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Idaho National Laboratory Human Capitol Development Program Summary

September 2014

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Idaho National Laboratory
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ACRONYMS

ATR	Advanced Test Reactor
BNL	Brookhaven National Laboratory
CAES	Center for Advanced Energy Studies
DCVD	Digital Cerenkov Viewing Device
DIV	Design Information Verification
DOE	U.S. Department of Energy
EOSS	Electronic Optical Sealing System
HCD	Human Capitol Development
HFEF	Hot Fuel Examination Facility
IAEA	International Atomic Energy Agency
INL	Idaho National Laboratory
ISU	Idaho State University
LIBS	Laser-Induced Breakdown Spectroscopy
LOF	Light output response function
NDA	Nondestructive Analysis
NGSI	Next Generation Safeguards Initiative
NRC	Nuclear Regulatory Commission
OSU	Oregon State University
PINS	Portable Isotopic Neutron Spectroscopy System
PSMC	Plutonium-Scrap Multiplicity Counter
TAC	To Amplitude Converter
TOF	Time of flight
TREAT	Transient Test Reactor
UU	University of Utah
VTC	Video Teleconferencing
ZPPR	Zero Power Physics Reactor

1. INTRODUCTION

The Next Generation Safeguards Initiative (NGSI) Human Capitol Development (HCD) subprogram has successfully employed unique nuclear capabilities and employee expertise through Idaho National Laboratory (INL) to achieve multiple initiatives in fiscal year (FY) 2014. These opportunities ranged from internship programs to university and training courses. One of the central facets of this work has been the International Safeguards Pre-inspector Training Course. The course, which ran for the fifth consecutive year, was redesigned in FY-14 to incorporate additional International Atomic Energy Agency (IAEA) expertise. Another significant milestone is the INL-led university engagement effort, which resulted in courses being offered at Idaho State (ISU) and the University of Utah (UU), introducing over 60 students to non-proliferation and international safeguards. The success of the university engagement effort at ISU and UU has led to the continuation of the program for the 2014-2015 academic year, and the potential expansion of the program Boise State University. The Nonproliferation Portal which provides students, faculty, young professionals, researches and industry from around the globe access to information which will help advance the fields of nuclear nonproliferation and international safeguards was also created in FY-14.This site revitalizes and expands the international safeguards human capital base by not only creating a center for professional development, but also by increasing public awareness and understanding of the role of international safeguards in nonproliferation efforts.

The university programs and the summer internship opportunities offered by INL and sponsored through NGSAI-HCD allow students hands-on experience while supporting the sustainable academic and technical programs needed to enhance the recruitment, education, training, and retention of the next generation of international safeguards professionals. A new approach to efficiently and effectively engaging high caliber graduate students and university professors in safeguards research projects supports the NGSI Human Capital Roadmap was introduced in 2013 and implemented throughout 2014. Through recalibration of the post doc program, INL aims to provide additional data points and metrics on human capital, such as which disciplines and skill sets are needed in the field, offering insight on how to address these issues to meet future demand.

2. SHORT COURSE

2.1 2014 International Safeguards Pre-Inspector Training Course

INL has worked to actively address the constantly evolving field of International Safeguards by hosting the fourth installment of the International Safeguards Pre-Inspector Training Course. Demographic challenges, increases in the amount of nuclear material under IAEA safeguards and the evolution of safeguards approaches have driven the need for the course as well as the annual reevaluation of the course content. Built on the foundation of the previous iterations of the course, INL adopted significant enhancements in the 2014 offering. The course reflects a dramatic increase in the pool of expertise available to develop, design, implement, and support the approaches, methods, and technologies necessary to respond to future safeguards challenges.

The training requires the students' active participation in demonstrations and exercises using safeguard technologies and equipment focusing on application of these technologies within international safeguards. Visits to the INL site facilities are also a required and important part of the two-week course. Shirley Johnson remained a key participant in the improvements and success of the course, providing the viewpoint of an inspector on several topics. Additionally John Oakberg was supplied expanded discussions on IAEA accounting practices and viewpoint from an IAEA analyst. Laura Rockwood attended the opening day of the course and presented a lecture on the legality and evolution of IAEA safeguards. IAEA staff provided a summary of the state level approach via video teleconference.

Participants in the 2014 course included students, national laboratory staff, NRC staff and DOE HQ staff and fellows, listed below. There remains a large demographic of qualified and interested participants

for this course, thus allowing for a rigorous student selection process to ensure the highest caliber of attendee.

Table 1. International Safeguards Pre-inspector Training Course, Class of 2014.

Participant Name	Organization	Title
Mike Bailey	INL-NRF	Engineer
Richard Clark	INL	Postdoc
Alex Day	LANL	Graduate Fellow
Mary Lou Dunzik-Gougar	ISU	Professor
Marek Flaska	Univ of Michigan	Researcher
Gisele Irola	DOE	Nonpro Fellow
Andrew Kurzrok	PNNL	Researcher
Valerie Lewis	PNNL	Researcher
Martin Lyons	AU Safeguards	Safeguards Officer
Katy Snow	ORNL	Research Associate
Taissa Sobolev	MELE	Program Manager

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Table 2. Presentation information for the course

Topic	Lecturer	Organization	Date
Introduction to Nonproliferation and International Safeguards	Mark Schanfein	INL	5/13/14
IAEA Legality, Capabilities and Evolution	Laura Rockwood	Consultant	5/13/14
Treaty on the Nonproliferation of Nuclear Weapons	Amanda Rynes	INL	5/13/14
Overview of the Global Nonproliferation Regime	Amanda Rynes	INL	5/13/14
Implementing IAEA Safeguards	Shirley Johnson	Consultant	5/13/14
Nuclear Safeguards and Fuel Cycles	Jeff Sanders	INL	5/14/14
International Safeguards at Item Nuclear Facilities	Shirley Johnson	Consultant	5/14/14
International Safeguards at Bulk Nuclear Facilities	Shirley Johnson	Consultant	5/14/14
Research Reactor Example of International Safeguards	Shirley Johnson	Consultant	5/14/14
Reprocessing Equipment Demonstration	Troy Garn	INL	5/14/14
Introduction to DIQ, DIE, DIV	Shirley Johnson	Consultant	5/14/14
Introduction to DIV/DIE Exercise – Presentation of ATR DIQ	Sean Morrell	INL	5/14/14
Case of Two States – Japan and Iraq	Shirley Johnson	Consultant	5/15/14
Nuclear Security Framework	Jason Harris	ISU	5/15/14
IAEA Nondestructive Assay Verification Equipment	Jeff Sanders	INL	5/15/14
Tour Safeguards Lab	Jim West	INL	5/15/14
DMOS / MiniGrand	Jim West	INL	5/15/14
High Resolution Gamma-Ray Systems	Jeff Sanders	INL	5/15/14
GARS Review	Jim West	INL	5/15/14
State Level Concept		IAEA	5/16/14

Topic	Lecturer	Organization	Date
State Evaluation Report Exercise	Jeff Sanders	INL	5/16/14
CAVE Visualization Tour	Shane Grover	INL	5/16/13
3DLR Exercise	Jay Disser	INL	5/16/14
HM-5 Handheld Lab Exercise	Jeff Sanders	INL	5/16/13
VACOSS and EOSS Seal Exercise	Amanda Rynes	INL	5/16/14
IAEA Nuclear Material Accountancy	John Oakberg	Consultant	5/19/14
Next Generation ADAM Module (NGAM)	Sean Morrell	INL	5/19/14
DCVD Lecture and Setup	Sean Morrell	INL	5/19/14
ATR DIV Exercise	ATR Staff	INL	5/20/14
Demonstration of DCVD on ATR Spent Fuel	Sean Morrell	INL	5/20/14
Fuel Measurements of ATR Fresh Fuel	Jeff Sanders	INL	5/20/14
Additional Protocol	John Oakberg	Consultant	5/21/14
Additional Protocol Declarations	John Oakberg	Consultant	5/21/14
State Evaluation Report Exercise	Jeff Sanders	INL	5/22/14
Living and Working at the IAEA	Johnson/Schanfein/Oakberg		5/22/14

Figure 1. 2014 INL International Safeguards Pre-Inspector Course Participants

3. UNIVERSITY ENGAGEMENT

2013-2014 Academic Year

The spring 2014 offering was comprised of 12 (3 hour) lectures which took place once a week as well as three exercises and a capstone presentation. Classes were attended at both ISU campuses (Pocatello

and Idaho Falls) as well as University of Utah through distance learning capabilities at both universities. Building on the technical backbone of the course, which includes the fuel cycle, diversion pathways, and the scientific basis of special nuclear material detection, the curriculum includes lessons discussing the history of nuclear weapons, relevant treaties and organizations, and the political implications of implementation. The spring 2014 offing illustrated a shift to a less traditional engineering curriculum with greater focus on readings and in-class interactions. Policy content was expanded and a capstone project was integrated into the course to act as a benchmark for student progress. A second university champion became involved in the course, allowing for even greater student to professor interactions. Students were expected to come to class prepared to discuss the week's readings as well as their responses for each of the three exercises (discussed below). This pushed the students to interact and consider the policy framework within which their technical advancements would have to take place. This was successfully accomplished as students from all three campuses routinely participated in discussions

The three larger exercises were designed to expand the student's working knowledge of state and policy specific areas of nonproliferation. The first required the students to review the NPT and establish what they would change about the Treaty. The second, a safeguards simulation, required students to become familiar with the limitations placed on the IAEA by each type of safeguards agreement as they carried out simulated inspections while partnered with a proliferent state. The final exercise was comprised of presentations covering the proliferation history of non-nuclear weapons states which had pursued a program in the past.

Course Objectives:

1. Introduce safeguards and nonproliferation concepts into the engineering curriculum.
2. Develop skills to communicate technical issues to policymakers.
3. Apply basic nuclear engineering principles to current policy challenges.
4. Understand the relationship between policy and technology.
5. Identify individuals for potential or advanced career opportunities in safeguards and nuclear nonproliferation.

Table 3. Spring 2014 Lecture Schedule

Week	Date	Monday	Date	Wednesday
1	01/17/2014	9:00 - 11:50	Course Into	Sean Morrell
2	01/27/2014	9:00 - 11:50	Evolution of Global Security Environment	Amanda Rynes
3	01/31/2014	9:00 - 11:50	NPT	Amanda Rynes
4	02/07/2014	9:00-11:50	Effects of Nuclear Weapons/Criticality	Dr. Kunze
5	02/14/2014	9:00 - 11:50	IAEA and International Safeguards	Mark Schanfein
6	02/21/2014	9:00 - 11:50	Nonproliferation Regime	Amanda Rynes
7	02/28/2014	9:00 - 11:50	Case Study Exercise	Amanda Rynes
8	03/07/2014	9:00 - 11:50	IAEA Exercise	Amanda Rynes
9	03/14/2014	9:00 - 11:50	Utah: Spring Break ISU: Safeguards Instrumentation Lecture	Jeff Sanders
10	03/21/2014	9:00 - 11:50	Diversion Pathways	Sean Morrell
11	03/28/2014	9:00 - 11:50	Utah: Safeguards Instrumentation ISU: Spring Break	
12	04/04/2014	9:00 - 11:50	MC&A	Jeff Sanders
13	04/11/2014	9:00 - 11:50	Security	Dr. Harris
14	04/18/2014	9:00 - 11:50	Utah: Week Off ISU: Safeguards Instrumentation	Sean Morrell
15	04/21/2014 04/25/2014	8:00-11:50 9:00 - 11:50	Utah: Student Presentations ISU: Student Presentations	(Students) (Students)
1	01/17/2014	9:00 - 11:50	Course Into	Sean Morrell
2	01/27/2014	9:00 - 11:50	Evolution of Global Security Environment	Amanda Rynes

Future and Sustainability:

Due to the importance of expanding the reach of a strong teaching curriculum and the possibility for greater multi institution cooperation, INL has created a university engagement program that thrives in multiple areas of nonproliferation and safeguards education. By continuing to build on previously developed material designed to leverage facilities and expertise, INL is producing a formal, flexible, and transferable curriculum that participating universities can adjust to fit their academic requirements..

The transferable nature of the product, which will allow the university staff to eventually deliver the material without the INL subject matter expert present, is critical to the future expansion and sustainability of this program. Beyond transferability, continued advancement of this program requires an active chairperson at the university, student demand, and a university that desires to provide this curriculum. It is paramount to the success of the course that a university champion is present who can drive the course at their institution, allowing INL to ultimately fill a supporting role in the future. The goal of the university and NGSI can be met by leveraging current infrastructure and safeguards

technology development expertise to lead hands on, focused research projects which can help to generate funding and a future programs.

Long-term goals for increased participation and sustainability create the opportunity for greater multi laboratory and multi university collaboration; allowing for increased breadth and depth of experience and research and subsequently an increased project outlook well beyond FY 14. Constant interest from universities that are already participating illustrates a continuing demand for this type and format of course.

The new university engagement model at INL will jumpstart the future sustainability of nonproliferation and safeguards education through a standardized yet flexible curriculum, increased collaborative small research programs and the subsequent broader applicability of newly learned skill sets. The collaborative model allows for INL and Next Generation Safeguards Initiative (NGSI) to direct university led research while engaging both students and professors in an effort to further develop safeguards human capital.

Future Course Material

In FY-13 INL (Sean Morrell) began working with Brookhaven National Laboratory (BNL) (Sarah Poe) to create an educational tool that does not rely on individual experts for dissemination and is easily transferrable to multiple applications within university settings. Below is an outline of a module format that could be established as this tool.

Modules:

1. Short Course - Nuclear Nonproliferation and Safeguards Concepts:
   - Introduce and Define Safeguards
   - Material Control and Accounting (MC&A)
   - Effects of Nuclear Weapons
   - Material Diversion
   - International nuclear nonproliferation regime and IAEA

   As the groundwork for a nonproliferation safeguards education, this module would be tailored to various levels of technical detail and include topics on nuclear materials that require safeguards, material diversion, international standards, material control and accountancy, and the consequence of nuclear weapons.
2. Nuclear Nonproliferation Policy:
   - Treaty on the Nonproliferation of Nuclear Weapons (NPT)
   - History of Proliferation
   - Additional Protocol/ Comprehensive Safeguards Agreement (AP/CSA)

   This module is designed provide students with an understanding of the structure supporting international nuclear nonproliferation. Students will be taken through a brief history of proliferation and the international response, emphasizing the basis for the current status of nuclear nonproliferation laws, treaties, and organizations. Topics include the Nuclear Nonproliferation Treaty, the IAEA, the Khan network, and examples of safeguards inspections in Iraq and Japan.
3. Safeguard Techniques:

   Safeguarded materials require a combination of measurement techniques to verify a state's declaration. Students will learn about the array of instrumentation developed specifically for material accountancy, spent fuel analysis, material in process, and other safeguards and nonproliferation measurements.

4. Safeguard Applications:

   Deployment of safeguards differs between member states and facility types. The application of standard IAEA equipment will be discussed in this module, along with the methodology behind equipment selection, installation, access, and maintenance. INL has established an elaborate suite of IAEA safeguards equipment that allows for unique training opportunities in a laboratory setting.

5. Nondestructive Analysis (NDA):

   The NDA module will cover the techniques used by nonproliferation and safeguards professionals to detect and characterize nuclear materials. It will include both passive and active interrogation methods that are currently employed to measure such quantities as fissile mass and isotopic/elemental composition. The basis of discussion will be centered upon standard gamma/x-ray spectroscopy, neutron coincidence counting, and calorimetry measurement practices and instrumentation, but can be expanded to include less standard methods to meet the needs of a specific audience. Examples of possible expansion topics include neutron resonance transmission analysis, nuclear resonance fluorescence methods, and lead slowing-down spectroscopy.

6. Nuclear Security:

   This module is designed for students to gain an understanding of the evolution and extent of international nuclear security instruments and initiatives. This course develops the students' understanding of the strengths, weaknesses, and gaps between the technical and political aspects of the field. Students will also assess the likely future of the structure supporting international nuclear security regime and the challenges to increasing global governance in this area.

4. NNSA NONPROLIFERATION AND SAFEGUARDS WEBSITE

Funded by NGSI, the Nonproliferation Portal website provides students, faculty, young professionals, researches and industry from around the globe access to information which will help advance the fields of nuclear nonproliferation and international safeguards. Site users have access to multi-lab educational material which can be read online or downloaded for personal use. Photographs, videos, job postings, courses and professional opportunities are also made readily available. Active participation and collaboration is encouraged in that registered users are able to suggest edits and submit job openings and links to other relevant sites.

A forum for discussion through which users can discuss and debate current issues in an open, yet monitored environment is also provided. This site revitalizes and expands the international safeguards human capital base by not only creating a center for professional development, but also increasing public awareness and understanding of the role of international safeguards in the effort to prevent the spread of nuclear weapons. This pipeline for the next generation of safeguards scientist and engineers has the potential to be recognized nationally and internationally for research and development. By helping to educate all users on the technical and political aspects of international safeguards and nuclear nonproliferation, the program will foster understanding of these fields academically and expand a knowledge base that is crucial to combating nuclear proliferation.

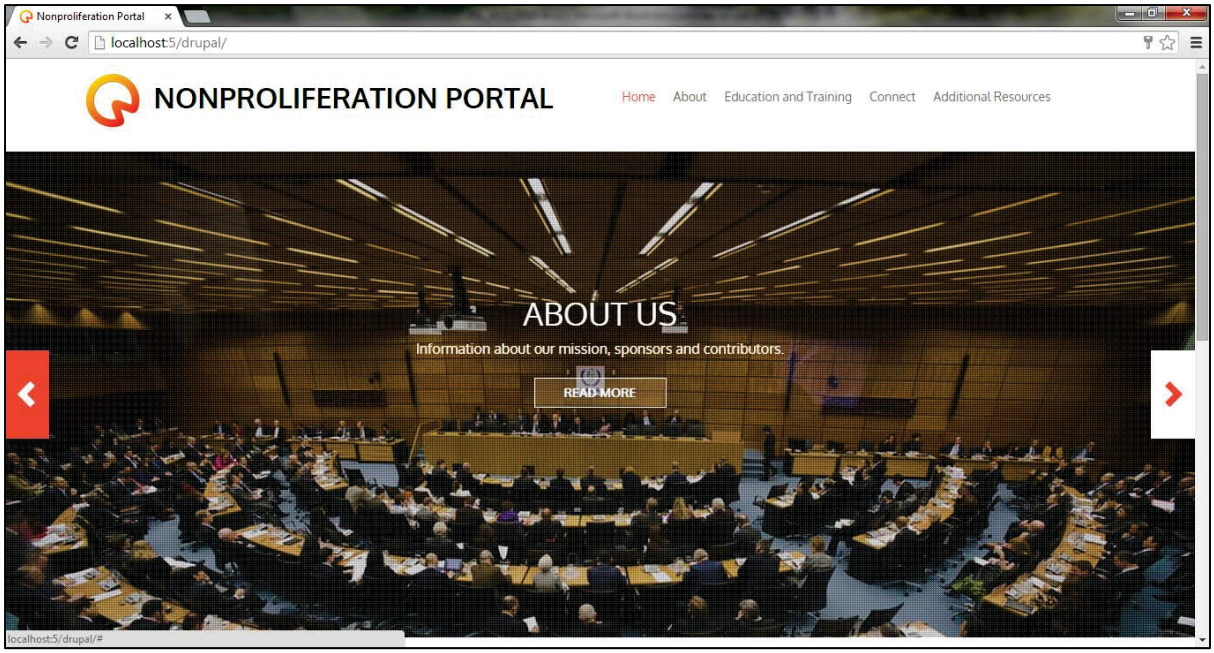

Figure 2. Nonproliferation Portal Homepage.

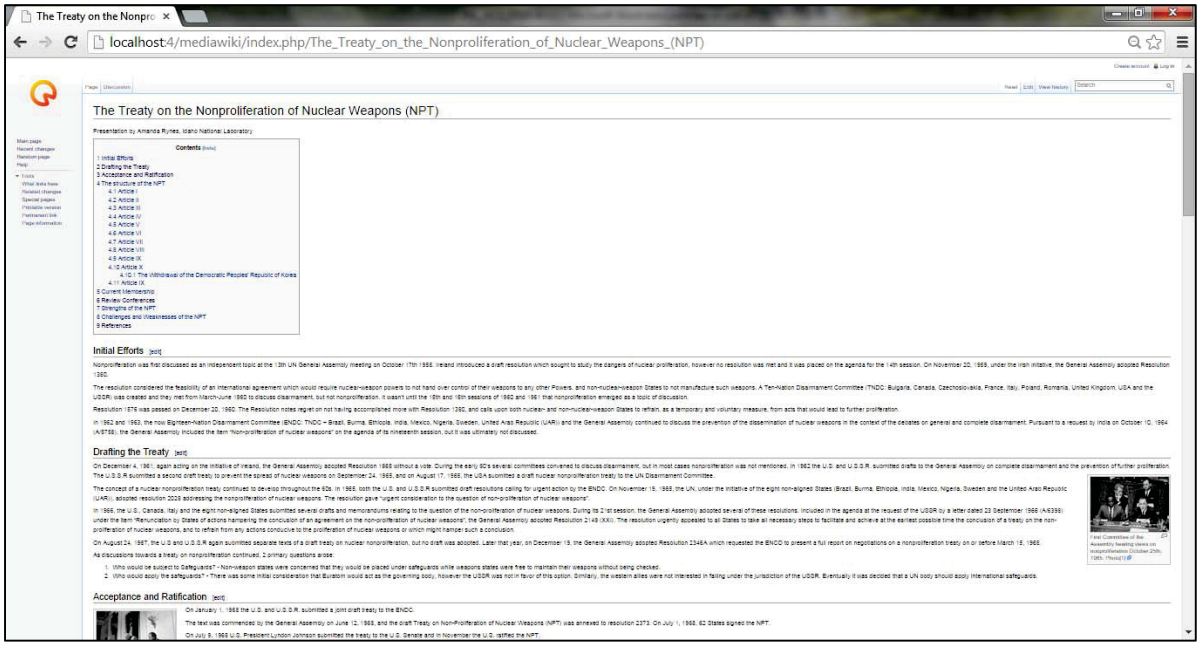

Figure 3. Course Material available online

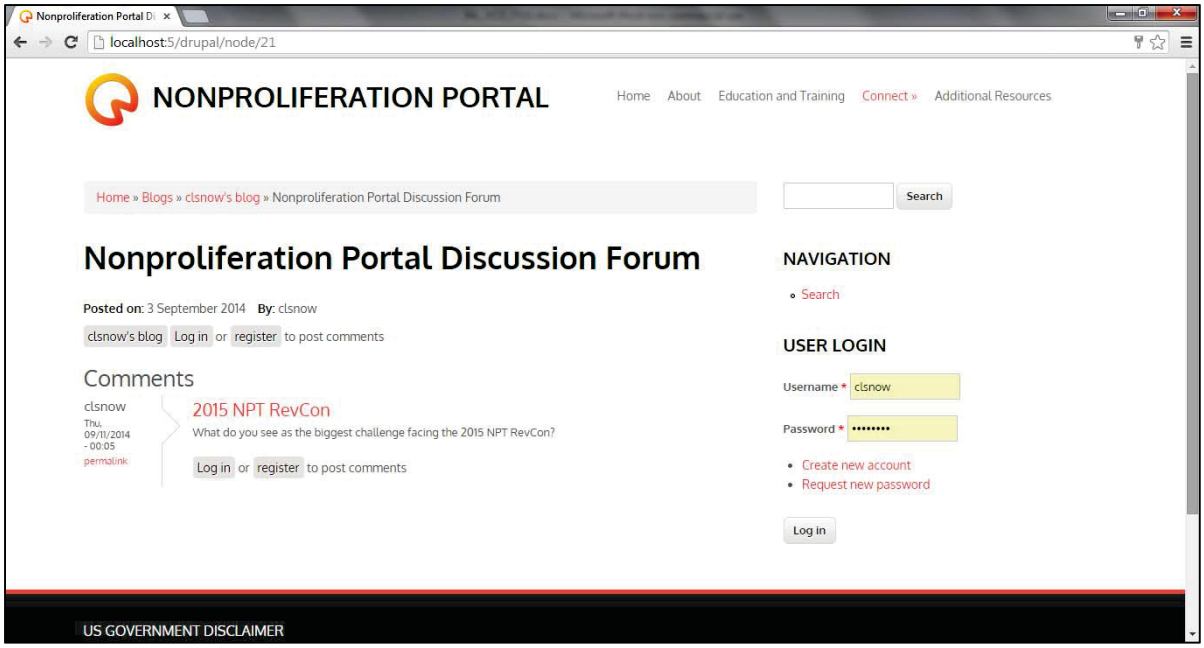

Figure 4. Discussion Forum for Registered Users

5. INTERNSHIPS

Mara Grinder

Mara came to INL from Eastern Washington University where her past research experience involved charge density mapping and analysis of lightning. She earned a Bachelor's of Science degree in Physics at EWU and plans to pursue a doctorate degree in Nuclear Physics starting in the fall of 2015. This NGSI internship at INL was first exposure to the fields of nonproliferation and safeguards.

She has been working on characterizing a Spectroscopic sCVD Diamond Detector for use in high radiation nonproliferation and safeguards applications. She has modeled the detector in both MCNP6 and GEANT4 and will be performing laboratory measurements for benchmarking. She will be using the new light ion library features of MCNP to incorporate new alpha cross section libraries for improved accuracy over the traditional light ion transport methods. In the future she will be applying the knowledge gained from alpha particle simulation and modeling towards an NNSA funded project to measure the (alpha, n) cross section of 19F with the goal of a more accurate assessment of uranium content in UF6 storage cylinders.

Charles S. Sosa

Charles has conducted both computational and experimental research in radiation detection and nuclear nonproliferation. Some of his past and present research includes pulse-shape discrimination for particle-type identification, novel radiation portal monitors, and portable neutron spectrometers. His research interests for the future involve treaty verification research, and designing or improving upon IAEA safeguard inspection equipment. Charles has participated in internships at INL, ORNL, NASA, and NOAA, and has served as student-chapter president for both ASME and ANS at his alma mater. He is pursuing both an M.S.E. and Ph.D. in Nuclear Engineering at the University of Michigan, under the advisement of Dr. Sara Pozzi. He earned his B.E. in Mechanical Engineering at the City College of New York - CUNY.

Charles' summer project, entitled, "An Unattended Spent Fuel Monitoring System for ATR," consisted of a feasibility report to test the capabilities and limitations of a conceptual safeguards system for monitoring the movement of spent fuel assemblies in the Advanced Test Reactor (ATR) spent fuel storage pool. CANDU-type reactors use such a system to monitor the loading and unloading of fuel in the reactor core. This is accomplished by placing radiation detectors in particular locations outside of the reactor pressure vessel, which feed signals to a data acquisition system called the Next Generation Autonomous Data Acquisition Module (NGAM). The goal of this summer project was to simulate a worst-case spent fuel diversion scenario using MCNP5. The simulations would help to establish design constraints for this conceptual safeguards system, which would ultimately make use of radiation detectors, and the NGAM, in a similar fashion to the safeguards system of the CANDU.

The ATR spent fuel storage pool is 20-feet deep and 8-feet wide. A five-foot section of the east-wing of the pool was accurately modeled in MCNP5. Two 5-foot-tall storage racks sitting at the bottom of the pool, which contain multiple spent fuel assemblies, were included in the model to simulate the background radiation signal. In addition, 30 ion-chamber (argon based) radiation detectors (3-inch in diameter and 6-inch long) were placed one on top of the other on one side of the pool, starting from 0.5 to 15 feet below the water. On the other side of the pool (~ 8-feet away from the detectors and directly above the storage racks) was a spent fuel assembly (4-feet tall) being diverted. The diversion scenario is as follows: an operator is aware of a particular spent fuel assembly that has been cooling for a relatively long amount time in comparison to nearby spent fuel in the same storage rack. The operator removes this assembly in the hope that the stronger radiation intensities of the assemblies surrounding it can mask its movement out of the storage rack by preventing the radiation detector(s) from signaling a fuel-movement event.

The diverted fuel and the storage racks (background) sources were defined using two distinct gamma-ray energy spectrums, which were measured using a high-purity germanium detector (HPGe) in the paper, "A Feasibility Study to Determine Cooling Time and Burnup of Advanced Test Reactor Fuel using a Nondestructive Technique and Three Types of Gamma-ray detectors" J.Navarro et.al, 2006. The relative intensities between the most prominent gamma rays were used to define emission probabilities of specific gamma-ray energies for each spectrum. The diverted fuel used a spectrum of a long-cooled fuel assembly (~1,200 days) and the fuel in the storage racks used a spectrum from an assembly that had been cooled during a much shorter period of time (~125 days).

Two simulation cases were run: total gamma-ray interactions in each detector cell from (1) strictly the storage racks and (2) strictly the diverted fuel. The sum counts from both of these simulations was used to divide the results from simulation (2); yielding a signal to background ratio (SBR) as a function of detector depth. The results indicated no discernable signal increase above background (< 1.2 SBR) to establish a threshold for an ion-chamber to register counts that could be statistically relevant to this particular diversion scenario. In conclusion, it is recommended that if such a conceptual safeguards system is to be deployed, that two detectors be used on each side of the pool, or that the operator is forced to bring the fuel into an area where a detector and camera are situated to provide higher fidelity information for the detector that could also be verified with the image taken by a camera.

Charles will return to the University of Michigan this fall semester to finish his M.S.E course work, in addition to developing a thesis topic for his doctoral studies. Pending funding approval in the coming months, Charles hopes to collaborate with INL and the University of Michigan to develop his thesis topic in treaty verification research.

Clive Townsend

Clive is currently in his third summer in the nonproliferation group at INL. His primary focus is in detector characterization, including the coupling of experimental measurements with modeling and simulation. His work at INL has explored the use of time-of-flight measurement methods as well as security, safeguards, and safety integration. His current project is supporting the development and use of a

1-dimensional gamma-ray scanning system to characterize down-blended highly-enriched uranium storage containers for material accountancy, criticality safety, and process optimization. Specifically, Clive spent the summer modeling the detector and fuel containers using MCNP6 and completing simulations on the High Performance Computing capabilities available at Idaho National Lab. Additional time was spent on-site assisting with setup, troubleshooting, and implementation of the scanning system.

He is pursuing an M.S. in Nuclear Engineering at Purdue University, and earned his B.S. in Nuclear Engineering and Physics there this past May. He plans to continue this summer's work into the Fall and return to INL for Summer 2015 to further support the nonproliferation group.

6. POST-DOCS

Because of previous challenges associated with recruiting and retaining post-docs, INL devised a creative solution to meet the needs of the HCD program while engaging highly skilled candidates in safeguards work at INL. Three university partnerships were established and students selected to conduct INL and NGSI approved research at the university. The partnerships targeted the professors at universities in order to further bolster the INL relationship and increase the relevance of the HCD university engagement program.

Thomas Holschuh

Thomas is currently a PhD student in nuclear engineering at Oregon State University, working under Dr. Wade Marcum. His engineering experience began at Sandia National Laboratories in 2007 and at Oregon State in 2009, where he has been involved in many projects, including the Next Generation Nuclear Plant (NGNP), Low-Enriched Uranium (LEU) Conversion for High Performance Research Reactors (HPRRs), and Supercritical Carbon Dioxide (S-CO2) Brayton Cycle projects, which are all DOE-funded programs. He received a B.S. in nuclear engineering from Oregon State in 2013, and future educational goals include the pursuit of a doctoral degree expected in June 2017, with a MEng expected in December 2014.

This research is funded by the NGSI program, and currently involves attempting to quantify the relative material signatures of fissile isotopes, such as uranium-235 or plutonium-239, in an operating nuclear reactor using Cherenkov light. The proposed method must be resistant to attempts to conceal the true reactor kinetics parameters, and error associated with any detection technique should resolve the disparity between expected and measured material quantities. The new, non-invasive technique allows for the calculation of relative kinetics parameters during normal operations in a research reactor. The goal of this research is to enable inspectors to determine fissile material discrepancies during reactor operations, though the method is limited to pool-type reactors.

This year, many scenarios have been evaluated for their effect on the determination of the kinetics parameters. During a diversion scenario, in which fissile has been removed or added to the core, altering the kinetics parameters, the state may wish to conceal their actions by replacing the removed material with other fuel or light-emitting material. During a small reactor power excursion (resulting in a delayed critical state), the reactor power increases quickly, but settles to a constant reactor period (steady increase in power) until feedback mechanisms cause the reactor to return to a shutdown state. In an analytical solution to reactor kinetics, the prompt jump approximation accurately describes the reactor power during this power perturbation. Using the solution to the approximation, the difference in fissile material content may be potentially identified to a small percent difference in fissile material content, though future work, such as modeling and experiments, will be needed to validate the analytical work already performed.

The modeling will be performed using GEANT4 or MCNP6.1.1 codes, which both include the capability of simulating Cherenkov light. The modeling in GEANT4 has been initiated, but simplicity in

geometry modifications and user familiarity may cause a transition to MCNP following the newest version's release in late 2014.

Ideally, experimental work will constitute the majority of research performed as part of this research. Since the focus of this research is the nonproliferation concerns of research reactors, the Oregon State TRIGA Reactor (OSTR) will be utilized to identify limitations of this nonproliferation technique and evaluate diversion scenarios that can be detected using this system. Other facilities will also be considered for additional data if available during the scope of the project.

Devin Rappleye

Devin Rappleye is currently a Ph.D. student in the Department of Metallurgical Engineering at the University of Utah where he maintains a 4.0 GPA. For his thesis research, he is currently developing methods to acquire and analyze electrochemical measurements in molten salts containing multiple actinides and/or lanthanides in order to make meaningful qualitative and quantitative predictions of process conditions. Of particular interest is predicting concentrations, species depositing on electrode surfaces, and the rates of deposition. He developed a model called Deposition Rates from Electrode Potentials (DREP) for predicting individual ion deposition rates based on electric potential measurements--a model that he is currently in the process of validating experimentally. Devin received two national paper awards in the last year, including top student paper at the 2014 Annual INMM meeting. He also received an Innovations in Fuel Cycle Research paper award from DOE-NE. Devin earned an M.S. in Nuclear Engineering from North Carolina State University in 2013 with a 3.9 GPA. He also earned a B.S. in Chemical Engineering from Brigham Young University in 2010 with a 3.6 GPA. He expects to finish his Ph.D. studies in 2016. Through HCD funded work, Devin was the first place winner of the J.D. Williames Student Paper Award at INMM this year, Paper #412: Simulated Response of Electrochemical Sensors for Monitoring Molten-salt Fueled Reactor." The success of the research funded by HCD at Utah in FY14 allowed for Nuclear Engineering University Partnership to grant funding for the project to continue serving both the interests in nuclear energy and safeguards.

Jenna Deaven

Jenna is currently a Ph.D. student in the Nuclear Engineering and Health Physics Department at Idaho State University. She earned an M.S. in Physics from Michigan State University in 2010, and a B.S. in Physics from Gettysburg College in 2007. For her research project, Jenna is applying rapid activation analysis in post-event measurements of materials with low concentrations of Uranium and Thorium. Presently, radiochemical techniques that require complete sample dissolution and take days are the standard for the assay of trace quantities of nuclear material and fission products. Through the use of rapid activation analysis, trace amounts of nuclear material could be identified within minutes without necessitating the destruction of the sample. From June 16th to June 20th, 2014 572 runs were recorded at the Idaho Accelerator Center in Pocatello, Idaho for which the data analysis is presently underway.

7. PROFESSIONAL DEVELOPMENT

Several INL staff members participated in the Institute of Nuclear Materials Management (INMM) 55th Annual Meeting in Atlanta, Georgia July 20-24. The INMM is an international nonprofit technical organization that promotes leading research and development as well as the practical application of new concepts, approaches, techniques and equipment for managing nuclear materials.

Jay Disser spoke on the International Safeguards Pre-Inspector Course. The course and presentation addressed the human capital challenge within the international safeguards community, particularly in regards to the relatively low percentage of IAEA inspectors who are US citizens. Designed to provide hands-on training with IAEA safeguards equipment and to bolster the applications of U.S. citizens applying to the IAEA, the annual 2-week course is comprised of lectures, laboratory exercises, and

facility-specific safeguards exercises, leveraging the unique facilities available at INL to provide critical information and hands-on experience, while establishing a foundational knowledge base prior to applying to the IAEA. Since 2011, the course has hosted over 48 participants. Many of the former participants have applied for positions at the IAEA and one has been successful in obtaining a position as an inspector. A large part of the success of this course can be attributed to the selection of highly motivated students that represent diverse fields from the national laboratory complex, government, and academia. Jay Disser also attended the Fundamentals of Nondestructive Assay at Los Alamos National Laboratory in September. This course included presentations and laboratory exercises on gamma ray spectroscopy, calorimetry, and neutron measurements and the World Nuclear University Alumni Assembly in April at Oak Ridge National Laboratory. The main topics covered in this meeting were leadership; safety, security, and safeguards; and public acceptance and communication. 70 participants from 15 countries attended.

Amanda Rynes presented on the University Engagement Program at INL. Her presentation highlighted the evolution of the Nuclear Nonproliferation Course which began at ISU in 2011. The success of the course has created the opportunity to expand to other universities, with lectures having been given at the Colorado School of Mines, Oregon State University, and the University of Utah, who participated in the full spring 2014 offering of the course and intends to do so again in spring 2015. INL is in the unique position to provide students with expertise from professors and professionals currently working in the field along with state of the art facilities and instrumentation. By creating and presenting courses that takes advantage of the ability to fully integrate a major university with a national laboratory, INL, ISU and the University of Utah will place local students in a prime position for employment within various arms of the U.S. Government, industry, and international organizations.

Sean Morrell was on the Technical Program Committee and a session Co-Chair for Session I-B: International Safeguards: Interface Among Safety, Security and Safeguards and participated in the Executive Committee and International Safeguards Division meetings. Because of the HCD support received for various INMM functions Sean has been selected for the ballot for an INMM member at large and asked to serve on the communications sub-committee.

8. CONCLUSIONS

The implication of the coordinated projects between NGSI and INL is the development of safeguards community of professionals. Many young professionals are better prepared to seek professional opportunities at U.S. national labs, the IAEA, or the U.S. Government via the pipeline created by the collaborative projects. The collaborative projects have materially improved the education, training, and knowledge of student in nuclear security and nonproliferation that will enable students to meet the future demands and present goals of NGSI.

INL and NGSI continue to address the imbalance between the demand for safeguards human capital and its supply, with a goal of supporting and strengthening the international nuclear nonproliferation regime. NGSI and the lab have successfully engaged opportunities to collaborate with and/or support safeguards international engagement efforts. NGSI through INL is offering a tailored and right-sized approach to the ongoing human capital challenge.

The high number of alumni continuing in the safeguards/nonproliferation field illustrates the sustainable academic and technical programs employed to enhance the recruitment, education, training, and retention of the next generation of international safeguards professionals. Many of the university students who have participated in NGSI programs have further oriented (or in some cases re-oriented) their studies toward safeguards and nonproliferation. Students in nuclear engineering and other technical or science fields have stated that before safeguards exposure under NGSI they were not aware of the professional opportunities that exist in the safeguards field.