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OVERVIEW, OPERATIONAL RESULTS, & OPPORTUNITIES OF THE GRADUATE NUCLEAR SECURITY PROGRAM AT THE KYIV POLYTECHNIC INSTITUTE

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ABSTRACT

To support a global interest in nuclear fuel cycle activities, the International Atomic Energy Agency (IAEA) offers technical guidance documents (e.g., Nuclear Security Series Document No. 12—Education Programme in Nuclear Security) and an international community of practice (e.g., the International Nuclear Security Education Network). These endeavors provide a comprehensive approach—and strong education foundation—for incorporating nuclear security knowledge, skills, and abilities into nuclear energy workforces across the globe. Yet, each nation is responsible for developing programs that build on this foundation to meet their specific educational systems.

One response is the graduate program in nuclear security currently offered at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (KPI) within the "Nuclear Energy" specialty of KPI's Nuclear Power Plants and Engineering Thermal Physics Department. The result of a partnership between the Ministry of Energy Ministry of Energy and the U.S. Department of Energy National Nuclear Security Administration Office of International Nuclear Security (NNSA/INS), this graduate program provides a comprehensive nuclear security education to both traditional and non-traditional students across Ukrainian stakeholders. In addition to the curriculum collaboratively developed between KPI professors and experts from Sandia National Laboratories (Sandia), this nuclear security program leveraged additional resource and expertise support from the Swedish Radiation Safety Authority, Canadian Ministry of Foreign Affairs, and the IAEA. Officially launched in the Fall of 2019, the KPI graduate program in nuclear security leverages a top-of-the-line curriculum and key hands-on experience capabilities (e.g., the George Kuzmich Training Center) to provide an educational capability to meet national and regional nuclear security needs.

After summarizing the collaboration between KPI and NNSA/INS to develop the program's curriculum, structure, and objectives, this paper will describe the various elements supporting this nuclear security education capability. Next, the events—and successes—of its first year of implementation will be described, including accommodations made to meet program objectives during COVID-19 safety protocols. Lastly, the paper will provide several lessons learned from its operational experience to inform other nations embarking on developing nuclear security education programs, and a list of action items to support the KPI program's continued development.

* SAND2021-9614 C. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

INTRODUCTION

To counter the concern to the international community of the possibility of sabotage of nuclear facilities and other radiation-hazardous activities—which could result in the release of large quantities of radioactive materials and expose personnel, the public, and the environment—global capabilities in nuclear security should be increased. Combined the growing interest in nuclear fuel cycle activities, various approaches for meeting this need are underway. For example, the International Atomic Energy Agency (IAEA) offers technical guidance documents (e.g., Nuclear Security Series Document No. 12—Education Programme in Nuclear Security [1]) and an international community of practice (e.g., the International Nuclear Security Education Network). These endeavors provide a comprehensive approach—and strong education foundation—for incorporating nuclear security knowledge, skills, and abilities into nuclear energy workforces across the globe. Yet, each nation is responsible for developing programs that build on this foundation to meet their specific educational systems.

Considering these challenges, provision of education, retraining and advanced training of personnel in the field of nuclear security is of fundamental importance for Ukraine. While developing new nuclear security professionals is the responsibility of each nation, Ukraine has several *unique* and *significant* characteristics driving its need to develop and deploy a robust nuclear security education option, including:

- Educating Physical Protection, Accounting and Control of Nuclear Materials specialists was *previously* done at Sevastopol National University of Nuclear Energy and Industry—which is located in the Crimea region and not currently available to Ukraine;

- Ukraine has recently experienced terrorism operations, resulting in significant amounts of uncontrolled armament in/through the country;

- Ukraine has 15 nuclear power reactors, 1 research reactor, and spent fuel from 13 VVER-1000 reactors stored on its territory;

- There is damaged unit #4 of the Chernobyl Nuclear Power Plant (NPP), with spent fuel of Units 1, 2, 3, and 4 and tremendous amounts of other radioactive wastes from the accident stored in the northern part of the country;

- Radioactive Ionizing Sources are widely used in the industry, medicine, geology and scientific researches that produce significant amount of radioactive wastes too;

- Territory of the Ukraine is used for transportation of radioactive materials, including transit of both fresh and spent nuclear fuel; and,

- Other universities did not provide the education of the experts in area of nuclear security.

To address this need, the Ukrainian Ministry of Energy Ministry of Energy and the U.S. Department of Energy National Nuclear Security Administration Office of International Nuclear Security (NNSA/INS) partnered to develop a graduate nuclear security program within the

"Nuclear Energy" specialty of the Nuclear Power Plants and Engineering Thermal Physics Department at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (KPI). This partnership leveraged that IAEA's NSS-12 as a technical guidance document to facilitate development and implementation of this program. While this best international guidance establishes a strong foundation for creating an educational capability in nuclear security, Ukraine still needed craft an educational program that met their specific needs and aligned with their national educational system. After summarizing the collaboration between KPI and NNSA/INS to develop the program's curriculum, structure, and objectives, this paper will describe the various elements supporting this nuclear security education capability. Next, the events—and successes—of its first year of implementation will be described, including accommodations made to meet program objectives during COVID-19 safety protocols. Lastly, the paper will provide several lessons learned from its operational experience to inform other nations embarking on developing nuclear security education programs, and a list of action items to support the KPI program's continued development.

KPI's NUCLEAR SECURITY GRADUATE PROGRAM DEVELOPMENT[1]

Estimates indicate that the total number of nuclear security specialists under the responsibility of the Ministry of Energy and Coal Industry of Ukraine is more than 1200 people. This suggests that the annual need for nuclear security specialists—particularly those from higher educational institutions—averages approximately 20-30 people. Based on these parameters, Ukrainian and U.S. security and curriculum development experts collaborated to develop a graduate nuclear security program at KPI.

After a stakeholder coordination meeting between representatives of the NNEG "Energoatom", Ministry of Energy and Coal Industry of Ukraine, State Nuclear Regulatory Inspectorate of Ukraine, Institute for Nuclear Research of National Academy of Sciences of Ukraine and KPI, a preliminary list of courses to be developed was identified and specific KPI professors were selected to help develop this program. The next step involved a "train the trainer" approach to building expertise and experience on these course topics in the KPI professors. Under the guidance of NNSA/INS, a nuclear security education technical tour was led by experts from Sandia National Laboratories (Sandia)—included collaboration with the Center for Nuclear Security Science and Policy (NSSPI) at Texas A&M University (TAMU)—in the summer of 2016.

Correspondence continued after this technical tour, and primarily consisted of electronic coordination to support a Sandia subject matter expert review of curriculum materials and responses to professor questions. In addition, there were several in-person meetings in Kyiv to assess program development in more detail:

- **Spring 2017:** Preliminary program structure development
- **Summer 2018:** Preliminary course curriculum review & program development/approval planning

[1] More details can be found in [2].

- **Summer 2019:** Post course development, detailed curriculum review

This in-person meetings also included site visits to the campuses of both KPI and the George Kuzmycz Training Center for Physical Protection, Control and Accounting of Nuclear Material (GKTC) to tour several of the hands-on facilities intended to be used to support the nuclear security program.

In addition to the curriculum collaboratively developed between KPI professors and Sandia experts, this nuclear security program leveraged additional resource and expertise support from the Swedish Radiation Safety Authority, Canadian Ministry of Foreign Affairs, and the IAEA. The Swedes supported the renovation of two rooms for laboratories; the Canadians purchased equipment and software for the first laboratory; and, the IAEA purchased equipment and software for the second laboratory. Throughout development of the KPI nuclear security program, information in the curriculum was continuously benchmarked against relevant IAEA Nuclear Security Series Documents.

The resulting structure of the KPI program (illustrated in Figure 1, below) was designed to properly situate this graduate nuclear security education program within the higher education constraints, requirements, and approvals in Ukraine. Since KPI has a license to conduct educational activities that culminate in the "Nuclear Energy" specialty, additional permits from the Ministry of Education and Science of Ukraine were not required. Yet, Ukrainian legislation deemed it necessary to obtain a license from State Nuclear Regulatory Inspectorate for the nuclear security program. Leveraging insights and decisions from the three in-person meetings, KPI's application was well-received and the president of Ukraine's State Nuclear Regulatory Inspectorate officially handed over the license to university representatives in Fall 2019.

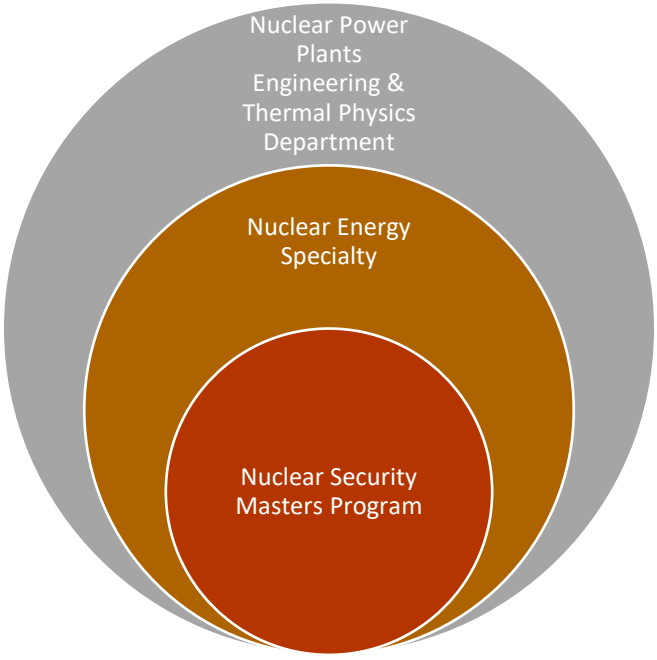

Figure 1. Illustration of the Nuclear Security Masters Program within the KPI educational structure

Designing the specific course curriculum for this masters program was guided by Ukrainian higher education requirements, which required this nuclear security specialization to consist of 90 credits. Program development discussions within the joint Ukrainian and U.S. team yielded the decision to design this masters program to be completed over two academic years. To meet these requirements, the program developed into a total of 15 nuclear security courses, summarized in Figure 2, that consists of one foundational course (#1), eight core course (#2-#9), and six elective courses (#10-#15). These courses span a full range of hard and soft science academic disciplines related to nuclear security. The courses themselves are composed of a mix of instructional approaches (e.g., lecture-based, seminar-based, and experiment-based courses) and incorporate a full range of student assessment tools (e.g., homework, quizzes, term papers, exams).

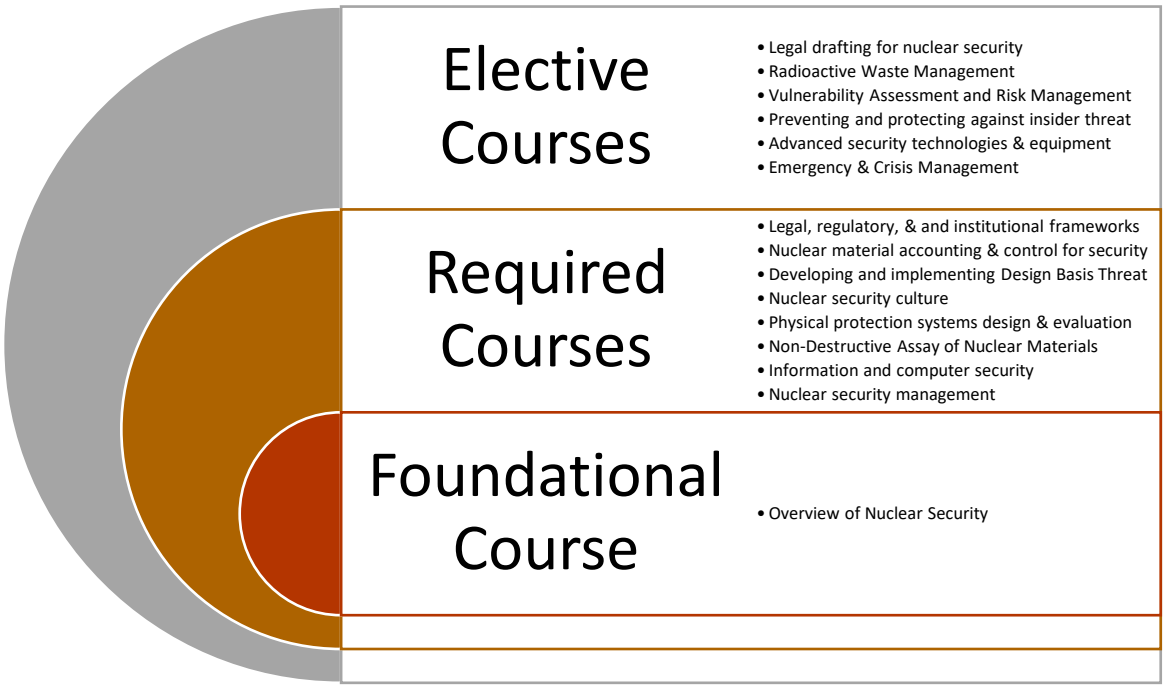

Figure 1. Course structure & summary for KPI's Nuclear Security Masters Program

The foundational course, "Overview of nuclear security," is the only course in the program offered to be taken at the bachelor's level at KPI. This decision was aimed at ensuring that all students studying at the Department of Nuclear Power Plants Engineering and Thermal Physics at KPI were acquainted with the basics of nuclear security. The important of nuclear security and the desire from Ukrainian stakeholders to get the topics introduced the students at the earliest opportunity (and avoiding the bureaucratic difficulty of changing current educational processes), this "Overview of nuclear security" was included as a separate module of 4 lectures in the existing Nuclear Safety Culture course in the 2017/2018 academic year. Beginning in the 2018/2019 academic year, however, the "Overview of nuclear security" course was offered to all students studying at the department.

The introduction to nuclear security offered by the overview course helped enable students to make informed choices about enrolling in the new Nuclear Security Masters program. In parallel,

various Ukrainian stakeholders conducted a wide-ranging advertising campaign for the new program. In addition the novel curriculum, the advertised benefits of KPI's Nuclear Security Masters program included its proximity and collaborative relationships with such modern laboratory facilities in Kyiv as GKTC and the VVR-M research reactor at the Institute for Nuclear Research of National Academy of Sciences of Ukraine. The result of this summer introductory campaign was the enrollment included both full-time and part-time students—demonstrating that the KPI nuclear security program meets the target populations. Officially launched in the Fall of 2019 with an opening ceremony attended by dignitaries from both Ukrainian and U.S. collaborating partners, the KPI graduate program in nuclear security leverages a top-of-the-line curriculum and key hands-on experience capabilities to provide an educational capability to meet national and regional nuclear security needs.

EARLY YEARS OPERATIONS & SUCCESS

The inaugural cohort of KPI's Nuclear Security Program included 9 traditional, full-time students and 29 non-traditional, part-time students and began their program in September 2019. The second program cohort began in September 2020 and included 7 traditional, full-time students and 19 non-traditional, part-time students (Table 1). Here, traditional students generally consisted of younger individuals, many of whom entered directly out of their undergraduate programs at KPI. Non-traditional students tended to consist of slightly older, more experienced individuals with some relevant professional or practical experiences. This mix of students greatly enhanced the classroom experience and quality of this program, as the traditional students tended to bring fresher, more "out of the box" thinking to course discussions, while the non-traditional students tended to bring more practical, real-world world problems and anecdotes. This mixture of students and perspectives enhanced overall classroom discussions and knowledge transfer.

Table 1. KPI Nuclear Security Masters Program cohort summary.

Cohort #	Academic Program Years	# Traditional Students	# Non- Traditional Students
1	2019-2020	9	29
2	2020-2021	7	19

As previously described, 15 total courses were developed to support this graduate program. Of these 15 courses, only the "Overview of nuclear security" course is offered every semester. The program them distributes core and elective courses between four total semesters—Fall 2019, Spring 2020, Fall 2020, and Spring 2021 for the first cohort, for example—to balance the workload for students and professors. Earning the KPI masters distinction requires enrolling in and satisfactorily meeting the requirements for all core courses and a subset of the elective courses. To help facilitate the desired two-year timeline for traditional students, all core courses are offered at least once per academic year, with many of the elective courses also being offered once per year. Table 2 summarizes the frequency and timing of course offerings for KPI's first two cohorts of students in the nuclear security program.

Table 2. Semester-based summary of KPI's Nuclear Security Masters program

Course Title	Fall 2019	Spring 2020*	Fall 2020**	Spring 2021**
Overview of nuclear security	X	X	X	X
International/national legal, regulatory and institutional framework for nuclear security	X		X	
Use of nuclear material accounting and control for nuclear security		X	X	
Developing and implementing Design Basis Threat	X		X	
Nuclear security culture		X	X	
Physical protection systems design and evaluation	X		X	
Non-Destructive Assay of Nuclear Materials	X			X
Information and computer security		X		X
Nuclear security management at national and facility level		X	X	
Legal drafting for nuclear security				
System of Radioactive Waste Management	X			X
Nuclear Facility Vulnerability Assessment and Risk Management		X		X
Preventing and protecting against insider threat	X			
Physical protection technologies and equipment		X		X
Management of Emergency and Crisis Situations at Nuclear Facilities				X
**Semester when courses switched from in-person to virtual, due to COVID-19 mitigations* ***Semesters where courses offered only in virtual format, due to COVID-19 mitigations*				

Performance assessments highlight both the high quality of the developed education program in nuclear security and the hard work of current program students. As summarized in Table 3, both traditional and non-traditional students in both cohorts are earning above satisfactory grades for a majority of their courses. This allowed traditional students in the first cohort to receive their graduate credential in February 2021. While, on average, non-traditional students take between 4 and 6 courses per semester, many of them are already more than 30% toward completing the requirements for earning the KPI nuclear security masters designation.

Table 3. Cohort-based summary of average grades & KPI Nuclear Security Masters Program completion

Cohort #	Student Type	Course Grade Average [%]	% Program Completed
1	Traditional	85	100
	Non-Traditional	90	100
2	Traditional	83	86
	Non-Traditional	92	100

Overall, students in the first two cohorts of KPI's nuclear security masters program are complimentary of the course materials and instructors. In response to generic surveys provided to

program participants, over 90% of cohorts 1 and 2 found utility in the program's curriculum. More specifically, 34% of participating graduate students found the knowledge they gained to be *useful*, whereas 61% of participating graduate students found the knowledge gained in the program courses to be *very useful.* Student feedback also described additional benefits of the program, including:

- *All teachers who taught were competent in matters of their discipline*
- *Courses about PPS are really useful for our specialty*
- *All at the highest level*
- *Immediately after graduating, I got a job at the nuclear regulator in the nuclear security department.*

Other student feedback provided insights into next steps that can be taken to improve the program, including:

- There needs to be more consistency between teachers (e.g., common terminology across subjects, the use of regulations more suitable for Ukraine)
- There are few practical classes
- Non-destructive NM analysis is a bit of a strange discipline. Additional knowledge is needed to properly understand the subject
- Under conditions of quarantine, [the PPS course] is a dry theory without practice, which, if you wish, you can read it yourself...I would like to do something in reality, see, design, etc.
- It would be useful to practice open lessons where to invite practitioners

Note: The authors would like to acknowledge the efforts put forth by the KPI professors in this nuclear security program to pivot from in-classroom to virtual instruction. As was experienced by all instructors around the world, completing the quick transition to online education was a significant undertaking and the KPI professors were able to do so successfully. Though several of the areas of improvement gleaned from student comments directly stem from the mandates for online instruction, the high levels of performance demonstrated by the students in the program's first two cohorts speak to the high-caliber knowledge transfer completed by the KPI professors.

LESSONS LEARNED & IMPLICATIONS

The success of KPI's nuclear security masters program is a result of leveraging international best practices and collaboration between KPI, Sandia, and NNSA/INS to successfully build the foundation for strong graduate-level education program that transfers knowledge to meet state-level needs and mitigate implementation complexities in nuclear security. To date, the KPI nuclear security masters program has not only served nearly 70 students in its first two years, it

also successfully prepared a cadre of academic faculty dedicated to meeting Ukraine's nuclear security education goals. Coming off the February 2021 celebration of its first cohort of graduates, KPI will continue to leverage its collaborative relationships to sustain—and advance—the capability of its program and faculty. Specific next steps include (but are not limited to) developing new courses to strengthen the program, continue to improve professors knowledge (and expertise) in nuclear security, and create an English version of the current KPKI curriculum.

Over the two years of its operation, the KPI program has matured in response to various lessons learned through implementation. While some generic lessons are shared in [2], additional lessons learned in the early years of this program include, but are not limited to:

- Create more uniformity in nuclear security-related terminology, ensuring alignment with Ukrainian context and consistency between courses/instructors;

- Continue the in-course practice of using different hypothetical facilities in teaching, both within the same course and across different courses; and,

- Conduct more practical classes (admittedly difficult under current COVID-19 protocols).

KPI's nuclear security masters program's success helps make it a resource for technical universities in other countries interested in developing graduate curriculum in nuclear security. Though still early in its lifespan, KPI's nuclear security masters program is oriented to continuously meet the security needs of Ukraine's various nuclear stakeholders and to serve as a model program for emulation by other states. With its early success, this new KPI masters program can help increase the Ukrainian voice in the international discourse on nuclear security.

REFERENCES

[1] International Atomic Energy Agency, "Educational Programme in Nuclear Security", IAEA Nuclear Security Series No. 12, Vienna, Austria, 2010.

[2] T. Bibik and A.D. Williams, "Lessons Learned from Developing the Graduate Nuclear Security Curriculum at the Kyiv Polytechnic Institute Primary," IAEA International Conference on Nuclear Security (CN-278-536), Vienna, Austria, 2019.