goals. The students had a full first day, which included discussions of DIQ/DIV, environmental sampling, and nuclear material accounting and control (Fig. 13). They were then able to learn the basics of NDA and use detectors to search for undeclared nuclear materials. They also learned how these NDA techniques could be applied to SNM. While at ORNL, the students participated in tours of the HFIR, REDC, Y-12, and the Graphite Reactor.



Fig. 13. University of Georgia masters students search for illicit nuclear material.

6.1.6 Texas A&M, Pennsylvania State University, and Massachusetts Institute of Technology

Students and faculty from Texas A&M University, Pennsylvania State University and the Massachusetts Institute of Technology (MIT) attended an NGSi Nonproliferation Workshop at ORNL November 10 to 14, 2014 (Figs. 14 through 16). This workshop included 17 graduate level nuclear engineering students and two faculty members.

Topics covered during the class included:

- Material accounting and control
- Uranium enrichment measurements using an HM5 with NaIGEM, WINU235, and U/Pu detection system
- Uranium holdup measurements
- Neutron coincidence counting using an AWCC
- ISOCS measurements

- Radiation portal monitors
- Portable NDA instrumentation operation, including
 - the FLIR Interceptor and HM5 (Identifinder)
 - the Canberra InSpector 1000
 - the Ortec Detective.

In addition, as a part of the class, students attended several technical tours including the PHDS Co. Crystal Growing Facility, the Spallation Neutron Source, and the Graphite Reactor.



Fig. 14. Texas A&M, Penn. State, and MIT Students Visiting SNS.



Fig. 15. Texas A&M, Penn. State and MIT students take holdup measurements at ORNL.

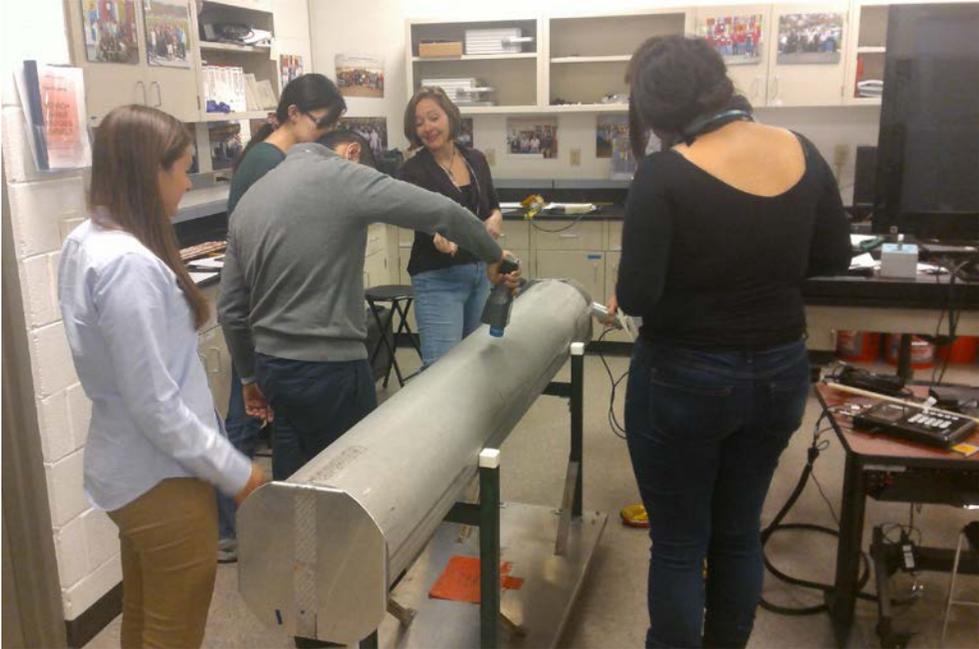


Fig. 16. Texas A&M, Penn. State and MIT students take holdup measurements at ORNL.

6.1.7 TISS and Mercyhurst

NGSI-HCD at ORNL partially supported two workshops focused on policy and analysis students. Thirty-three Triangle Institute for Security Studies (TISS) students and professors from Duke University, University of North Carolina, and NCSU participated in a nuclear nonproliferation workshop led by Nuclear Security and Isotope Technology Division (NSITD) staff on November 13 and 14. The agenda included time at Y-12 and understanding the technology at ORNL supporting threats facing the nonproliferation world today (Fig. 17).



Fig. 17. Jim Garner speaking with TISS participants about the IAEA.

In the fall of 2014, the Global Security Directorate gave ten seniors from Mercyhurst University's intelligence studies department two semester research projects. At the end of the semester, the students presented their findings to ORNL staff and participated in a nonproliferation and nuclear security focused workshop.

6.2 MODELING AND SIMULATION FOR SAFEGUARDS AND NONPROLIFERATION

The Modeling and Simulation for Safeguards and Nonproliferation Workshop was held December 15–18, 2014, at ORNL and was made possible by NGSI-HCD. The idea of the workshop was to move beyond the tried-and-true boot camp training of nonproliferation concepts to spend several days on the unique perspective of applying modeling and simulation (M&S) solutions to safeguards challenges.

It is challenging to cover all topics of M&S that are implemented in nuclear safeguards and nonproliferation. The majority of material presented at the workshop was based on nuclear engineering, whereas nuclear applications span other scientific areas such as physics, chemistry, and radiochemistry.

The IAEA has a variety of M&S projects particularly associated with the nuclear fuel cycle. Numerous open literature publications are also available in which the use of computational models has been applied to nonproliferation and safeguards cases. M&S has been found to play a key role in validating experimental and measured data. In the absence of the latter, M&S can be used in predicting future and past behavior.

During the four-day workshop, 50 participants and speakers discussed past and current work (See Fig. 18 for group photo). This included looking at past and current work funded at universities by NGSI as well as ways to utilize well-established software packages such as those developed at ORNL. After a

presentation on NGS and the HCD program, the workshop began with a focus on safeguards to build a common base for the M&S talks. The workshop then segued into M&S currently used in safeguards and ongoing research projects.

The closing plenary session was a lively discussion representing academic and research perspectives. There was a consensus to invite more operations staff in the future to facilitate communication between those who need tools and those who develop them. There was also a desire to attract more students to a future workshop that could include break-out groups to brainstorm solutions to challenges presented by operations staff.

This workshop was a professional development opportunity for early and mid-career professionals. It also drew in new professionals to safeguards by offering a collaborative environment for M&S professionals to apply their skills to nonproliferation. In attendance were individuals from a variety of backgrounds, ranging from graduate students to senior researchers.

The full report, *Modeling and Simulation for Safeguards and Nonproliferation Workshop* (ORNL/TM-2015/8), includes metrics and photos and was delivered to NPAC in January 2015.



Fig. 18. Partial group photo of workshop participants.

7. PROFESSIONAL DEVELOPMENT

7.1 NEXT GENERATION SAFEGUARDS PROFESSIONAL NETWORK ACTIVITIES

7.1.1 NGSPN Workshop

In December 2014, Louise Worrall attended the Next Generation Safeguards Professional Network (NGSPN) workshop held by Idaho National Laboratory (INL). During the week, the participants attended a variety of safeguards presentations given by subject matter experts and received a condensed version of the *International Safeguards Pre-Inspector* course. The agenda also included a research reactor case study on safeguards at item facility with DIV exercise at the Advanced Test Reactor and tours of the Bonneville County Technology Center, Portable Isotopic Neutron Spectroscopy Laboratory, Security Systems Laboratory, and Experimental Breeder Reactor-I (EBR-I). They were able to interact with their peers and become more familiar with safeguards technologies used by IAEA inspectors in the field. This workshop also provided excellent network opportunities, including the chance for Dr. Worrall to become involved with the Nonproliferation Portal, a multi-laboratory effort being spearheaded by INL (Figs. 19–20).

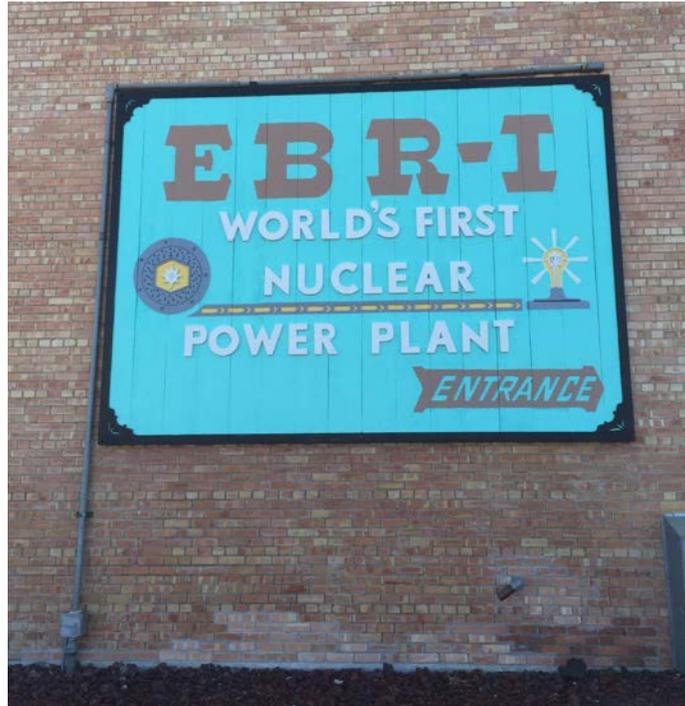


Fig. 19. Participants in the NGSPN workshop visited EBR-I.



Fig. 20. Nuclear powered jet engines at EBR-1.

7.1.2 NGSPN Website and NonproliferationPortal.com

ORNL NGSi-HCD continues to maintain the Next Generation Safeguards Professional Network website. It currently has more than 70 members (Fig. 21). It is anticipated this will be absorbed into the new Nonproliferation Portal. ORNL's Louise Worrall is the point of contact for the portal effort being spearheaded by INL. Louise is also the lead for the NDA section of the Nonproliferation Portal.

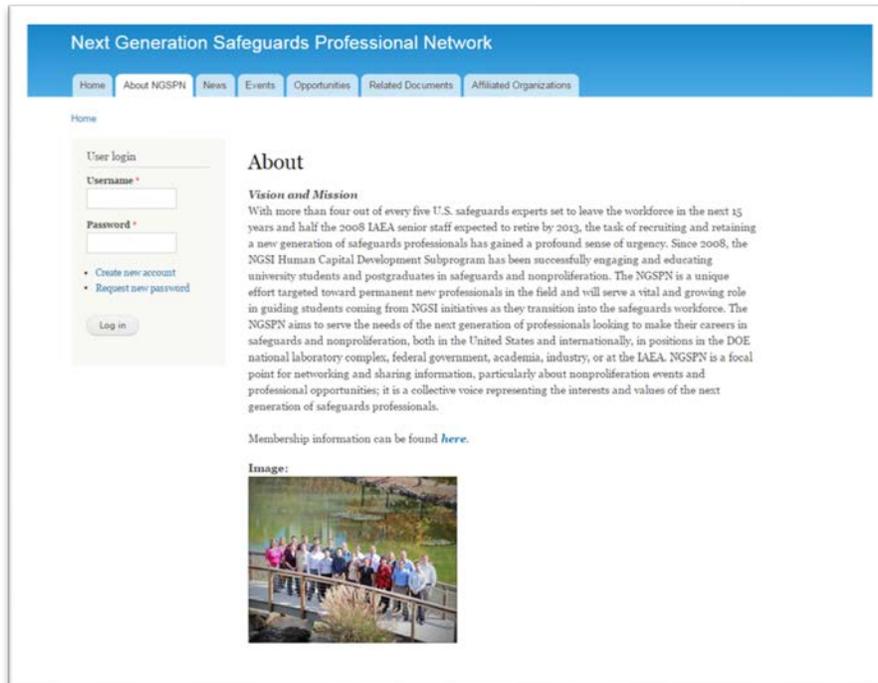


Fig. 21. Screenshot of the NGSPN.org website.

7.2 OTHER PROFESSIONAL DEVELOPMENT OPPORTUNITIES

7.2.1 Joint International Conference on Mathematics and Computation, Supercomputing in Nuclear Applications and the Monte Carlo Method

Dr. Jianwei Hu is a junior staff member in the reactor physics group of Reactor and Nuclear Systems Division. Dr. Hu has been working on the NGSi Spent Fuel project since 2009, for which he has primarily worked on NDA instrument designs, spent fuel modeling and simulations, and radiation source term characterizations. The NGSi-HCD program sponsored Dr. Hu to attend the Mathematics and Computation conference (full name: Joint International Conference on Mathematics and Computation, Supercomputing in Nuclear Applications and the Monte Carlo Method) in April 2015, in Nashville, Tennessee. Dr. Hu attended at the MCNP6 workshop and learned some new features about this nuclear transport code that is widely used for safeguards applications. Dr. Hu also presented a paper titled "Spent fuel modeling and simulation using ORIGAMI for advanced NDA instrument testing" at the Mathematical Methods in the Nuclear Nonproliferation and Safeguards Applications session, and he received very positive feedback from the peers. It was a well-attended session with about 40 international participants. Nine papers were presented in this session, with six from Europe, three from the United States, and one from Asia. The conference also provided a great opportunity for Dr. Hu to network with international peers. Dr. Hu found the discussions with experts from IAEA, Belgium, and Germany

particularly helpful because of the new information he received regarding neutron coincident counting, advancement about Fork detector, and nuclear data uncertainty, information which he can readily apply to his ongoing research.

7.2.2 ESARDA NDA Working Group

Dr. Louise Worrall participated in the ESARDA Non-Destructive Analysis Working Group (NDA-WG) meeting and Joint DA(Destructive Analysis)/NDA-WG meeting held in Manchester, United Kingdom. As part of the plan for the future management of the ESARDA NDA-WG, it has been agreed upon by the ESARDA Executive Committee that Dr. Worrall will take the next term as Vice Chair, beginning 2017, and then hold the Chair position. In the meantime, Dr. Worrall will work closely with the current Chair and Vice Chair in preparation for these roles.

Dr. Worrall is currently the Coordinator of the Enrichment Monitoring Application Group (one of several subgroups) within the ESARDA NDA-WG, and she will be responsible for coordinating international technical input to a series of task sheets designed to capture the state of the art in NDA techniques for this application. Michael Whitaker and Brent McGinnis will assist Dr. Worrall in this capacity. This is a voluntary position.

Discussions held in Manchester that were pertinent to NSITD included an update on the International Working Group on Gamma Spectroscopy Techniques and related Medium Resolution Gamma Spectroscopy project (ORNL currently has a proposal for a U.S. Support Program task for the IAEA in this area); continuing ESARDA NDA-WG interest in a tool for calculating NDA total measurement uncertainties, and a proposed international benchmark exercise on simulated gamma-ray spectra; the relationship between NDA uncertainties and basic nuclear data needs for safeguards; ESARDA NDA-WG interest in the use of simulation as a calibration tool for Euratom and IAEA inspectorates; and collaborative training opportunities.

7.2.3 International School of Nuclear Law Completion

In FY 2014, NGSF partially supported Jessica White-Horton's participation at the International School of Nuclear Law at the University of Montpellier. The program is organized by the Organisation for Economic Co-operation and Development Nuclear Energy Agency annually. In FY 2015, she completed additional requirements to earn a University Diploma in International Nuclear Law from the University of Montpellier. This did not use NGSF funds but was an extension of the original investment by NGSF. Nuclear law directly affects White-Horton's current NNSA work such as supporting implementation of IAEA safeguards in the United States.

8. STATEMENTS BY THOSE BENEFITING FROM NGSII

Below is a sample of the feedback ORNL NGSII-HCD receives throughout the year, attesting to the value and benefits of the NGSII-HCD program.

NGSII GRA Experience by Student Alexandra Hackett (UTK)

Overall, I have been pleased with my ORNL experience. My semester working here has been a great introduction to safeguards research. I have gained effective knowledge and made valuable connections – both of which will benefit me in my future studies and research. I am in my first semester of graduate school at the University of Tennessee and I plan on pursuing a Ph.D. in nuclear safeguards and security.

NGSII-Funded Course Experience by Professor John Mattingly (NCSU)

The field trip to ORNL is the cornerstone of NE591: NCSU students enroll in the course because it provides them the unique opportunity to receive hands-on training from ORNL scientists in the real-world application of technology used by IAEA and NNSA to verify compliance with international nonproliferation agreements. The students receive nearly 40 hours of training during the field trip, which actually exceeds the in-class contact they have with me and the visiting lecturers from ORNL (which totals about 35 hours over the duration of the semester).

NGSII-Funded Course Experience by Anonymous Students (NCSU)

Awesome course! I enjoyed taking this course more than any other course I have taken in the curriculum. Extremely interesting!!

This was one of my favorite courses of my college career. The format was completely different from normal classes and the opportunity to interact with field professionals was invaluable. The ORNL trip was an incredible learning experience.

This class has such a strong combination of an instructor that cares about the material, as well as interesting material, that it was a pleasure to attend. The whole experience was fresh and new, and has been by far the most interesting special topics class I have taken. The opportunity to spend a week at Oak Ridge is worth losing spring break, and the class was a chance to look at a field of nuclear engineering that isn't prominent in the regular classes NE undergraduates take.

NGSII Undergraduate Intern Experience by Rachel Gaudet (UTK)

As an undergraduate student in nuclear engineering, I was very limited in the courses I was able to take due to the rigid schedule the department has set forth in the Bachelor's program. With the desire to learn material outside of my required classes, I applied for the NESLS program through ORAU, specifying my interest in safeguards & security - this resulted in my fortunate placement under the NGSII HCD project scope. Through this project I was able to gain a wealth of knowledge about the international safeguards fields while also learning invaluable information about the workforce that would go on to help me determine what areas I would like to research for my graduate degree thesis. I cannot express how appreciative I am of the opportunities I have had while interning at ORNL through the NGSII program for the past year and a half and hope to continue supporting the mission of nonproliferation as I advance in my education.

NGSI Post Grad Experience by Kaara Patton (UTK)

My internship at ORNL in NGSi gave me a rare opportunity to have an accelerated 'hands-on' laboratory course in the nuclear fuel cycle. I was able to work with a great group of people at a great laboratory. The experience I gained through NGSi will be immensely valuable in helping me pursue a career in safeguards.

9. BIBLIOGRAPHY

1. NNSA Office of Nonproliferation and International Security, *International Safeguards: Challenges and Opportunities for the 21st Century*, Executive Summary, http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/NGSI_Report.pdf, October 2007
2. *NNSA Program Plan*, November 2008.
3. *Oak Ridge National Laboratory: Next-Generation Safeguards Initiative*, ORNL/TM-2014/8, UT-Battelle LLC, Oak Ridge National Laboratory, 2014.
4. *Oak Ridge National Laboratory: Next-Generation Safeguards Initiative*, ORNL/TM-2012/539, UT-Battelle LLC, Oak Ridge National Laboratory, 2012.
5. *Oak Ridge National Laboratory: Next-Generation Safeguards Initiative*, ORNL/TM-2011/402, UT-Battelle LLC, Oak Ridge National Laboratory, 2011, <http://info.ornl.gov/sites/publications/Files/Pub32787.pdf>.
6. Nuclear Engineering Science Laboratory Synthesis, http://www.ornl.gov/sci/nsed/outreach/internship_nesls.shtml.