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NATIONAL LABORATORY
MANAGED BY UT-BATTELLE
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ORNL/TM-2011/402

Oak Ridge National Laboratory Next-Generation Safeguards Initiative

October 2011

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Reactor and Nuclear Systems Division

OAK RIDGE NATIONAL LABORATORY NEXT-GENERATION SAFEGUARDS INITIATIVE

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Sharon Wagner

1. INTRODUCTION

In 2007, the Department of Energy's National Nuclear Security Administration (DOE/NNSA) Office of Nonproliferation and International Security (NA-24) completed a comprehensive review of the current and potential future challenges facing the international safeguards system. The review examined trends and events impacting the mission of international safeguards and the implications of expanding and evolving mission requirements on the legal authorities and institutions that serve as the foundation of the international safeguards system, as well as 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 (October 2007)". The executive summary is in the following link, http://nnsa.energy.gov/nuclear_nonproliferation/documents/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's 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 resource development
- Infrastructure development

The ensuing report addresses the "Human Resource Development (HRD)" component of NGSI. The goal of the HRD as defined in the NNSA Program Plan (November 2008) is "to revitalize and expand the international safeguards human capital base by attracting and training a new generation of talent." One of the major objectives listed in the HRD goal includes education and training, outreach to universities, professional societies, postdoctoral appointments, and summer internships at national laboratories.

ORNL is a participant in the NGSI program, together with several DOE laboratories such as Pacific Northwest National Laboratory (PNNL), Lawrence Livermore National Laboratory (LLNL), Brookhaven National Laboratory (BNL), and Los Alamos National Laboratory (LANL). In particular, ORNL's participation 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 (SUMMER 2011)

ORNL hosted 27 Next-Generation Safeguards Initiative (NGSI) interns in summer 2011. A great majority of the interns came under the Nuclear Engineering Science Laboratory Synthesis (NESLS) internship program, which is geared towards students in scientific disciplines who have interest in nuclear science and engineering applications.

http://www.ornl.gov/sci/nsed/outreach/internship_nesls.shtml

The universities represented by the students are listed below and shown in Fig. 1. Figures 2 and 3 classify the students by type of degree and field of concentration, respectively.

Cumberland College
East Tennessee State
Mercyhurst College
North Carolina State
Ohio State
Rensselaer Polytechnic
University of Missouri
University of Virginia
University of Washington
Vanderbilt University
Tennessee Technological University
Texas A&M
University of Florida
University of Tennessee

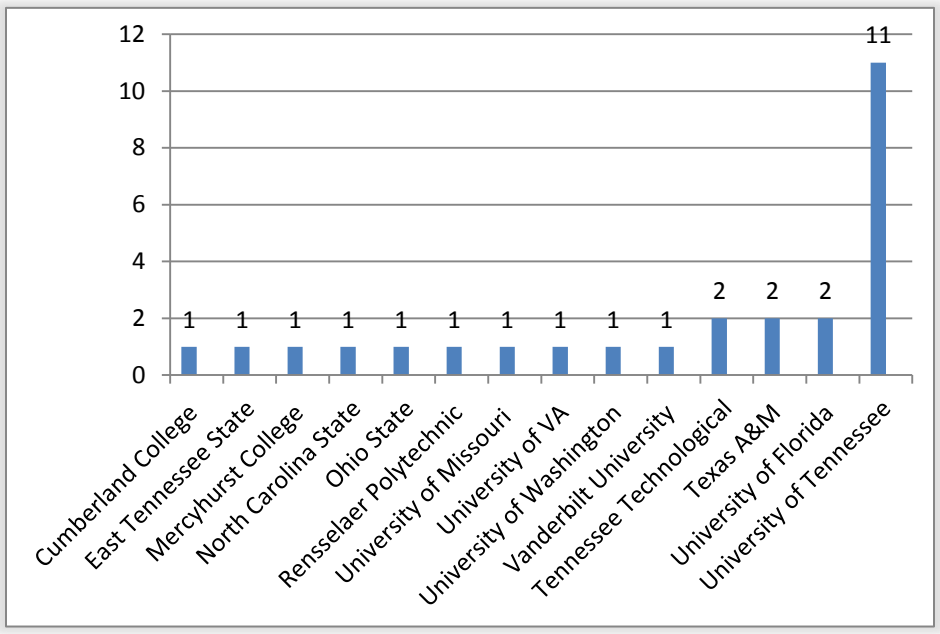

Fig. 1. Summer 2011 interns by university.

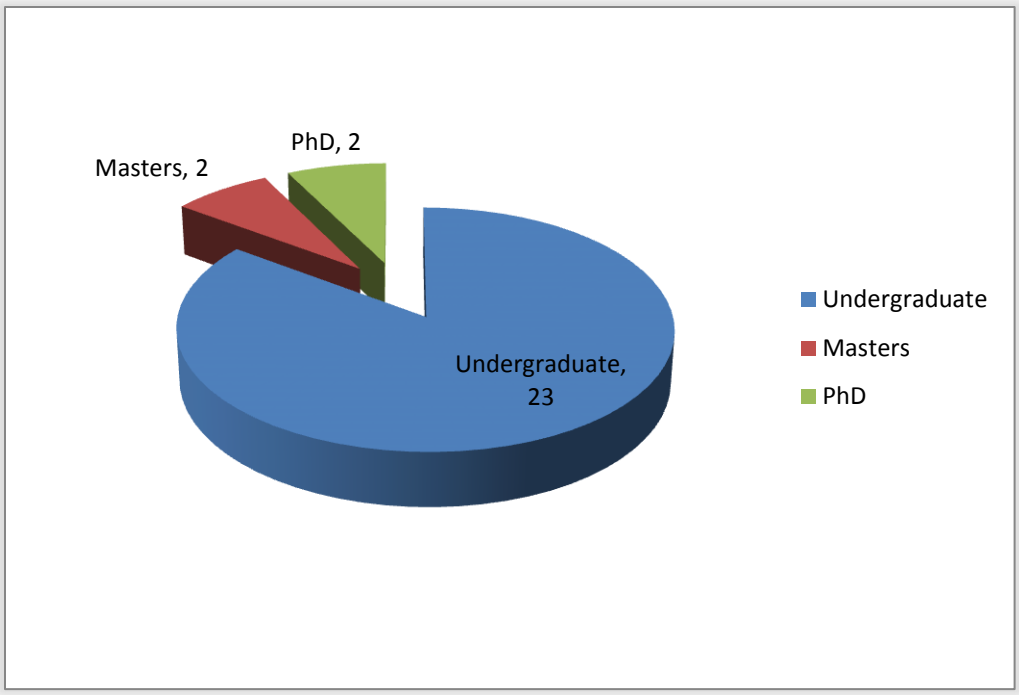

Fig. 2. Summer 2011 interns by degree.

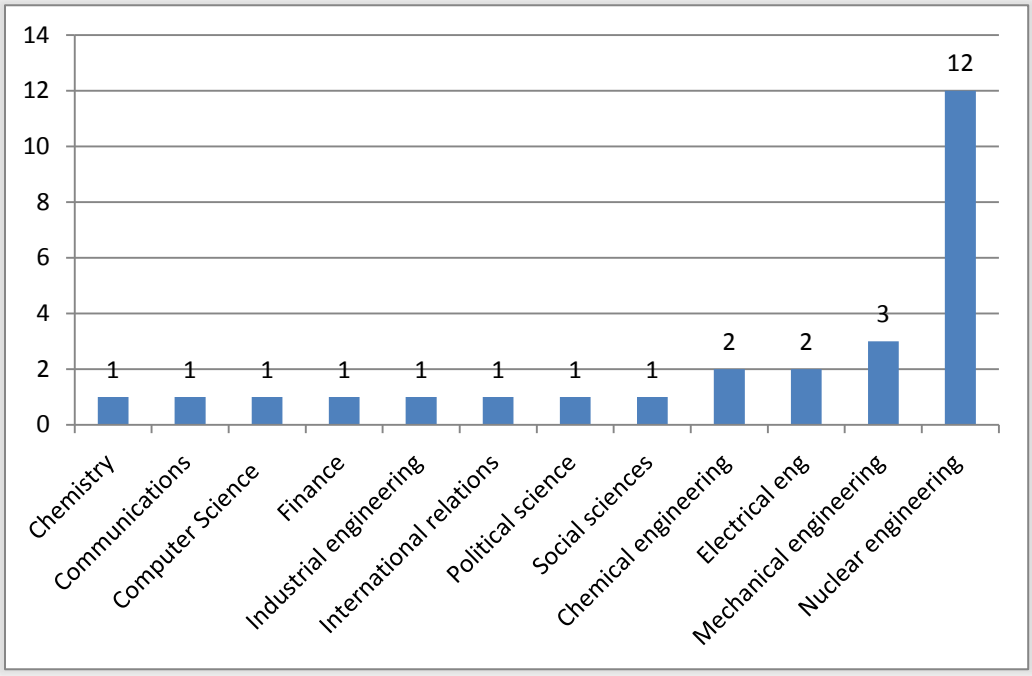

Fig. 3. Summer 2011 interns by major field.

2.1 SUMMER INTERN PROJECTS

- Collect, organize, consolidate, and perform analysis of information related to physical protection upgrades and other nonproliferation projects; perform analysis of equipment maintenance data and consolidate into database with special focus on equipment failures
- UF_6 handling, packaging, and transport; UF_6 chemistry in gas centrifuge enrichment plant (GCEP) facilities, production of material holdup as uranyl fluoride, and the evaluation of neutron emission rates
- Investigate commercially available network surveillance equipment for safeguards use
- Hybrid K-Edge implementation and miscellaneous measurement
- Hybrid K-Edge implementation, modeling, and analysis
- Embedding an OPC-UA server into an electronic scale for safeguards unattended monitoring systems
- Steps for improving RF technology for safeguards applications
- Unattended monitoring for stored materials demonstration
- Automated Solution Delivery Array (ASDA)
- Development of cascade transient models for International Atomic Energy Agency (IAEA) safeguards evaluations
- Unattended monitoring systems — understanding the inner workings of the OPC-UA technology to assess its viability at meeting stringent unattended monitoring system requirements in safeguards environments can only be gained through hands-on activities and use.
- Development of 2012 spring quarter lecture — Rotation between ORNL, Y-12, and Baker Center. A research project — serve as graduate assistant during lecture to monitor groups during simulation
- Use of process control data to detect diversion by insider at bulk nuclear material processing facilities
- Gulf Cooperation Council (GCC) International Safeguards Technical Training Program
- Modeling a gas centrifuge enrichment plant using commercially available SCADA HMI tools
- Nuclear Nonproliferation Summer Program (former “Summer Seminar Series”)
- X-ray spectral analysis and algorithms used for the HKED system and the in situ SNF counter in Building 3525
- International Safeguards Financial Portfolio and Women in Nuclear Information Technology
- Development of regression test for SCALE/ORIGEN
- Molten Salt Heat Transfer Experiment pre-testing and data acquisition setup
- Integration of DELFIC with HYSPLIT
- Proliferation resistance of advanced reactor concepts
- Integration of ORIGEN with GADRAS
- Modeling uranium and plutonium isotope changes in fuel pins to understand potential differences in nondestructive assay (NDA) measurements
- Spent nuclear fuel passive gamma and XRF measurements and data analysis
- New ORIGEN-ARP libraries for pressurized water reactors (PWRs)

3. POSTDOCTORAL APPOINTMENT

PROJECT: REVIEW AND RANKING OF NONDESTRUCTIVE ASSAY (NDA) TECHNIQUES TO DETERMINE PLUTONIUM CONTENT IN SPENT FUEL

Postdoctoral Fellow: Jesse Cheatham
Mentor: John Wagner
December 2009 to December 2010

Fig. 4. NGSI Postdoctoral Fellow Jesse Cheatham.

3.1 GOAL OF PROJECT

To distinguish the merits and drawbacks of the different nondestructive assay (NDA) techniques that are currently being investigated for the Next-Generation of Safeguards Initiative (NGSI). These new techniques must be able to determine the plutonium content in spent nuclear fuel without any nuclear power plant declarations of initial enrichment, cooling time, or burnup.

3.2 SUMMARY OF PROJECT

Ranking criteria have been developed to determine which of the NGSI NDA techniques currently being researched will best meet future safeguard needs. The criteria cover a broad range of topics that attempt to balance not only the accuracy of the technique but also the logistics of actually conducting the measurement. The criteria are broken down into several categories as follows:

a. Obtrusiveness of the measurement to a facility — Associated doses, personnel time, restricted operations, retrofitting equipment, etc., that occur due to the measurement
b. Plutonium content verification within assay range — The capability of the NDA technique to directly measure total plutonium content and the isotopic masses within the specified measurement range of the technique
c. Deployability of the technique — The door-to-door shipment of equipment to a facility and associated challenges that could occur if radioactive sources are also transported
d. Sensitivity of the assay — If the plutonium content doubles, will the NDA response also double in magnitude? This criterion helps determine how discerning a technique is on the actual changes in spent fuel composition.
e. Measurement time — The length of time required to successfully assay the assemblies
f. NDA synergy — The best combination of NDA measurements to discern the actual plutonium content in the fuel with the least likelihood of a false positive

3.3 NONPROLIFERATION/SAFEGUARDS SIGNIFICANCE

The purpose of this analysis is to ensure that the measurement techniques being investigated have a cost/benefit analysis on their actual use. Even though a technique may be the most accurate, it may not be the best solution if it is challenging to implement in the field. Determining how these techniques would integrate into the current nuclear fuel cycle will impact what techniques make practical sense for field use.

3.4 ACCOMPLISHMENTS

The review and ranking procedure outlined above has been presented, both as a talk and a poster, and published by the Institute of Nuclear Materials Management (INMM). A more specific analysis of the NDA synergy approach has been presented at the INMM Central Chapter's fall conference and hopefully will turn into a publication for the INMM.

4. CURRICULUM DEVELOPMENT

In fiscal year 2010, ORNL worked with the following five university professors of nuclear engineering to introduce safeguards concepts into their curricula:

- Nolan Hertel at Georgia Institute of Technology
- Sara Pozzi at University of Michigan
- Jason Hayward at University of Tennessee
- Glenn Sjoden at University of Florida
- Man-Sung Yim at North Carolina State University

Except for the University of Florida, which experienced a restructuring of its department, the universities continued further development of the courses in fiscal year 2011 in collaboration with ORNL.

The following is a summary of the courses taught and the corresponding ORNL Safeguards Laboratory experience.

4.1 GEORGIA INSTITUTE OF TECHNOLOGY

Professor Nolan Hertel

4.1.1 Review of Year 1 Activities

Most of the fundamentals needed by nuclear engineers are covered in the existing Nuclear and Radiological Engineering Curriculum at Georgia Institute of Technology, but a special topics course was added and taught during the spring semester of 2010. The centerpiece of this course was a trip to ORNL by the 13 students enrolled in the course to take the Nondestructive Assay Applications for International Safeguards course. Dr. Hertel and Mr. Blaylock, the Georgia Tech Laboratory Manager, accompanied the students. Twelve of the 13 students were nuclear radiological engineering (NRE) students, and the other student was a Ph.D. student in the Sam Nunn School of International Affairs. Originally, the course was to be entitled "Material Control & Accountability in the Nuclear Fuel Cycle," but the undergraduate faculty committee preferred that it be named "Nuclear Safeguards." The course was a 3 hour credit course, for which the course at ORNL fulfilled 1 hour of the credit. The course, which met twice per week, was based on information largely taken from the following sources:

- Doyle (ed.), *Nuclear Safeguards, Security, and Nonproliferation: Achieving Security with Technology and Policy*, Butterworth-Heinemann, Boston, 2008.
- Bodansky, *Nuclear Energy: Principles, Practices, and Prospects*, Springer, 2004.
- Other sources included the Nuclear Threat Initiative (NTI) and the International Atomic Energy Agency (IAEA) websites.

Outline of Course as Taught

1. Fuel Cycle (with emphasis on material flow and quantities)
    a. Uranium Mining and Milling (location of world's reserves)
    b. Uranium Conversion
    c. Enrichment
        i. Methods
        ii. Cascade Modeling
        iii. Location of World's Present and Future Capacity
        iv. Comparison of methods for making Highly Enriched Uranium (HEU) for Weapons

    d. Fuel Fabrication
    e. Fuel Burnup and Incore Isotope Growth Fundamentals
        i. Fission Products
        ii. Production of Plutonium and Synthetic Uranium
        iii. Reprocessing and Recycling
            1. Current and Future Methods
            2. Locations of World's Reprocessing Capabilities
        iv. Grades of Plutonium
2. Future Directions for Nuclear Power
    a. Mixed Oxide (MOX) Fuel
        i. Recycling Used Fuel
        ii. Fast Reactors and MOX
    b. Thorium-Based Fuel Cycles
        i. Light Water Breeders
        ii. Proliferation Resistant?
    c. Generation IV Nuclear Reactors (or whatever term is now in vogue)
        i. Gas-Cooled Fast Reactor
        ii. Lead-Cooled Fast Reactor
        iii. Molten Salt Reactor
        iv. Sodium-Cooled Fast Reactor
        v. Supercritical Water Cooled Reactor
        vi. Very High Temperature Reactor
    d. More on Fast Reactors
3. The Evolution of International Safeguards
    a. History before the Nuclear Nonproliferation Treaty (NPT)
    b. Atoms for Peace and the Birth of The IAEA
    c. Nuclear Nonproliferation Treaty
        i. Content of the Treaty
        ii. NPT Criticisms
        iii. 1995 Extension and Associated Principles
        iv. Issues Pending the 2010 Meeting
    d. Comprehensive Test Ban Treaty
    e. The IAEA and Safeguards
        i. Model Agreements
        ii. Model Additional Protocol
    f. U.S. Views of the NPT
4. Highly Enriched Uranium Fuel (HEU)
    a. HEU and the Potential for Terrorism
    b. Settings of Particular Concern
        i. Russian Security of HEU
        ii. Pakistan
        iii. Research Reactors
    c. Improvised Nuclear Devices (IND) and Requirements to Build One
    d. Low Enriched Uranium (LEU) Conversion of Research Reactors
        i. Georgia Tech Reactor as an Example of LEU Technical Requirements
        ii. Programs in United States and Worldwide to Convert from HEU to LEU
5. Nuclear Proliferation (including some history)
    a. Principal Routes to Proliferation
    b. Nuclear Weapons Development
        i. NPT Nuclear Weapons States (US, USSR, UK, France, and China)
        ii. Non-NPT Acknowledged to Have Weapons (India, Pakistan)

iii. Countries Believed to Have or to Be Seeking Nuclear Weapons (Israel, DPRK, Iran)
iv. A look at Iraq's Program

6. Nuclear Energy: The International Dimension (lecture by Bernard Gourley of the International Affairs (INTA) school)
7. Nuclear Power and the Weapons Threat – Links, Potential
8. Nuclear Weapons Basics (brief review of atomic bombs – very basic)
9. Nuclear Material Measurement Technologies
    a. Destructive Analysis
    b. Nondestructive Analysis
        i. Isotopic Signatures
        ii. Various Measurement Techniques
10. International Safeguards Inspection
    a. Significant Quantities
    b. Timeliness
    c. Facilities under IAEA Safeguards
    d. Material Balance Areas
    e. Example of LWR Inspection from Doyle's Book
11. Nuclear Weapons and Strategy (lecture given by Captain Exline of the US Army)
12. Safeguards for Plutonium Processing (lecture given by Chuck Goergen of Savannah River National Laboratory)
    a. Example — Rokkasho Reprocessing Plant

4.1.2 Review of Year 2 Activities

The course was modified for spring 2011 to include the following:

- More country-by-country reviews of nuclear capabilities
- At least three lectures by Drs. Stulberg, Hastings, and Kosal of the Sam Nunn School of International Affairs
    - At least one of the lectures will center on network analysis of how material might flow and how to detect its flow including the interactions of states
    - One lecture will center on the Nuclear Fuel Bank and its implications
    - One lecture on which countries are most likely to proliferate
- In addition, three lectures on relevant topics will be requested from ORNL Safeguards and Security professionals.
- The enrollment will be set at 18, and Dr. Hertel will make every effort to fill at least three of those slots in the class with INTA students. The limit of 18 is largely dictated by the size of the group that ORNL can handle for the "NDA Applications for International Security" week-long laboratory portion of the course.

In addition, Dr. Hertel will modify the NRE 4328 course to include more in-depth coverage of techniques related to safeguards, particularly signatures to locate HEU and plutonium and active interrogation techniques. This was to have been done in Year 1, but Dr. Hertel spent that semester in France and was unable to teach the course. However, while in France he taught a course entitled "Nuclear Technology, Power and Policy."

4.2 NORTH CAROLINA STATE UNIVERSITY

Professor Man-Sung Yim

4.2.1 Abstract

The purpose of this project is to offer a graduate-level course entitled "Nuclear Nonproliferation and Safeguards Technology and Policy" based on the experiences from the first year. The course was developed and delivered in Academic Year 2009–2010 by Professor Man-Sung Yim with the support of DOE/National Nuclear Security Administration (NNSA). The total number of students enrolled for the course was 18. A holistic approach was taken in teaching the course by covering the materials from both global and technical perspectives. A number of technical and policy experts from North Carolina State University, Duke University, University of North Carolina, Oak Ridge National Laboratory, and Savannah River National Laboratory participated in teaching the course materials. The students were equipped with the state-of-the-art techniques of nuclear safeguards and security through the course while being engaged in policy-related activities in nuclear safeguards and international security. In the second year, the course will be reorganized as a 4 credit hours course to offer it to both engineering and political science students with different sets of prerequisites and course requirements. Instructional materials will also be organized into a course package that will eventually become a textbook for the subject.

4.2.2 Project Description

This objective of this project is to revise and offer the graduate-level course entitled "Nuclear Nonproliferation and Safeguards Technology and Policy" to students at North Carolina State University and two collaborating universities — Duke University and the University of North Carolina. The goal of the course is to support the Next-Generation Safeguards Initiative in partnership with ORNL, and in support of the goals and underlying mission of NNSA.

The course was developed and delivered in Academic Year 2009–2010 by Professor Man-Sung Yim with the support of DOE/NNSA. The total number of students enrolled for the course was 18. Most of the students were from the Nuclear Engineering Department with a few from the Physics Department. The course was successful in teaching nuclear security and safeguards from both global and technical perspectives. A number of technical and policy experts from North Carolina State University, Duke University, University of North Carolina – Chapel Hill, ORNL, and Savannah River National Laboratory (SRNL) participated in teaching the course materials, as shown in Table 1. The students were equipped with the state-of-the-art techniques of nuclear safeguards and security through the course with a holistic understanding of nuclear safeguards and security issues. Table 2 provides a tentative schedule for Academic Year 2010–2011.

In the second year, the course will be reorganized as a 4 credit hours course (3 lecture hours + 1 lab hour, instead of 3 lecture hours) and will be offered to both engineering/physical science students and policy/political science students. Different sets of prerequisites and course requirements will be used for the two groups. Use of interdisciplinary class projects, interactions with subject matter experts, and a field trip to ORNL's safeguards training laboratory will continue to be part of the course to enhance students' learning. With second-year project support, the instructional materials will be organized into a course package (a draft textbook for the course).

Table 1. Guest lecturers for the "Nuclear Nonproliferation and Safeguards Technology and Policy" class

Guest instructors	Title/Affiliations	Expertise
William Boettcher	Associate Professor of Political Science and Public Administration, North Carolina State University	Management of risk in foreign policy decision making
Peter Feaver	Alexander F. Hehmeyer, Professor of Political Science and Public Policy, Duke University	International security and policy, nuclear nonproliferation
George Flanagan	Oak Ridge National Laboratory	Reactor safety and safeguards
Robin Gardner	Professor of Nuclear and Chemical Engineering, North Carolina State University	Radiation detection and radioisotope applications
Dyrk Greenhalgh	Oak Ridge National Laboratory	Physical protection and security
Churck Goergen	Savannah River National Laboratory	Reprocessing operation/safeguards
William Hopwood	Oak Ridge National Laboratory	Nuclear material control/accounting
Mark Laughter	Oak Ridge National Laboratory	Safeguards by design
Jun Li	University of North Carolina at Chapel Hill	Nuclear fuel cycle studies and proliferation assessment
Steve McGuire	Oak Ridge Y-12 Plant	Statistics in safeguards
Mark Nance	Assistant Professor of Political Science and Public Administration, North Carolina State University	International political economy and international organization
John Oakberg	Senior Information Analyst, IAEA (retired)	International safeguards
Alex Roland	Professor of History, Duke University	Military history and the history of technology and nonproliferation
Mike Struett	Assistant Professor of Political Science and Public Administration, North Carolina State University	International politics, international law, and international organizations
Kris Wheaton	Mercyhurst College	Intelligence analysis
Mike Whitaker	Oak Ridge National Laboratory	Safeguards in uranium enrichment

Specific features of the course include the following.

a) Holistic approach to nuclear security and safeguards learning: This course encompasses all major elements of nuclear nonproliferation and safeguards in an integrated fashion. This was achieved by (1) examining the issue of nuclear proliferation from the perspective of civilian nuclear power development; (2) examining the technologies and processes for protection, control, and accounting of nuclear materials; (3) examining the science of detecting nuclear proliferation; (4) studying physical protection and vulnerability analysis; (5) integrating the subject matters under the goal of strengthening the global nuclear nonproliferation regime; and (6) examining the subject of nuclear nonproliferation and safeguards from a global policy perspective.

b) Implementation of class projects and homework for practical understanding: class projects and homework played a very important part of the class. The homework and class projects involved practical problem solving exercises. The homework problems were developed in collaboration with subject matter experts from ORNL, SRNL, and IAEA.

c) Use of case studies for interdisciplinary policy studies: One of the main requirements for the course is conducting two case studies. The case study is a team effort and requires understanding of both technical and policy issues.

Table 2. Tentative course schedule for Academic Year 2010–2011

Date	#	Lecture title	Lecturer
1/11	1	History of world nuclear development	Man-Sung Yim
1/13	2	History of nuclear nonproliferation	Alex Roland (Duke)
1/18	3	NPT/IAEA/NCSU	Mark Nance (NCSU)
1/20	4	Culture of nuclear security	Mike Struett (NCSU)
1/25	5	Requirement for nuclear weapons development	Man-Sung Yim
1/27	6	Nuclear fuel cycle: uranium enrichment, reactors, plutonium production	Man-Sung Yim
2/1	7	Dynamics of nuclear proliferation	Man-Sung Yim
2/3	8	Proliferation resistance and safeguards	Man-Sung Yim
2/8	9	International safeguards	John Oakberg (IAEA)
2/10	10	Inspection and safeguards implementation	John Oakberg (IAEA)
2/15	11	Materials control and accountability	William Hopwood (ORNL)
2/17	12	Probability models/measurement error models	Jun Li (UNC)
2/22	13	Safeguards for plutonium reprocessing	Chuck Goergen (SRL)
2/24	14	Nuclear measurement technologies	Robin Gardner (NCSU)
3/1	15	Physical protection process[a]	Dyrk Greenhalgh (ORNL)
3/3	16	Overview of DA/NDA	Man-Sung Yim
3/8		Field trip to ORNL safeguards training laboratory	Spring break
3/10		Field trip to ORNL safeguards training laboratory	Spring break
3/8	17	Sequential testing and verifying declarations	Steve McGuire (Y12)
3/9	18	Safeguards for uranium enrichment	Mike Whitaker (ORNL)
	19	Safeguards by design	Mark Laughter (ORNL)
3/10	20	Open source based intelligence analysis	Kris Wheaton (Mercyhurst College)
3/15	21	Irradiated fuel measurements	Jun Li (UNC)
3/17	22	Design Information Questionnaire/Verification[a]	George Flanagan (ORNL)
3/22	23	Proliferation analysis – predictive modeling	Man-Sung Yim
3/24	24	Exam	
3/29	25	How policy is made I	Bill Boettcher (NCSU)
3/31	26	How policy is made II	Bill Boettcher (NCSU)
4/5	27	Role of policy in nuclear nonproliferation	Peter Feaver (Duke)
4/7	28	Presentation of Case Study 1	Yim/Boettcher
4/12	29	Presentation of Case Study 1	Yim/Boettcher
4/14	30	Presentation of Case Study 2	Yim/Boettcher
4/19	31	Presentation of Case Study 2	Yim/Boettcher
4/26	32	Role of engineers/scientists in policy making	Man-Sung Yim
4/28	34	Course Wrap-up	Man-Sung Yim

[a] Extended session

<Case Study 1> Each team examines the scenarios of nuclear proliferation based on those countries who were at least once involved in activities toward nuclear proliferation (e.g., Pakistan, India, North Korea, Iraq, Iran, Libya, South Africa, South Korea, Brazil, Argentina, Yugoslavia). The scenarios need to be characterized by capabilities of a state (economic, industrial, and military), types and characteristics of (nuclear fuel cycle) facilities and human resources involved, the objectives of the proliferation actions, types of proliferation actions, and the outcome of the attempts. Each team will develop policy lessons from the country for world nuclear nonproliferation.

<Case Study 2> Each team will examine the countries of potential nuclear proliferation concerns in the future (e.g., Syria, Myanmar, Egypt, Turkey, Vietnam, Japan, UAE, Jordan, Indonesia, Thailand) with respect to each country's capabilities, security concerns, and possible proliferation scenarios and develop recommendations on how the potential proliferation threat of the country can be effectively prevented. The recommendations should include the use of technology, policy, and other institutional measures, along with the needs for R&D to enhance nonproliferation/safeguards technologies to effectively address country-specific issues.

d) In-class interactions with subject matter experts: the students in the class have direct in-class interactions with subject matter experts from national laboratories, IAEA, and universities in the Triangle area.

e) Field trip to a national laboratory: Students will have first-hand experiences in using safeguards technologies at ORNL. The detection laboratory at ORNL as a national user facility for safeguards training is well utilized through a week-long training course.

The current textbook for the course is *Nuclear Safeguards, Security and Nonproliferation: Achieving Security with Technology and Policy* by James Doyle (Elsevier, Inc., 2008). Our long-range goal is to develop a new textbook based on the instructional materials developed for this course.

4.2.3 Course Content: Nuclear Nonproliferation and Safeguards Technology and Policy

History of nuclear nonproliferation (1 week)
- History of world nuclear development
- History of nuclear nonproliferation

Current nuclear nonproliferation regime (1 week)
- NPT
- IAEA
- Export Control
- Other treaties and conventions

Link between nuclear technology and proliferation (1 week)
- Requirement for nuclear weapons development
- Dynamics of nuclear proliferation

Role of technology in nuclear nonproliferation (0.5 week)
- Proliferation resistance
- Safeguards

Basic physics and technology of nuclear fuel cycle (1 week)
- Plutonium production
- Uranium enrichment

International safeguards (2 weeks)
- IAEA safeguards
- State Evaluation Reports
- Evaluating international safeguards systems

Materials Control and Accountability
- Significant quantities and timeliness of detection
- MBA and KMP
- Safeguards applications at facilities

Physical protection (1 week)
- Physical protection process
- Physical protection system design

Nuclear material measurement technologies (1 week)
- Destructive analysis
- Nondestructive assay (NDA) (gamma-ray spectroscopy, neutron assay)

Irradiated fuel measurements (0.5 week)
- Passive neutron counting
- Gamma spectroscopy
- Active techniques

Statistical methods in nuclear nonproliferation (1 week)
- Basics of probability models
- Measurement error models
- Sequential testing
- Verifying declarations

Field trip: ORNL Safeguards Laboratory training (1 week)

Proliferation analysis (1 week)
- Open source–based analysis
- Satellite imagery
- Nuclear test monitoring

Role of policy in nuclear nonproliferation (2 weeks)
- How policy is made
- How nuclear nonproliferation policy will affect the future
- Role of engineers/scientists in policy making

Presentation of case studies (2 weeks)

4.3 UNIVERSITY OF MICHIGAN

Professor Sara Pozzi

4.3.1 Project Summary

In the next 3 years, we propose to significantly enhance the newly created graduate-level course NERS 590, Nuclear Safeguards. The course complements the instruction of graduate and senior undergraduate students in the Department of Nuclear Engineering and Radiological Sciences at the University of Michigan (UM).

The course will include a description of currently used neutron and gamma-ray measurement systems in the areas of nuclear material safeguards and techniques for nuclear material control and accountability at all stages of the nuclear fuel cycle. The course will include several lectures on policy aspects related to nuclear safeguards, such as a discussion of the Nuclear Nonproliferation Treaty.

The students enrolled in the course will take part in the week-long training offered at the Safeguards Laboratory (SL) at ORNL. This training provides hands-on testing, evaluation, and validation of radiation measurement equipment, as well as training for integrated safeguards methods, procedures, and instrumentation. The SL is a national user facility open to everyone — US citizens and foreign guests. Through training at the SL, UM students have the opportunity to interact with staff that includes internationally recognized nuclear engineers, certified health physicists, NDA experts, and international safeguards experts. The experience will include experiments with fissile material. Upon returning at UM, the students are required to prepare a report and give an oral presentation detailing their experience at the SL.

4.3.2 Previous Course Offering

In 2009, the DOE NNSA funded UM to offer the nuclear safeguards course for the first time. The funding covered travel for 17 students and 3 faculty members to attend the ORNL SL course at ORNL in the fall of 2009. The instruction provided in the course was highly rated by the students (Excellent Course: 4.6/5.0, Excellent Teacher: 4.9/5.0).

4.3.3 Complementing Existing Instructional and Research Programs

The Department of Nuclear Engineering and Radiological Sciences (NERS) at the UM is one of the nation’s largest and consistently highly ranked nuclear engineering departments. With 20 faculty, 7 research faculty, 125 undergraduate students, 110 graduate students, 15 staff, and 37,000 square feet of space, the department has management and administrative structures in place to manage the instructional and research activities associated with a leading department of nuclear engineering. This includes management and oversight of nearly 100 grants with total annual expenditures that will probably exceed $11 million this year.

Several existing instructional and research programs in the NERS department at UM are directly related to the technical areas related to the successful implementation of a course in nuclear safeguards. In particular, the radiation measurements and imaging, the medical and health physics, and the fission engineering areas offer courses and research activities at the undergraduate and graduate level in the technical areas related to nuclear safeguards and nonproliferation. For example, courses are taught in radiation measurements, including advanced techniques for the measurement of neutron and gamma-ray radiation, and fission engineering, including aspects of interest in the nuclear fuel cycle.

Several special graduate-level courses have been offered in 2007, 2008, and 2009 that have direct application to the NNSA mission. For example, NERS 590-2, Detection Techniques for Nuclear Nonproliferation, is a laboratory course that is focused on the detection and characterization of nuclear materials, and NERS 490-1, Nuclear Environmental Forensics, is a course that discusses the use of measurement techniques such as gamma spectrometry and mass spectrometry. NERS 590-1, Nuclear Safeguards, is a newly developed course that has direct application to the graduate program: the course includes a description of currently used neutron and gamma-ray measurement systems in the areas of nuclear material safeguards and techniques for nuclear material control and accountability at all stages of the nuclear fuel cycle. The course offers a 1-week practicum at ORNL. In addition, the Ford School of Public Policy offers several graduate-level courses that have direct application to the NNSA mission. For example, PUBPOL 650, Introduction to Science and Technology Policy Analysis, is a course that introduces students to science and technology policy-making in the United States and abroad. PUBPOL 673, International Security Affairs, introduces students to the policy issues involved in the areas of defense, deterrence, and arms control in the contemporary context. Students will be encouraged to integrate these policy courses into their curriculum.

As a leading research institution, NERS has multiple projects in the areas of interest to the Nuclear Nonproliferation International Safeguards Graduate Fellowship Program. These include multiple projects in collaboration with national laboratories (ORNL, Los Alamos National Laboratory, Sandia National Laboratories, and Idaho National Laboratory) and industrial and academic partners. The research programs that are under way in NERS provide a framework for the growth and mentoring of graduate students in the department. The course offering will complement and strengthen the fellowship opportunities available in NERS: the Nuclear Nonproliferation International Safeguards Graduate Fellowship and the Nuclear Forensics Graduate Fellowship, for which Professor Pozzi is the principal investigator.

4.3.4 Deliverables and Outcomes

- Training of approximately 20 students per year in the area of nuclear materials safeguards
- Samples of student reports
- Yearly and final reports detailing the course outcome

5. NONDESTRUCTIVE ASSAY (NDA) AT THE ORNL SAFEGUARDS LABORATORY

5.1 SUMMER 2011 INTERN WORKSHOPS

The Safeguards and Security Group at ORNL provided 3 days of training in the following areas to summer interns (Fig. 5).

- NDA Fundamentals
- Holdup
- Quantification of Nuclear Materials

The interns were notified of the class topics and given an opportunity to sign up for the topics of interest to them. The NDA Fundamentals class was attended by 17 interns and specifically covered the basics of NDA and measurement techniques. A Holdup class was attended by 13 interns and provided an opportunity for students to use detectors and software applications to measure holdup in mocked-up apparatus with point, line, and area sources that simulated realistic holdup situations. The Quantification of Nuclear Materials class was attended by 11 interns and focused on the use of the In Situ Object Counting System (ISOCS) and Active Well Coincidence Counter (AWCC) to make quantification measurements.

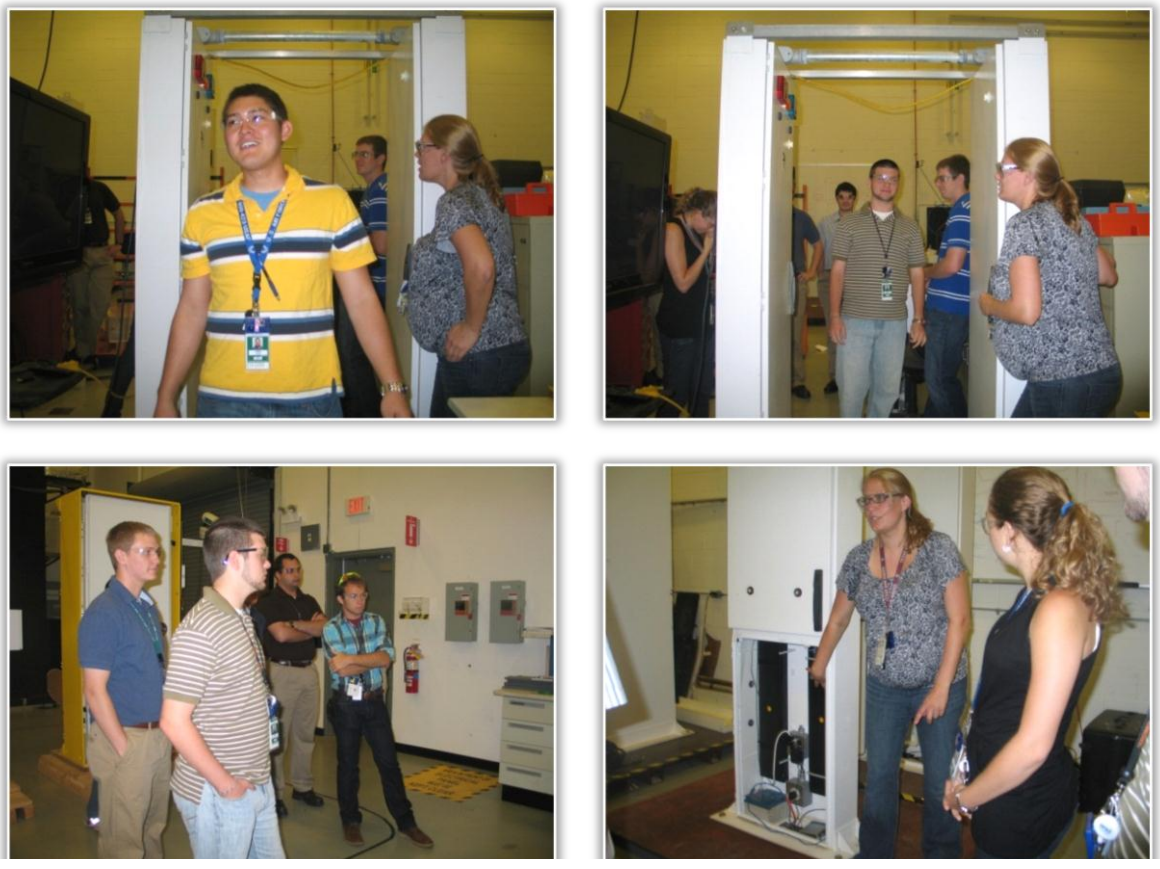

Fig. 5(a). Summer interns at the Safeguards and Security Group Workshop.

Fig. 5(b). Summer interns at the Safeguards and Security Group Workshop (continued).

5.2 UNIVERSITY OF TENNESSEE

March and April 2011

Safeguards Laboratory staff from ORNL's Safeguards Technology Integration Center conducted three laboratory hands-on-based classes for the University of Tennessee nuclear engineering students during the months of March and April 2011. The three classes were Special Nuclear Material Holdup Monitoring, In Situ High-Resolution Gamma Ray Counting, and Hybrid K-edge Densitometry. These classes were attended by 10 graduate and undergraduate students and consisted of both lecture and valuable hands-on experience. Safeguards instrumentation and software provided the students with a practical understanding of a number of NDA techniques used for analyzing special nuclear material (Fig. 6).

5.3 NORTH CAROLINA STATE UNIVERSITY

March 7–11, 2011

Safeguards Laboratory staff from ORNL's Safeguards Technology Integration Center conducted a course entitled "NDA Applications for International Safeguards" for nuclear engineering and international studies for students from North Carolina State University, March 7–11, 2011. The class, attended by seven graduate and undergraduate students, consisted of both lecture and valuable hands-on experience. Safeguards instrumentation and software provided the students with practical understanding of a number of NDA techniques used for analyzing special nuclear material.

Topics covered during the class included lectures on Safeguards for Uranium Enrichment Facilities, Safeguards Verification Measurements for SNF Recycle, the Hybrid K-Edge NDA system, Safeguards for Uranium Enrichment, Safeguards by Design, and Intelligence, Nonproliferation and Safeguards; uranium enrichment measurements encompassing peak ratio, peak fitting, and enrichment meter techniques using an Inspector 1000 and an HM5 with NaIGEM software, WINU235 software, and uranium/plutonium detection system; uranium holdup measurements; neutron coincidence counting using an AWCC; portal monitors; and portable NDA instrumentation operation, including the ICX Interceptor and HM5 (Identifinder), Canberra's InSpector 1000, and Ortec's Detective. In addition, as a part of the class, students attended several technical tours: Spallation Neutron Source (SNS, ORNL), Canberra's Germanium Crystal Growing Facility, the X-10 Graphite Reactor, and the Radiological Engineering Development Center (REDC, ORNL).

Fig. 6. North Carolina State University students attending the "NDA Applications for International Safeguards" course.

5.4 GEORGIA INSTITUTE OF TECHNOLOGY

NDA Applications for International Safeguards
March 21–25, 2011

Safeguards Laboratory staff from ORNL's Safeguards Technology Integration Center conducted a course entitled "NDA Applications for International Safeguards" for nuclear engineering and international studies students from the Georgia Institute of Technology, March 21–25, 2011. The class, attended by 16 graduate and undergraduate students, consisted of both lecture and valuable hands-on experience with safeguards instrumentation and software that provided the students with practical understanding of a number of NDA techniques used for analyzing special nuclear material (Fig. 7).

Topics covered during the class included lectures on Safeguards for Uranium Enrichment Facilities, Safeguards Verification Measurements for SNF Recycle, the Hybrid K-Edge NDA system, Safeguards for Uranium Enrichment, Safeguards by Design, and Intelligence, Nonproliferation and Safeguards; uranium enrichment measurements encompassing peak ratio, peak fitting, and enrichment meter techniques using an Inspector 1000 and an HM5 with NaIGEM software, WINU235 software, and uranium/plutonium detection system; uranium holdup measurements; neutron coincidence counting using an AWCC; portal monitors; and portable NDA instrumentation operation including the ICX Interceptor and HM5 (Identifinder), Canberra's InSpector 1000, and Ortec's Detective. In addition, as a part of the class, students attended several technical tours: Spallation Neutron Source (SNS, ORNL), Canberra's Germanium Crystal Growing Facility, the X-10 Graphite Reactor, the Radiological Engineering Development Center (REDC, ORNL) and the Mobile Uranium Facility (MUF, ORNL).

Fig. 7. Georgia Institute of Technology students attending the "NDA Applications for International Safeguards" course.

6. CAREER FAIRS

ORNL staff participated in several career fairs.

- October 5, 2010 – North Carolina State University
- October 29, 2010 – University of Michigan
- November 9–10, 2010 – American Nuclear Society (ANS)
- February 1–2, 2011 – University of Wisconsin
- April 14–17, 2011 – ANS Student Conference
- July 17–21, 2011 – Institute of Nuclear Materials Management
- September 14–15, 2011 – Texas A&M
- September 26, 2011 – Missouri University of Science and Technology

6.1 AMERICAN NUCLEAR SOCIETY

November 7–9, 2010, Las Vegas, Nevada

Fig. 8. ORNL staff Bill Toth with student visitors.

Fig. 9. ORNL staff Josh Scull with student visitors.

6.2 AMERICAN NUCLEAR SOCIETY STUDENT CONFERENCE

Georgia Tech, Atlanta, Georgia, April 14–17, 2011

Fig. 10. ORNL staff Kim Gilligan with a student visitor.

Fig. 11. ORNL staff Bernie Kirk with a student visitor.

6.3 INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

Career Fair, Palm Springs, California, July 17–21, 2011

Fig. 12. ORNL staff Rob McElroy and Chris Pickett with student visitors.

Fig. 13. ORNL staff Bernie Kirk with a student visitor.

7. WORKSHOPS

7.1 MID-CAREER OUTREACH

An informal, open discussion on nuclear nonproliferation and international safeguards was held at the ORNL cafeteria on Wednesday, August 24, 2011, from 10:00 am to 11:00 am. The target audience included scientists who have an interest in these topics and who have not had the opportunity to be exposed to the subject areas. The discussion was led by participants in the Next-Generation Safeguards Initiative (NGSI) — Dawn Eipeldauer, Tim Margrave, Bernie Kirk, Ann Pedersen (intern), and John Gunning. The purpose of the discussion is to share information on nuclear nonproliferation and international safeguards, as well as to provide opportunities to network among kindred spirits. Four ORNL mid-career staff attended the open discussion. Their fields of expertise included chemistry, biochemistry, computer science, and material science (Fig. 14).

Fig. 14. Initial discussions on NGSI for mid-career professionals.

7.2 HOWARD BAKER SCHOOL OF PUBLIC POLICY SCHOLARS WORKSHOP ON GLOBAL NUCLEAR SECURITY

Dawn Eipeldauer and Tim Margrave (Safeguards Post Masters) planned and coordinated a 1 day workshop to introduce the incoming class of Baker Center Scholars to issues and topics in global nuclear security. The workshop was held with the help of staff at the Baker Center. Experts from ORNL and the Y-12 National Security Complex (Y-12) provided an overview of technical and policy challenges associated with international nuclear security, securing nuclear materials, and supporting the work of treaty monitoring organizations such as the IAEA (Figs. 15-17). The workshop concluded with a panel on human capital development. Table 3 provides the agenda for the workshop.

Baker Center scholars are rising juniors and seniors at the University of Tennessee with a grade point average of 3.35 or higher. The central undertaking of each Baker Scholar is research. Each scholar must address public policy around one of the center's core areas of focus and/or utilize the Modern Political Archives through a year-long research project. Scholars are paired with faculty mentors who serve as resources and ultimately determine their project's eligibility for course credit.

Table 3. Agenda for Baker Scholars Workshop on Global Nuclear Security

Baker Scholars Workshop on Global Nuclear Security UTK Haslam Business Building, West Wing (Rm. 440), Monday August 15, 2011		
10:30–11:00	Welcome	Carl Pierce, Nissa Dhalin-Brown, Mark Walker, Dawn Eipeldauer
11:00–11:45	Nuclear Fuel Cycle	Mike Ehinger
11:45–12:30	What is Global Security? (working lunch)	Howard Hall
12:30–1:15	Physical Security	Dyrk Greenhalgh
1:15–2:00	Explosives and Nuclear Weapons	Dyrk Greenhalgh
2:00–2:30	The IAEA and Experiences Working in Vienna	Pat Lynch
2:30–2:45	Breaks and afternoon snack	
2:45–3:30	IAEA – "Day in the life of an inspector"	Mike Ehinger
3:30–3:45	Intro to ORNL	Alan Icenhour
3:45–4:00	Intro to Y-12	Chris Robinson
4:00–4:45	Panel on Career Paths in Global Security	Facilitated by Bernie Kirk and Dawn Eipeldauer

Fig. 15. Mike Ehinger discusses the nuclear fuel cycle.

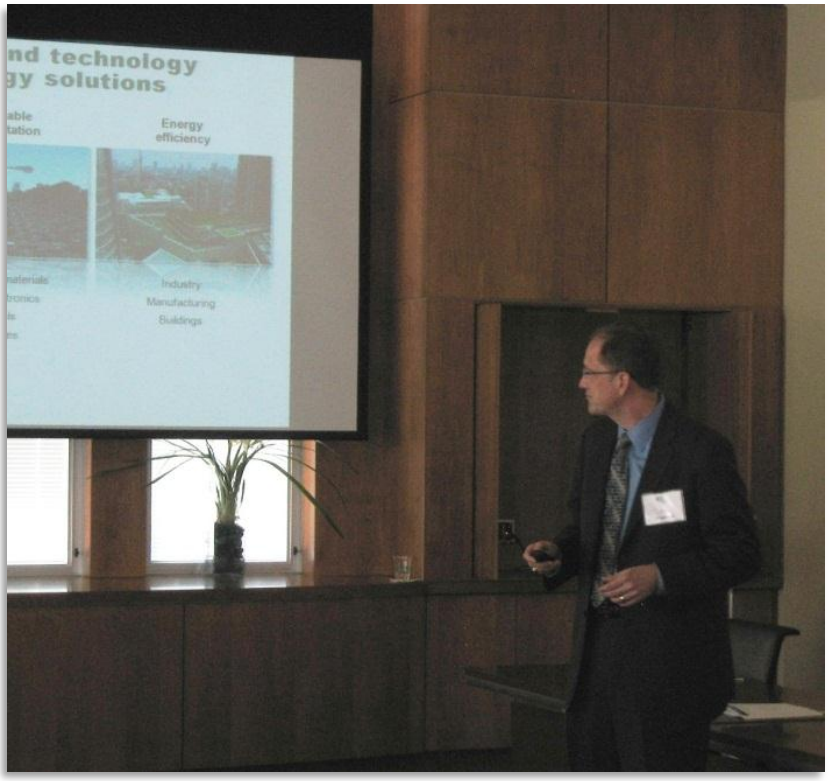

Fig. 16. Alan Icenhour talks about global nuclear security technologies at ORNL.

Fig. 17. Carl Pierce, Baker Center Director, welcomes the scholars.

7.3 SAM NUNN SCHOOL OF INTERNATIONAL AFFAIRS FELLOWS

October 18, 2011

A total of 16 staff and fellows from the Sam Nunn School of International Affairs visited ORNL on October 18, 2011. Jeff Chapman gave an overview of safeguards technologies and hosted a tour of the Safeguards Laboratory. A group discussion was held at lunchtime and touched on several topics including NGSI internship and postdoctoral opportunities (Table 4).

The visitors represented several disciplines.

- International Affairs/Public Policy
- Electrical and Computer Engineering
- International Affairs, Science and Technology
- Aerospace (Systems Design)
- Neuroscience
- Chemical and Biomolecular Engineering
- Civil and Environmental Engineering
- Material Science and Engineering

Table 4. Agenda for Sam Nunn School of International Affairs visit to ORNL

8:15 a.m.	Welcome and Opening Remarks	Kelly Beierschmitt
8:30 a.m.	Global Nuclear Security Technology Division	Alan Icenhour
9:00 a.m.	Global Security & Nonproliferation Program	Alan Icenhour
9:30 a.m.	Reactor and Nuclear Systems Division	
10:00 a.m.	Computational Sciences and Engineering	Brian Worley
10:30 a.m.	Safeguards and Security Technologies	Jeff Chapman
11:00 a.m.	Measurement Science & Systems	Gary Alley
11:30 a.m. – 12:45 p.m.	Group Session: GA Tech Visitors, Alan Icenhour, Jim Roberto, Howard Hall, John Randolph	
1:00 p.m.	Safeguards Laboratory Tour	Jeff Chapman
1:30 p.m.	Global Security Directorate	Blair Ross
2:30 p.m.	EVERST Tour	Ross Toedte
3:00 p.m.	Break	
4:00 p.m.	Close out discussion / End of Program	

7.4 SAM NUNN SCHOOL OF INTERNATIONAL AFFAIRS POSSE FELLOWS

May 17, 2011

Professor Adam N. Stulberg of the Center for International Strategy, Technology & Policy at Georgia Tech and Professor William C. Potter of the James Martin Center for Nonproliferation Studies (CNS) at the Monterey Institute of International Studies made a 1 day visit to ORNL with Program on Strategic Stability Evaluation (POSSE) fellows. The POSSE participants who visited ORNL were experienced professionals from China, Russia, and the United States. POSSE is supported by the Carnegie Corporation of New York (CCNY).

POSSE seeks to promote international scholarship on issues of strategic stability under deeply reduced or eliminated nuclear arsenals. The objectives of the program are to (a) forge a global network of young scholars on strategic stability; (b) increase interaction both between members of the network and between the network and policy practitioners; (c) fill knowledge and methodological gaps concerning analysis of strategic stability; and (d) identify the means to advance and sustain nuclear arms reductions and disarmament under changing strategic landscapes.

John Randolph, ORNL staff member, coordinated the visit. Larry Satkowiak, Alan Icenhour, Michael Whitaker, Jim Radle, Jeff Chapman, and Jim Younkin gave presentations on nonproliferation and safeguards topics. Bernie Kirk and John Randolph introduced the POSSE participants to ORNL's educational and internship programming.

The participants also toured the Safeguards Laboratory and Surveillance and Containment Laboratory programs that showcase some of the technical/technology support ORNL provides to its customers, including contribution to treaty verifications. There was definite interest in internship opportunities.

8. MISCELLANEOUS

8.1 TOURS OF ORNL FACILITIES

Table 5. Summer 2011 ORNL facility tour agenda

June 7	***Safeguards Laboratory***
June 14	Graphite Reactor
June 21	Stable Isotopes
June 28	High Flux Isotope Reactor (HFIR) and Radiochemical Engineering Development Center (REDC)
July 11	Spallation Neutron Source (SNS)
July 19	Supercomputing Facility and EVERST
July 19	High Flux Isotope Reactor and REDC

Fig. 18. Safeguards Interns Carolyn McGraw (Texas A&M) and Matt Monteriel (University of Florida) listen to ORNL staff Julie Ezold at the REDC.

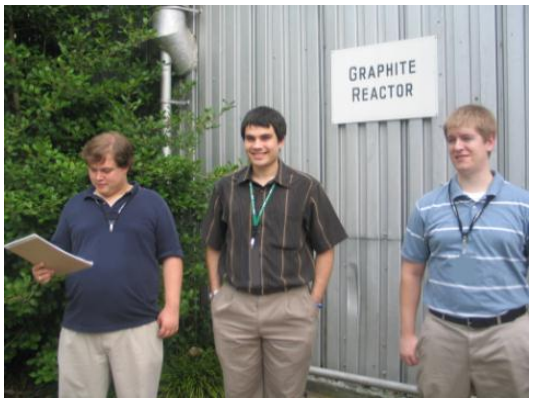

Fig. 19. Students at the Graphite Reactor.

Fig. 20. Mike Ehinger explains the history of the Graphite Reactor.

8.2 SUMMER INTERN VISIT TO DC

On July 28, 2011, several safeguards interns visited NA-24 to give presentations on their summer projects to Dunbar Lockwood and other headquarters staff. In the afternoon, the group, together with ORNL staff, visited Senator Lamar Alexander. Neena Imam, legislative fellow on loan from ORNL, helped to facilitate the visit.

Table 6. Safeguards intern presentations at NA-24

Title	Student presenter	Mentor	University/Major
Nondestructive Assay Projects and Mission Overview	Shaheen Dewji	Jeff Chapman	Georgia Tech Nuclear Engineering
Use of UNCLE Facility for Detection of Diversion at Uranium Conversion Facilities	Shaheen Dewji	Jeff Chapman	Georgia Tech Nuclear Engineering
Modeling of UNCLE facility in AutoCAD	Erik Ellis	Jeff Chapman	Tennessee Tech Electrical Engineering
3D Scans of UNCLE using the Z+F Imager 5006i	Alice Begovich	Jeff Chapman	University of Tennessee Environmental Engineering
Operational Implementation and Training of the Hybrid K-Edge System at ORNL	Jeremy Townsend	Jeff Chapman	University of Tennessee Nuclear Engineering
MCNP Modeling of the Hybrid K-Edge Densitometer at ORNL	Ben Farr	Jeff Chapman	University of Tennessee Nuclear Engineering
Transient Modeling of Centrifuge Cascade Concentrations	Patrick Migliorini	Michael Whitaker	University of Virginia Mechanical Engineering
Validation of TRITON for the AHTR System using MCNP/VESTA	Ryan Kelly	Dan Ilas	Texas A&M Nuclear Engineering
Embedding an OPC-UA Server into an Electronic Scale for Safeguards Unattended Monitoring Systems	Jesse Fritz	Jim Younkin	Tennessee Tech Electrical Engineering
Second Line of Defense Cost Analysis	Michael Arwood	Elizabeth Krispin	Vanderbilt Political/Environmental Science
Summer Seminar Series	Allison Toth	Alena Zhernosek	University of Tennessee Industrial Engineering

Fig. 21. Senator Lamar Alexander, Allison Toth (UT), Ben Farr (UT), Jeremy Townsend (UT), Dawn Eipeldauer (ORNL), Bernie Kirk (ORNL), Michael Arwood (Vanderbilt), Patrick Migliorini (University of Virginia), Alice Rice (ORNL), Eric Ellis (Tennessee Technological University) , Jesse Fritz (TTU), Alice Begovich (UT), Shaheen Dewji (Georgia Institute of Technology), Ryan Kelly (Texas A&M), and Diana Tucker (ORNL).

8.3 POSTER SESSION AUGUST 11, 2011

Fig. 22. August 11, 2011, ORNL Summer Intern Poster Session.

8.4 SUMMER SEMINAR SERIES AND VIDEOTELECONFERENCE (VTC)

Table 7. Summer Seminar Series and VTC agenda

August 10, 2011, 2–3 PM, Building 4500N, Room K-221 Karen Miller, Los Alamos National Laboratory (via video teleconference) Title: Technology Development for Safeguards Applications
August 8, 2011, 2–3 PM, Building 4500N, Room K-221 Ron Cain, Oak Ridge National Laboratory (via video teleconference) Title: Additional Protocol Implementation
August 4, 2011, 10:00 AM, Research Office Building (5700), RM L202 Rose Boll Title: Radiochemistry
August 3, 2011, 2–3PM, Building 4500N, Room K-221 Susan Pepper, Brookhaven National Laboratory (via video teleconference) Title: Careers in Safeguards at the IAEA
August 1, 2011, 10:00 AM, Research Office Building (5700), RM L204 John Mattingly, North Carolina State University Title: "Solution of Multivariate Inverse Radiation Transport Problems"
August 1, 2011, 2–3 PM, Building 4500N, Room K-221 Sarah Frazar, Pacific Northwest National Laboratory (via video teleconference) Title: "Safeguards Infrastructure Development"
July 27, 2011, 2–3 PM, Building 5300, N3109 Jonathan Essner, Lawrence Livermore National Laboratory (via video teleconference) Title: Syria and Safeguards Noncompliance
July 25, 2011, 2–3 PM, Building 4500N, Room K-221 Ross Williams, Lawrence Livermore National Laboratory (via video teleconference) Title: Actinide Mass Spectrometry for Nuclear Forensics and Safeguards
July 21, 2011, 10:00 AM, Research Office Building (5700), RM L202 Carsten Burstedde Title: AMP Fuel Modeling
July 14, 2011, 10:00 AM, Research Office Building (5700), RM L202 Lee Riedinger, University of Tennessee Title: Energy Science and Engineering at the University of Tennessee and Oak Ridge National Laboratory

Table 7. (continued)

July 14, 2011, 12:30–1:30 PM, Building 4500N, Wigner Auditorium Randy Beatty, IAEA Title: IAEA Perspective on the Fukushima Incident Title: TEPCO Perspective
July 13, 2011, 2–3 PM, Building 4500N, Room K-221 Mark Schanfein, Idaho National Laboratory (via video teleconference) Title: IAEA Unattended Monitoring Systems
July 11, 2011, 2–3 PM, Building 4500N, Room K-221 Hal Undem, Pacific Northwest National Laboratory (via video teleconference) Title: Sealing Systems for International Safeguards
July 8, 2011, 10:00 AM, Research Office Building (5700), Room L204 Dion Sunderland Title: Nuclear Fuel Modeling
July 7, 2011, 10:00 AM, Research Office Building (5700), RM L204 Jim Roberto Title: Element 117 Discovery
July 6, 2011, 2–3PM, Building 4500N, Room K-221 Roger Johnston, Argonne National Laboratory (via video teleconference) Title: Vulnerability Assessments, Physical Security, and Safeguards
June 30, 2011, 10:00 AM, Research Office Building (5700), RM L202 Michael Whitaker Title: Key Nuclear Nonproliferation Documents
June 29, 2011, 2:00 PM Ron Cain, Oak Ridge National Laboratory (via video teleconference) Title: Key Additional Protocol Implementation
June 27, 2011, 2–3 PM, Building 4500N, Room K-221 David Chichester, Idaho National Laboratory (via video teleconference) Title: Nondestructive Analysis
June 23, 2011 Larry Ott Title: Anatomy of Fukushima Tragedy Title: Fukushima Accident Overview Title: BWR Safety

Table 7. (continued)

June 22, 2011, 2–3PM, Building 4500N, Room K-221 Michael Simpson, Idaho National Laboratory (via video teleconference) Title: Sustainable Nuclear Power via Implementation of a Closed Fuel Cycle
June 15, 2011 Michael Whitaker (via video teleconference) Title: Safeguarding Uranium Enrichment: The Challenge of Large Gas-Centrifuge Facilities
June 16, 2011 Markus Piro Title: Computation of Thermodynamic Equilibria of Nuclear Materials within Multi-Physics Codes
June 15, 2011 Brian Boyer, Los Alamos National Laboratory (via video teleconference) Title: The Role of the IAEA Safeguards Inspector
June 14, 2011 George Flanagan Title: Export Control of Nuclear Reactor Components and Dual Use Materials and Equipment Title: ORNL Research and Demonstration Reactors
June 13, 2011 Justin Reed, Lawrence Livermore National Laboratory (via video teleconference) Title: Introduction to International Safeguards

Fig. 23. Students and ORNL staff during a VTC.

8.5 REDESIGNED SUMMER SEMINAR SERIES

A Project by Safeguards Intern Allison Toth (Mentor: Alena Zhernosek)

8.5.1 Description

As part of the Next-Generation Safeguards Initiative (NGSI), ORNL started the Summer Seminar Series Program, which is intended to "educate and engage students in the field of safeguards and nonproliferation." Beginning in 2005, the program had seven participants and focused on bringing in lecturers to speak to students about a variety of topics in nonproliferation. Students also attended some tours of ORNL facilities. Although students were given a plethora of valuable information about nonproliferation and safeguards, when asked to evaluate the program they expressed a concern that they could not make a connection between the information they learned in lectures and the facility tours they attended. Taking their comments into account, the Summer Seminar Series was redesigned to facilitate the application of information presented in lectures.

In summer 2011, the pilot of the redesigned program, the Summer Seminar Series sought to engage students in the field of nonproliferation and safeguards by (1) teaching them about the field through overview lectures, seminars, workshops, and brown bag lunches and (2)giving them an opportunity to apply the information they learned in the presentations to the facilities at ORNL. The students worked closely with subject matter experts throughout the summer to learn about safeguards and nonproliferation, supporting not only NGSI's mission of transferring knowledge to the next generation of professionals but also aiding in the human capital base development effort.

8.5.2 Kick-off

A student kick-off meeting with students, program organizers, and subject matter experts launched the program on Monday, June 20, 2011. At this meeting, all NGSI-funded students were divided into four teams, consisting of six or seven members each. During the meeting, each team was instructed to select a team leader, elect representatives to go on each tour, and take notes during tours and seminars for the wrap-up meeting presentations. During the second portion of the meeting, Mike Ehinger kicked off the technical program with a presentation about the IAEA and its role to give the students some background for what they would be hearing in the overview lectures.

Shortly following the kick-off meeting, the overview lecture meeting was held on Thursday, June 23. The four subject matter experts, Mark Baldwin, Bill Hopwood, Dyrk Greenhalgh, and Mike Ehinger, gave 15 minute talks on Safety, Material Control and Accounting, Security, and Inspection, respectively. Most of these experts had participated in the program in the past and reduced their previously hour-long presentations to 15 minute overviews. In addition to a general background about their topic, they gave examples of specific elements to look for in ORNL facilities, such as personal protective equipment, limited access controls, guard rails, caution signs, and evidence of accounting measurements. With a general understanding of these elements, the students embarked on their tours of the High Flux Isotope Reactor and Radiochemical Engineering Development Center (HFIR/REDC), the Safeguards Laboratory, and the Graphite Reactor. Tours were conducted by facility personnel with the exception of the Graphite Reactor tour, which was given by Mike Ehinger. All four teams attended the tours, and the students took notes and asked questions at each facility. Between the tours, the students were provided other learning opportunities that supported their project.

Fig. 24. Dyrk Greenhalgh presenting at a brown bag lunch on explosives.

Due to high student interest, two brown bag lunches were scheduled, one covering careers at the IAEA with Dawn Eipeldauer, Jim Garner, Kim Gilligan, and Mike Ehinger; the other was a presentation by Dyrk Greenhalgh about physical protection and explosives. Each of these events was a more informal learning experience than the traditional lecture and was more conducive to discussion with the subject matter experts. Student turnout at both brown bag lunches was very high, with about 10 students attending the IAEA careers event and more than 20 attending the explosives presentation. In addition to brown bag lunches, many NGSI students attended the video-teleconferences (VTC) hosted by Lawrence Livermore National Laboratory (LLNL). VTC's allowed the students to hear lecturers from across the DOE national laboratories speaking on subjects ranging from the technical aspects of NDA to more general topics such as nuclear safeguards policy. A full list of topics is provided in Table 7. Oak Ridge student attendance continuously outnumbered that of other laboratories throughout the summer, with a peak attendance of 15 students.

8.5.3 Laboratory Experience

The NDA courses held in the Safeguards Laboratory (SL) were credited by many students to be the highlight of their summer internship at ORNL. In this 3 day, hands-on workshop, students learned different methods of analyzing nuclear material. The first class focused on quantifying the enrichment of UO_2 samples using peak height and peak area ratios and spent some time finding source material with detectors. In the second class, students used handheld detectors to try to estimate the amount of holdup material in an L-shaped airway, a large pipe, and a pipe array. After finding the location of the material with the detectors, students used the software to get a measurement for the amount of material held up in the ducts. The wide range of estimates of material emphasized the difficulty in obtaining accurate holdup measurements. Finally, the third workshop was on In Situ Object Counting System (ISOCS) and active well measurements, with an emphasis on learning to use the software. While waiting for the measurements, the students also visited another area of the SL and experimented with the pedestrian detectors. In addition to being a great course on NDA, this workshop served as the tour of the SL. While students were waiting for computers to analyze data or detectors to take their measurements, they observed features of the laboratory discussed by the subject matter experts.

8.5.4 Wrap-up

After many safeguards and nonproliferation courses, lectures, activities, and tours of ORNL facilities, the wrap-up meeting was held to give students the opportunity to present what they learned over the summer. For this meeting, each team was responsible for preparing a four-slide PowerPoint presentation with one slide per topic presented in the overview lectures. Team 4 presented their first slide on safety. Among the safety features they observed were personal protective equipment, caution signs, and professional training. Team 3 covered security and noted that some of the safety features Team 4 found could serve as security elements. Team 3 also saw security cameras, guards, and log books on the tours. Following the security presentation, Team 2 presented materials control and accountability (MC&A). They saw in-house storage of spent fuel, counting of pins, and easily quantifiable sources as ways of accounting for nuclear material and also mentioned that safety and security features can aid in MC&A. Finally, Team 1 presented their findings on inspection, sparking a discussion as to how facilities are inspected in the United States and noting that many facilities at ORNL are regulated by the Department of Energy, not the

Nuclear Regulatory Commission. The subject matter experts attended the wrap-up meeting and asked questions after the presentations to highlight any important elements of safeguards the students may have missed.

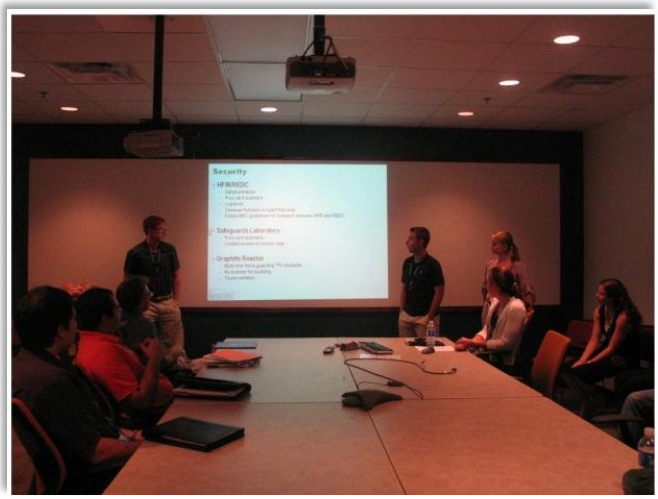

Fig. 25. Team 2 presents security at the wrap-up meeting.

Before fully wrapping up the summer, students gave their input on ways to improve the program for next year. Some of their suggestions included varying the tours so returning students have something new to learn, possibly letting returning students give the tours, visiting a wider variety of facilities, and having tours scheduled specifically for the program to avoid problems with wait-lists. A pizza party concluded the meeting and the Summer Seminar Series program for 2011.

8.5.5 Conclusions

Based on the evaluation sheets returned by the students, the Summer Seminar Series accomplished its goal of engaging students in the field of nonproliferation and safeguards. Students unanimously found the overview lectures to be informative and helpful for identifying the focus elements on the tours and reported that they felt they had a better understanding of safeguards and nonproliferation at the end of the summer than at the beginning. However, student comments also called for some changes to next year's program. First, students enjoyed and learned the most from the hands-on NDA workshop, so incorporating more hands-on activities would be beneficial in the future. Additionally, students really enjoyed working with the subject matter experts, so next year's program should incorporate them in more activities so they can further share their knowledge of the field. Finally, since many students return from summer to summer, next year's program could change the tours or information presented to maintain interest. Overall, next year's goals should include an increase in student participation as well as finding ways to further engage students with more experienced professionals.

Team 1	Team 2	Team 3	Team 4
Group Leader: Cody Wiggins	**Group Leader:** Ben Farr	**Group Leader:** Bryan Schwarz	**Group Leader:** Michael Sharp
Team Members: Ross Snow Carolyn McGraw Dwayne Tucker Megan Ketron Tyler Burkle Danyal Turkoglu	**Team Members:** Tim Jackson Michael Arwood Alice Begovich Joey Birchfield Alex Okowita Ryan Kelly	**Team Members:** Katrina Kaldenbach Jesse Fritz Burns Cunningham Erik Ellis Matt Mullens	**Team Members:** Jeremy Townsend Matt Monterial Stephen Holland Steve Cleveland Allison Toth

8.6 WORLD NUCLEAR UNIVERSITY

Kimberly Gilligan was a fellow at the World Nuclear University (WNU) Summer Institute from July 8 through August 20 in Oxford, UK. WNU is an intensive 6 week nuclear leadership development program for professionals between 27 and 37 years of age. This year, there were 80 fellows from 32 countries. The program includes lectures, tutorials, field trips to nuclear and industrial facilities, and team projects led by some of the world's foremost authorities. Some of the topics covered include global environment and sustainable development, nuclear-related technology innovation, nuclear diplomacy, and nuclear operations.

Along with Jay Disser (Brookhaven National Laboratory) and Adrienne LaFleur (Los Alamos National Laboratory), Kimberly represented nonproliferation interests and perspectives on every issue. They were the only nonproliferation experts among the fellows. Thanks to her experience at WNU, Kimberly now has a more extensive and comprehensive knowledge of the nuclear field. She has also developed a network that is far-reaching globally and through all aspects of the nuclear field. This professional growth opportunity benefited Kimberly's career, her laboratory, and the NNSA.

Fig. 26. World Nuclear University Summer Institute Fellows.

8.7 STUDENT FEEDBACK

With the end of my academic career just around the corner, my internship through NGSI has enlightened me about possible career paths in nonproliferation that I am both very hopeful and excited about. In December, I will graduate with a Master of Science in Mechanical Engineering from the University of Utah. Prior to my internship with the Global Nuclear Security Technologies Division at Oak Ridge National Laboratory, I knew nothing about nonproliferation or that my interests and background could bring anything to it. The 10 weeks I spent working at Oak Ridge helped get my feet wet in nonproliferation and sparked an interest to purse it as a career. After I graduate in a few months, I hope to continue working in nonproliferation through a post-master's or graduate fellowship opportunity. At least for me, NGSI was very successful in informing and interesting me in nuclear nonproliferation.

–Ross Snow, University of Utah

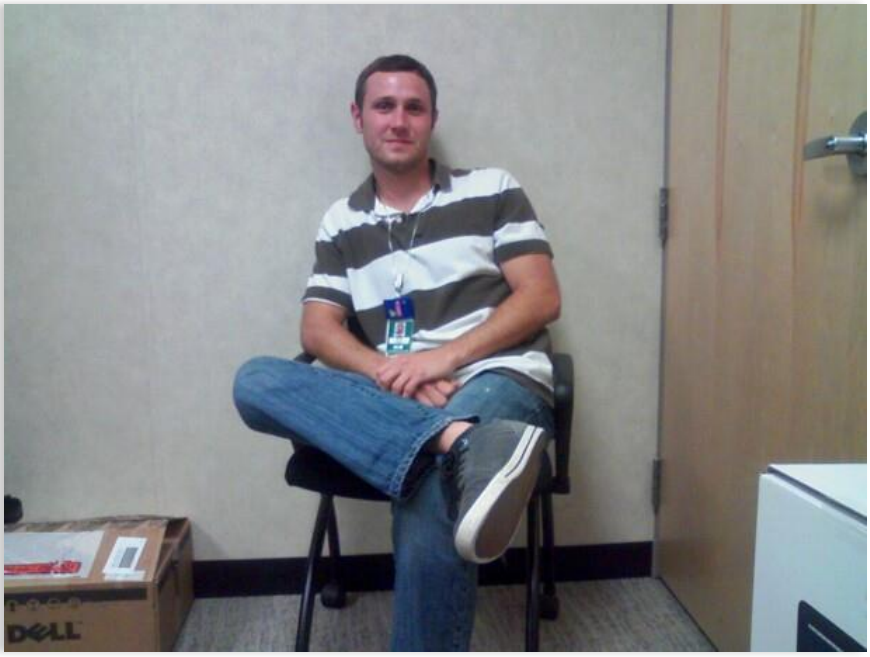

Fig. 27. Ross Snow, University of Utah.