Education and Outreach Activities within the Consortium for Verification Technology

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ABSTRACT – The Consortium for Verification Technology (CVT) was funded by the United States National Nuclear Security Administration to provide the research and development and human capital needed to address technology and policy issues in treaty-compliance monitoring. The CVT consists of thirteen universities and eight national laboratories, forming a diverse, geographically distributed team committed to educating the next generation of nuclear-nonproliferation specialists. Throughout the five-year duration of the project, new courses will be developed, and existing courses will be enhanced through interdisciplinary research performed by CVT team. These curricula will provide a unique opportunity for students to be trained in a unique blend of technical and policy-related content. The result will be a large pool of students and professionals who are trained in the complexities of international treaty verification. This paper describes the relevant curricula that are already available at CVT institutions and describe plans for future content development.

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1. INTRODUCTION

The Consortium for Verification Technology (CVT) was funded by the United States National Nuclear Security Administration to provide the research and development and human capital needed to address technology and policy issues in treaty-compliance monitoring. The CVT universities and national laboratories form a diverse, geographically distributed team, with faculty and scientists who have demonstrated outstanding research capabilities and well-

established collaborations, and who are committed to educating the next generation of nuclear-nonproliferation specialists. The team will address the major gaps and emerging challenges in treaty verification through six thrust areas: (i) treaty verification: characterizing existing gaps and emerging challenges, (ii) fundamental data and techniques, (iii) advanced safeguards tools for accessible facilities, (iv) detection of undeclared activities and inaccessible facilities, (v) disarmament verification, and (vi) education and outreach.

Throughout the five-year duration of the project, new courses will be developed, and existing courses will be enhanced through interdisciplinary research performed by CVT team. These curricula will provide a unique opportunity for students to be trained in a unique blend of technical and policy-related content. The result will be a large pool of students and professionals who are trained in the complexities of international treaty verification. The full paper will describe the relevant curricula that are already available at CVT institutions and describe plans for future content development.

2. CVT Fellowship Activities

The CVT will train the next generation of professionals in nuclear nonproliferation, safeguards, and arms control verification by introducing new topic-relevant courses, updating existing ones, organizing workshops and conferences, and engaging students in multi-institution research and development projects. These activities will enable the establishment of the following fellowships:

1. Undergraduate research fellowships
2. Graduate research fellowships
3. Postdoctoral research fellowships
4. Faculty sabbatical fellowships
5. National laboratory expert fellowships

CVT member universities have established undergraduate fellowships that will attract undergraduate students in the research and development areas of interest to NNSA. The involvement of students at early stages is critical to recruiting and retaining the best talent in support of the NNSA mission. Because of the research and teaching activities within the CVT, these students will be exposed to the basics of nuclear nonproliferation science and policy and will gain important skills in the fundamentals of nuclear science and engineering.

CVT member institutions have also established fellowships to support graduate student research for the duration of the graduate studies. The experience of the graduate fellows will be enhanced by student internships at the national laboratories, where they will take part in research under the mentorship of laboratory scientists. CVT graduate fellows will become major contributors to research activities. By the completion of their studies, Ph. D. graduate fellows will have become exceptionally well trained in their respective fields of expertise.

3. CVT Course Development Activities

3.1 Enhanced Laboratory Courses

UM offers a course entitled *NERS590: Nuclear Safeguards*, taught by Sara Pozzi. Students enrolled in this course take part in a week-long hands-on training course offered at the Safeguards Laboratory at ORNL. This training includes integrated safeguards methods, procedures, and instrumentation, including experiments with small quantities of fissile material. The course offered a unique opportunity for U-M students to critically apply the tools of nuclear safeguards in realistic scenarios. While security restrictions preclude tests with enriched uranium samples on the U-M campus, the Safeguards Laboratory at ORNL has access to samples covering the full range of enrichments. The students at the course measured and characterized nuclear material with tools identical to those used by IAEA field inspectors to verify nuclear activities at sites around the world. The students were able to analyze these samples in a variety of configurations, many of which were known only to the organizers.

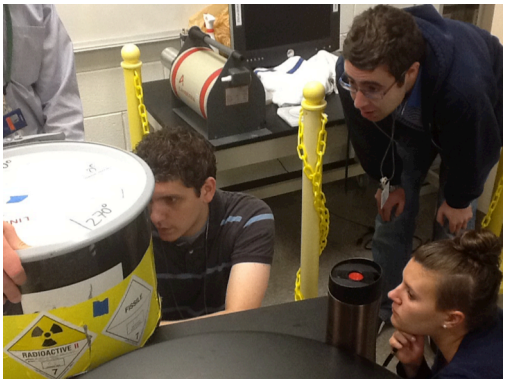

Fig. 1. NERS590 students inspect a container of unknown nuclear material.

UM also offers a course entitled *NERS535: Detection Techniques for Nuclear Nonproliferation*, taught by Sara Pozzi, which introduces students to the science and technology associated with nuclear nonproliferation. Students are taught state-of-the-art techniques for the detection, identification, and characterization of nuclear materials through hands-on experience with radiation detectors and their application to nonproliferation. This course also includes the study of Monte Carlo simulation with MCNPX and MCNPX-PoliMi and measurement techniques through experiments with gamma ray and fast neutron sources. The students build Monte Carlo models for each experimental configuration and validate their models with their own measured data.

NCSU offers a course entitled NE591*: Nuclear Nonproliferation Technology and Policy*, taught by John Mattingly, which focuses on the intersection of nuclear technological means and policy implementation for (1) verifying compliance with international nonproliferation agreements, (2) securing nuclear materials and technology against diversion to state-sponsored nuclear weapons development programs, (3) thwarting nuclear terrorism, and (4) responding to nuclear emergencies. NE591 students study all of the major international nuclear nonproliferation initiatives, including the Atoms for Peace Program, the Nuclear Nonproliferation Treaty (NPT), establishment of the Zangger Committee and the Nuclear Suppliers Group (NSG), the Partial and Comprehensive Test Ban Treaties, the IAEA Additional Protocol, Strategic Arms Control Treaties, the Proliferation Security Initiative, and UN Security Council Resolution 1540.

NE591 students also spend a week at ORNL conducting measurements of SNM in the ORNL Safeguards Lab. During the field trip to ORNL, the University of Tennessee, Knoxville (UTK) Institute for Nuclear Security (INS – led by Prof. Howard Hall of UTK) hosts a table-top

exercise (TTX) in physical security, dubbed the Uranium Bowl. NCSU and UTK students compete in the Uranium Bowl TTX by taking turns playing the opposing force, which attempts to steal or sabotage SNM stored in a high-security facility, and the protective force, which protects the SNM from theft or sabotage.

NCSU also offers a course entitled *NE795: Characterization of Special Nuclear Material (SNM)*, taught by John Mattingly, which is a project-oriented course that focuses on applying radiation measurements to non-intrusively characterize SNM. The course evolution follows a hypothetical scenario initiated by the discovery of unprotected radioactive material. Students are initially provided basic measurement data from low-fidelity instruments, like radiation pagers. They then must (a) learn what they can from the data they were provided, (b) decide what additional information they need to continue the characterization of the source, and (c) determine what radiation measurements they need to obtain that information. This sequence of discovery, analysis, and further inquiry continues through the semester, typically culminating with high-resolution gamma spectroscopic and neutron multiplicity counting measurements. By the conclusion of the course, the students develop a detailed characterization of the source, which includes isotopic composition, fissile mass, neutron multiplication, and reflection and shielding. The data the students are provided is derived from measurements of real, unclassified SNM.

3.2 Enhanced Nuclear Security and Policy Courses

MIT, PSU, and Texas A&M University have jointly developed multiple Nuclear Security and Policy courses funded by Global Threat Reduction Initiative (NNSA) that are specifically designed to be shared with other universities. This collaborative, multi-year initiative forms the basis of specific education programs designed to educate the next generation of personnel who plan on careers in the nonproliferation and security fields with both domestic and international focus. The three universities worked collaboratively to develop five core courses consistent with the GTRI mission, policies, and practices. The courses include Global Nuclear Security Policies, Detectors and Source Technologies, Applications of Detectors/Sensors/Sources for Radiation Detection and Measurements Nuclear Security Laboratory, Threat Analysis and Assessment, and Design and Analysis of Security Systems for Nuclear and Radiological Facilities. PSU has recently commissioned a dedicated Nuclear Security Education Laboratory equipped with state-of-the-art radiation detection instrumentation for this purpose (Fig. 2a), organizes experiences for students at Oak Ridge National Laboratory, as well as field exercises (Fig. 2b).

Thus, the nuclear security graduate level curriculum and the prior NNSA-led initiative is being leveraged to enable the two CVT participating universities (PSU and MIT) to educate future nuclear security experts, along with an opportunity to provide these educational experiences to all CVT members and engage a broader community of students. To help accomplish those goals, the nuclear security education program at PSU will all start granting Master's degree in nuclear security in the near future. The detailed curriculum for this degree program is under development.

Fig. 2. (a) Nuclear Security Education Laboratory at PSU; (b) Search exercise at PSU

In Spring 2015, Princeton University offered for the first time a new course entitled "Unmaking the Bomb: The Science and Technology of Nuclear Nonproliferation, Disarmament, and Verification" (MAE 354/574). Taught by Alexander Glaser, the course is open to juniors, seniors, and graduate students. It breaks up into two main parts. In the first six weeks, the course covers a wide range of key concepts in nuclear physics and engineering, including: the principles of nuclear fission and neutron interactions; diffusion theory and the concept of critical mass; the dynamics of neutron chain reactions; the effects of nuclear weapons; the principles of fissile material production; nuclear decay and radiation; the Monte Carlo method; and the principles of radiation detection and measurement. This material is designed to equip the students with the background and skills for the final project in the second half of the semester. This year, the class participated in a "verification challenge" that involved the development and construction of a number of prototype "information barriers" for use with a radiation detection inspection system based on a sodium-iodide detector. To this end, students were divided into several teams (in this case, 3 teams with 4 students each). Each team started with the same "development kit" and a small budget for extra hardware and material. All systems were based on a Raspberry Pi board connected to the common detector unit via ethernet. In addition to the technical work, the teams jointly negotiated in several sessions the procedures for the inspection exercise and determined all essential features of their inspection systems. All three systems were successfully tested in several rounds of mock inspections in the last week of the semester: using statistical tests on the acquired data, the information barriers were able to detect even small anomalies in the spectra. A revised version of one of the boxes will be presented in July 2015 at the International Summer Symposium on Science and World Affairs in Nagasaki.

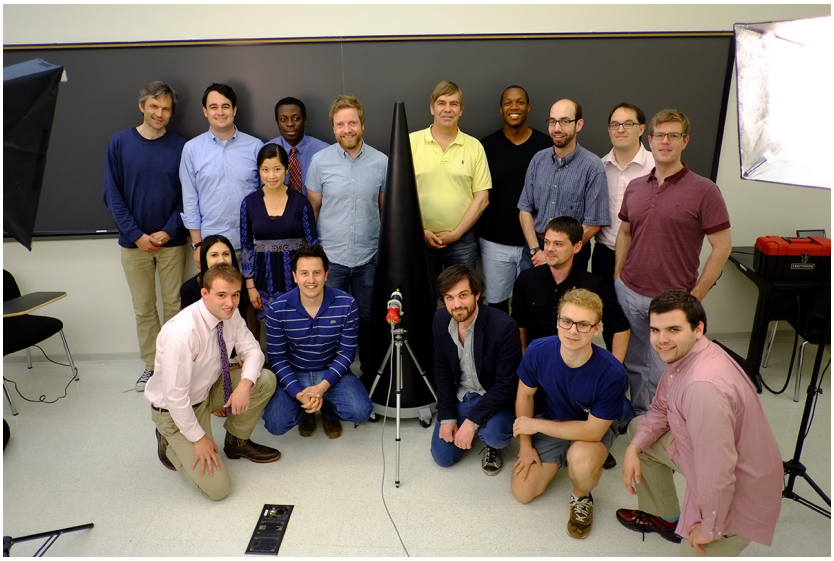

Fig. 3. Students after a series of mockup inspections carried out as part of "Unmaking the Bomb," a new course offered at Princeton University in Spring 2015. Students developed and demonstrated radiation detection inspection systems to determine whether a "valid" or "invalid" mock warhead (with embedded calibration sources) is presented. Technical experts from the UK and Norwegian Delegations to the NPT Review Conference in New York (April–May 2015) joined this exercise as observers and provided valuable feedback to the students.

3.3 Subcritical Measurements of Category-I SNM at the Nevada National Security Site

NCSU is working with UM and LANL to plan and conduct subcritical experiments with Category-I quantities of SNM in the Device Assembly Facility (DAF) at the Nevada National Security Site. The first such campaign will take place in July 2015. Fig. 4 shows a past measurement setup at the DAF.

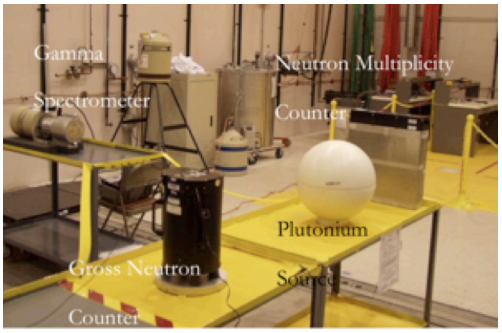

Fig. 4. Example measurement setup showing a moderated plutonium sphere, and two neutron detection assemblies.

Students will measure objects such as: (a) BeRP ball: a 4.5 kg sphere of alpha-phase weapons-grade plutonium metal (b) Rocky Flats Shells: a collection of 80 nesting hemispherical shells of HEU with individual masses ranging from 176 grams to 8.4 kilograms. The sources will be measured bare and in approved reflected configurations passively or using pre-approved active interrogation neutron sources (e.g., ^{252}Cf or a D-T generator). Data collected during the experiments will be distributed to interested universities for use in research projects and for courses.

3.4 CVT Course Certificate Programs

In order to broaden Fellows' educational experiences, several CVT universities have existing certificates of public policy that incorporate public policy and technology.

- UM offers the Science Technology and Public Policy Graduate Certificate Program in which students explore the politics and policy related to science and technology.
- PSU offers bachelor's, master's, and doctoral degrees in public policy.
- UH offers graduate certificates in Public Policy and a program in Futures Studies.
- Princeton University's Woodrow Wilson School of Public and International Affairs offers the Science Technology and Environmental Policy graduate fellowship.
- UW offers the Energy Analysis and Policy Graduate Certificate Program in which students combine studies in technology, policy, economics and environmental science.
- MIT has a Technology and Public Policy Program which studies technology policy and also a Security Studies Program that integrates technical and political analysis.
- UIUC offers an undergraduate certificate in Global Security through the Program in Arms Control, Disarmament, and International Security.

The NCSU NE and PS departments are collaborative developing a graduate certificate program in nuclear nonproliferation science and policy. The certificate will require a 12 semester hours of coursework in a mixture of NE and PS courses focusing on nuclear nonproliferation. Subject matter will include proliferation vulnerability in the civilian nuclear fuel cycle; nuclear weapon strategy; domestic international nuclear nonproliferation initiatives, agreements, and treaties; and technical and physical security measures to protect nuclear material. The program will be structured to enable both on-campus and distance education students to obtain the certificate.

4. CVT Outreach Activities

The consortium faculty and laboratory researchers represent a remarkable pool of interdisciplinary talent. We will showcase this expertise through open short courses and workshops, during which both fundamentals and research results will be shared. Table I shows a list of existing and proposed workshops, summer schools and conferences that will benefit the CVT participants and other students and faculty.

A major goal of the CVT is to provide a stream of well-educated and bright scientists and technologists into our national laboratory system. In order to ensure that the CVT does not overlook exceptional talent, we will encourage aggressive steps to increase the pool of under-represented minority applicants for our graduate programs through our undergraduate summer research opportunities program. For example, UM has strong, ongoing relationships with urban and historically black colleges (e.g., Central State University) and tribal communities (e.g., Pine Ridge Indian Reservation), which will be used to recruit exceptional students into this program. Collaborating universities have similar programs to be exercised.

In addition, UM, NCSU, and PSU have vibrant student chapters of the INMM founded by Profs. Pozzi, Mattingly, and Jovanovic. The student chapters bring experts from the national laboratories and industry to campus and provide the opportunity to further expose students to the areas of nonproliferation and safeguards. The CVT will benefit from and enhance these activities.

*Table I. Existing and **proposed** summer schools, workshops, and conferences of CVT institutions*

Institution	Annual Summer Schools	Annual Workshops/Conferences
University of Michigan		**CVT Annual Workshop** MCNPX-PoliMi Training Workshop Symposium on Radiation Measurements and Applications (SORMA)
Massachusetts Institute of Technology	Nuclear Plant Safety, Nuclear Operational Risk Management	Multiple conferences on topics from fundamental science to the Annual MIT Energy Conference
Princeton University		International Panel on Fissile Materials. Topical workshops for the International Panel on Fissile Materials International workshops on political and technical verification challenges
Columbia University	Lamont-Doherty Earth Observatory Summer School	Science and Technology conference sponsored by the CTBTO
North Carolina State University	Young Investigators Summer Program in Nuclear Engineering.	
University of Hawaii		Annual CTBTO Infrasound Technology Workshop Biennial CTBTO Science and Technology Conference
Pennsylvania State University	Toshiba-Westinghouse Fellows program	2014 American Nuclear Society Student Conference
Duke University		Workshops on analysis of high-dimensional sensing data
University of Florida	PNNL Radiation Detection for Nuclear Security Summer School	Regular host for the annual FL-HPS and FL-AAPM joint meeting
Oregon State University	Advanced Radiation Detection and Radioanalytical Methods offered to distance students (ECampus program)	IAEA International Collaborative Standard Problem (ICSP) on Prediction of Hydro-Mechanical Behavior in Reactor Core with a Plate-type Fuel Assembly Nuclear Future: New Nuclear Power Plants from Design to Generation, International Workshop
Yale University	Solid State Dosimetry	International Conference on Solid State Dosimetry
University of Illinois		Summer Workshop in International Security

5. SUMMARY AND CONCLUSIONS

Because of the interdisciplinary nature of nonproliferation issues, there is a growing need for the integration of policy and technology. A complete understanding of treaty verification requirements is needed to guide the technology development. To this end, the CVT have been funded by the National Nuclear Security Administration to provide the research and development and human capital needed to address technology and policy issues in treaty-compliance monitoring. Over the next five years, the CVT will explore new instruments and methods for nuclear nonproliferation, safeguards, and arms control treaty verification. This expertise is being disseminated through an array available at the various CVT institutions as outreach activities such as summer schools, workshops and conference.

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