Dissemination of Practice of Master's Program in Nuclear Material Safeguards and Nuclear Nonproliferation Field Realisation at Tomsk Polytechnic University

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ABSTRACT

The Institute of Physics and Technology (IPT) at the National Research Tomsk Polytechnic University (TPU) has established a Master of Science in Nuclear Engineering that focuses primarily on Nuclear Safeguards, Security and Nonproliferation. This program has been effective at educating the third generation of safeguards experts in nuclear engineering.

However, the safeguards community must increase its capability to educate a broader audience of nuclear engineers, such as those in the commercial nuclear power sector, in addition to recruiting and educating outside nuclear engineering departments. As a result, IPT department of nuclear power station has already developed and realised a pre-sessional course to all first-year students in the TPU Nuclear Engineering program. In addition to this, lectures that will be delivered in the senior level of designed courses at both the undergraduate and graduate level are being developed. These lectures are a first step toward developing a lecture series that may be given in all the disciplines applicable to safeguards such as mathematics, law, physics and other engineering disciplines. To support this lecture series, reading materials or videos to provide background information, and post-lecture exercises as a homework assignment or mechanism for engaging professors of the other disciplines may be required.

Keywords: *nuclear safeguards, security, non-proliferation education, lecture series*

INTRODUCTION

The constantly evolving nature of global terrorism requires the nuclear community to address a shifting landscape of threats. Possible nuclear terrorism scenarios are many and varied, consisting of the use of radiological dispersal devices (RDD), sabotage of commercial nuclear facilities, theft of weapons useable material, theft of nuclear devices, etc. These threats have been made all too real by the many times senior Al Qaeda leadership has expressed interest in nuclear attacks (Ignatius, in press), and attacks on existing nuclear targets (Rajghatta, in press). The threat of nuclear terrorism has also been acknowledged by Kofi Atta Annan, the seventh Secretary-General of the United Nations, and was highlighted during the proceedings of the 57th Session of the United Nations General Assembly: "The necessity of education and professional training in the field of disarmament and nonproliferation has never been such a key note as it is now. Education and professional training remain important but not used in their full capacity means to enhance security, promote disarmament and nonproliferation" (Annan, 2002).

In order to effectively address these threats, we must first ensure that the nuclear safeguards community remains robust. The need for future workers, in all nuclear-related fields, has been expressed on a global scale. This workforce challenge stems from many concerns, from replacing the aging workforce in its existing capacities, to meeting the growth needs of the expanding nuclear community. At present in Russia, coping with the issue of the aging workforce in the nuclear industry will be a challenging task. The average age of the workforce – top and line management in the field – is 55-60 and of specialists is 45 (Efimkova, 2011). This equates to the industry possibly losing up to 40% of its workforce in the next five years. Unfortunately, the demographics in the safeguards community are even more dire, particularly in Russian National research universities like the National Research Nuclear University "MEPhI", TPU, etc.

In order to address the need to both replace the aging safeguards workforce and expand the existing capacity to meet the changing threat environment, it is essential that the community:

- Manage safeguards knowledge;
- Redirect existing nuclear workforce personnel to the safeguards area;
- Educate the next generation of safeguards specialists;
- Increase the knowledge of existing technical disciplines on safeguards issues and core needs; and
- Increase public awareness of safeguards and nonproliferation issues.

The Institute of Physics and Technology at the National Research Tomsk Polytechnic University is addressing many of these concerns.

EDUCATION OUTREACH

IPT has already successfully created a Master of Science degree program "Nuclear Technical Control and Regulation" at TPU that is designed to educate graduate students in the field of international nuclear safeguards and security. This program has been a tremendous success and has already produced young professionals that have gone on to find employment throughout the Russian and Kazakhstan nuclear community. To date two generations of students have graduated, totalling 12 masters degree holders. However, there are many other branches of knowledge that must be involved in safeguards education for it to be effective. While a comprehensive nuclear engineering based safeguards education is the logical first step, all of the other requisite branches of knowledge must be addressed. The most notable specialists from these branches of knowledge that should be involved in safeguards education are:

- Physicists,
- Chemists,
- Statisticians,
- Computer Scientists,
- Political Scientists,
- International Affairs Experts,
- Lawyers,
- Law Enforcement/Security Specialist,
- Nuclear Engineers,
- Mechanical Engineers,
- Electrical Engineers,
- Chemical Engineers,
- Industrial Engineers, and
- Environmental Engineers.

It should be noted that Nuclear Engineering must still be included in this list. While IPT already offers a Master of Science in this area, the majority of students in any nuclear engineering department will still take the typical nuclear engineering course load focusing on commercial nuclear power applications, largely to the exclusion of courses in other disciplines that may be more appropriate to safeguards specialists.

All of the disciplines listed above should be made aware of nuclear safeguards as a profession and employment opportunity and should be apprised of our operating procedures and the importance of safeguards as a field, as the safety culture within nuclear engineering has already accomplished. This is crucial to the realisation of an effective safeguards culture in Russia. The nuclear community as a whole must realise that safeguards is an integral part to ensuring that nuclear power remains available to future generations.

Existing Courses at TPU

Outreach to students outside of IPT program has already begun. As first-year students in the nuclear engineering department, all students are required to take Introduction to Nuclear Engineering. This course provides basic principles of nuclear engineering, including global and national energy requirements, radioactivity, radiation protection, and fission and fusion reactor concepts. It consists of a semester-long series of two academic hours lectures that now includes an introductory segment on safeguards, arms control and non-proliferation. This segment is meant to ensure that as students progress through their undergraduate career at TPU, they are capable of putting all of the knowledge they gain about commercial applications of nuclear engineering within the context of how safeguards may be applied and affect the overall system.

A senior level undergraduate course is also being offered as Nuclear Nonproliferation and Arms Control. The course description is as follows:

> "This course will study the technologies associated with the proliferation of nuclear weapons and the attempts to halt this proliferation. Topics will include the history of nuclear weapons development, descriptions and effects of weapons of mass destruction, nuclear material safeguards, protection of nuclear materials, proliferation resistance, proliferation pathways in the nuclear fuel cycle and nuclear terrorism."

The objectives of this course include Safeguards Systems and Technologies. This course ensures that seniors who elect to enrol will be exposed to safeguards as a field as they are making their decisions concerning future employment or graduate studies. Additionally, this course is much more in depth that the initial introduction they received as first-year students.

Recently Russia has transferred to tertiary level education system of specialists training, and it is envisioned that the existing coursework for undergraduate studies will serve as a first step to the Master of Science degree which is offered by IPT in nuclear safeguards and nonproliferation. Currently, there are sufficient undergraduate students whose specific area of study may not be directly related to nuclear safeguards who recognise safeguards as an exciting field, and have elected to take IPT courses as electives. This alone is a very positive indication for our field.

Future Coursework

TPU already offers a course titled The Design of Nuclear Reactors. The course addresses the application of reactor theory and other engineering disciplines in the fundamental and practical design of nuclear reactor systems for power applications. A short series of lectures is currently being developed that will ideally be introduced to expose these students to existing safeguards systems and safeguards by design for next-generation reactor systems. This will serve to

reinforce safeguards as an integral part of the reactor systems they are studying. Additionally, this will instil a positive safeguards culture in future members of the larger nuclear community.

There is a similar class taught at the educational program of five-year specialists training according to the Russian system of education that will eventually be included as well. The lecture material will be adapted to be applicable to the specific systems being studied.

Nuclear Safeguards Education Introductory Lecture Series (NSEILS)

The piloting of IPT NSEILS took place in 2012 as an effort to provide introductory information to undergraduate students interested in safeguards who study in Kazakhstan universities within active Memorandums of Understanding between TPU and the universities of Kazakhstan within the framework of realisation of the National Research Tomsk Polytechnic University Integrated Program of Strategic Development 2011-2015. IPT launched NSEILS in the spring of 2013 for undergraduate students interested in safeguards who study in TPU and Kazakhstan universities with the purpose of providing effective recruitment to the Master of Science degree "Nuclear Technical Control and Regulation".

These courses are offered to undergraduate students from a wide variety of backgrounds with a varying degree of technical expertise with no working experience. This year, these courses were developed as required modules for students unfamiliar with the technical aspects of safeguards. Students from two countries participated with a large degree of success. The current modules are:

- Basics of Elementary Particles Physics,
- Basics of The Nuclear Fuel Cycle, and
- Basics of Radiation Detection.

All of these modules were specifically designed to provide educational resources for students with an interest in nuclear safeguards and the security of nuclear materials anywhere in the world. All of the current modules will be open and available to anybody regardless of whether or not they are enrolled at TPU.

The goal of NSEILS is to focus primarily on technical education in the area of nuclear safeguards. This will serve to develop individuals with the technical skills needed to help design and implement systems and technologies for securing nuclear materials at commercial nuclear facilities.

All of the modules consist of reading materials, supporting online materials from professors at TPU (located at http://lms.tpu.ru), along with links to additional resources. In the future, all of the modules will also contain self assessments to test the students' understanding of the material. This is ideal for students engaging

in continuing education efforts, students that are off site, etc. However, it is important to point out that this type of education is not suitable for all topics. Certain subjects must be taught in residence at an educational institution.

Basics of Elementary Particles Physics

Prerequisites: Students taking this module should have a working knowledge of basic algebra and geometry, basic physics and chemistry.

Learning Objectives: Students completing this module should be able to describe the structure of the atom, the constituents of the nucleus and different types of radiation. The student should be able to: give definitions of basic nuclear physics terms and units of measure; use a periodic table and chart of the nuclides to identify specific isotopes and elements and their properties; explain the interactions of radiation with matter and the physics of nuclear fission; and complete simple calculations using energy and mass relationships, atomic density, and radioactive decay.

Outline: This module consists of seven sections:

1. Energy and mass relationships,
2. Atomic structure,
3. Periodic table and chart of the nuclides,
4. Nuclear Stability,
5. Fission,
6. Particle and Electromagnetic Radiation, and
7. Radioactivity and Radiation.

Basics of The Nuclear Fuel Cycle

Prerequisites: Students taking this module should have a working knowledge of basic algebra and a basic understanding of physics and chemistry.

Learning Objectives: In this module, students will be introduced to the basic nuclear fuel cycle including the different processes involved and the basic physics of the fundamental components. Students completing this module should be able to describe all of the steps in military and civilian nuclear fuel cycles and be able to perform basic analysis of known fuel cycles. Students should be able to describe how fuel cycle facilities operate and the materials used and produced by those facilities.

Outline: This module consists of four sections:

1. Introduction to the Commercial Nuclear Fuel Cycle
2. The Front End of the Nuclear Fuel Cycle
3. Fuel Irradiation and Fuel Storage
4. The Back End of the Nuclear Fuel Cycle

Basics of Radiation Detection

Prerequisites: Students taking this module should have a working knowledge of basic algebra and know what a neutron and gamma-ray are.

Learning Objectives: Students completing this module should be able to describe the physical mechanisms for detection of gamma and neutron radiation. They should also be able to identify and explain the general operation of gas-filled, scintillation, and semiconductor detectors.

Outline: This module consists of seven sections:

1. Introduction,
2. Counting Statistics,
3. Gas-Filled Detectors,
4. Neutron Detectors,
5. Gamma-Ray Spectroscopy,
6. Semiconductor Detectors, and
7. Detector Lab.

CONCLUSION

The existing M.S. in "Nuclear Technical Control and Regulation" at TPU is creating young professionals ideally suited to become the next generation of safeguards experts, both domestically and internationally. This program is becoming increasingly popular, with student enrolment constantly increasing. Individual courses within this program are also becoming increasingly popular with students not associated with IPT. Additional efforts are being made within IPT TPU to ensure that all graduates of the undergraduate program are aware of safeguards regardless of their future employment goals. This ensures that a positive safeguards culture is encouraged prior to students even entering the work force. Finally, students not associated with TPU and IPT have the opportunity to educate themselves and be introduced to safeguards as a profession and viable career path through NSEILS.

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