ADVANCED NUCLEAR 3S EDUCATION AND TRAINING IN CYBER-PHYSICAL SPACE (ANSET-CP) IN TOKYO TECH

Yoshihisa MATSUMOTO, Hiroshi SAGARA, Chi Young HAN, Noriyosu HAYASHIZAKI, Takehiko TSUKAHARA, Masako IKEGAMI, Tatsuya KATABUCHI, Hiroshige KIKURA, Koichiro TAKAO, Hiroki TAKASU, Katsumi YOSHIDA and Satoshi MATSUURA

Tokyo Institute of Technology, Tokyo, Japan

ABSTRACT

Tokyo Institute of Technology (Tokyo Tech) has newly developed the Advanced Nuclear 3S (Safety, Security, and Safeguards) Education and Training in Cyber-Physical space (ANSET-CP) program in 2022, by expanding the already established university 3S education curriculum both with the practical hands-on training of nuclear material and radioactive isotopes destructive assay, and the cyber-incident response training for nuclear facility security. The ANSET-CP program provides students with 3S Lectures, 3S Exercises, 3S Internships and 3S Research Projects, to cultivated them in professionalism, insight and leadership, and practical skills. The curriculum is systemized to organically integrate nexus among 3S, and provide more practical hands-on exercises to build response capacity to social needs. This program is financially supported by the Nuclear Regulation Authority (NRA) Japan.

1. INTRODUCTION

Tokyo Tech has started the nuclear science and engineering since 1957 at by the establishing the department of Nuclear Engineering as the graduate major, it was one of the earliest universities in Japan. For more than 66 years, Tokyo Tech has kept the front runner in both research and education in nuclear field [1].

Nuclear Safety and Security education program was initiated in Tokyo Tech, in 2011, with the Global Nuclear Safety and Security Dojo Program, a specially designed curriculum from multiple disciplines for selected graduate students in nuclear engineering. In 2017, Tokyo Tech established the Advanced Nuclear 3S Education and Training (ANSET) program, in nuclear safety, security, and safeguards, and can take the lead in 3S-related decision-making supported by the NRA Japan[2-5]. This program was targeted at not only students specialized in nuclear engineering, but also students in other fields including part-time students, and open to young professionals as well. In 5 years program, the total 559 students had taken courses and 32 students had completed the curriculum. In 2022, Tokyo Tech has developed the ANSET-CP program, by expanding the already established university 3S education curriculum both with the practical hands-on training of nuclear material and radioactive isotopes destructive assay, and the cyber-incident response training for nuclear facility security[5].

The objectives of the present paper are to introduce the newly developed ANSET-CP program and to share the challenges and best practices of 3S education.

2. THE CURRICULUM OF ANSET-CP

The ANSET-CP program provides students with 3S Lectures, 3S Exercises, 3S Internships and 3S Research Projects, to cultivated them in 3S professionalism, insight and leadership, and

practical skills. The curriculum is systemized to organically integrate nexus among 3S, and provide more practical hands-on exercises to build response capacity to social needs.

Figure 1 shows an overview of the program. The curriculum is systemized to organically integrate nexus among 3Ss, and provide more practical hands-on exercises to build response capacity to social needs of nuclear security.

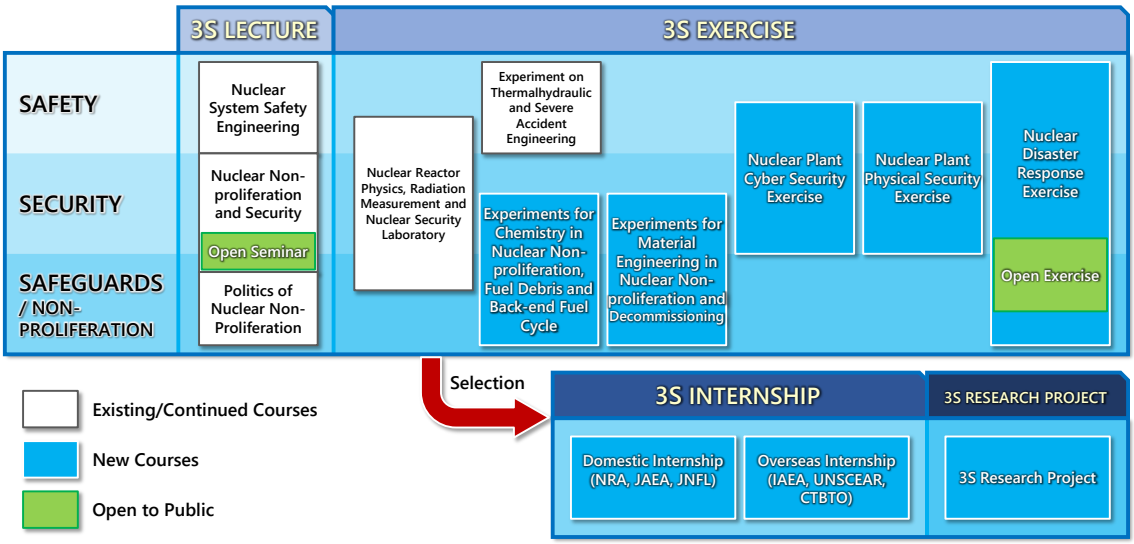

Figure 1. Overview of the ANSET-CP Program

(1) 3S LECURES

The following three lectures relating to 3Ss are already developed and opened in Tokyo Tech;

- **Nuclear System Safety Engineering**

This course offers the fundamentals of nuclear reactor systems and its system safety. Safety engineering is discussed with system safety, deterministic safety and probabilistic risk analysis, touching on the historical accidents of nuclear power plant and fuel cycle facilities.

- **Nuclear Non-proliferation and Security**

This course offers the fundamentals of nuclear non-proliferation and security. A comprehensive view is presented of history and legal framework, science and technology, proliferation resistance and physical protection, and human factors and security culture. The nuclear security part of the lecture will be opened to the outside university students as the Nuclear Security School of Tokyo Tech in year 2023 and 2025 hosted by ANSET-CP program.

- **Science, Technology and Innovation Policy Analysis I：The Politics of Nuclear Non-Proliferation**

This course will give students an understanding of weapons of mass destruction and the global efforts to control their spread and reduce their dangers, by covering policy tools from treaties and diplomacy to sanctions and war.

(2) 3S EXERCISES

We have established the following 6 exercises including 5 newly developed exercises;

- **Experiments for Chemistry in Nuclear Non-proliferation, Fuel Debris and Back-end Fuel Cycle (*NEW!*)**

This course offers students to study the various chemical analysis operations, which are required for the treatment of nuclear material for nuclear safeguards and security with destructive assays, nuclear debris and nuclear liquid and solid waste matrix generated from the nuclear severe accidents.

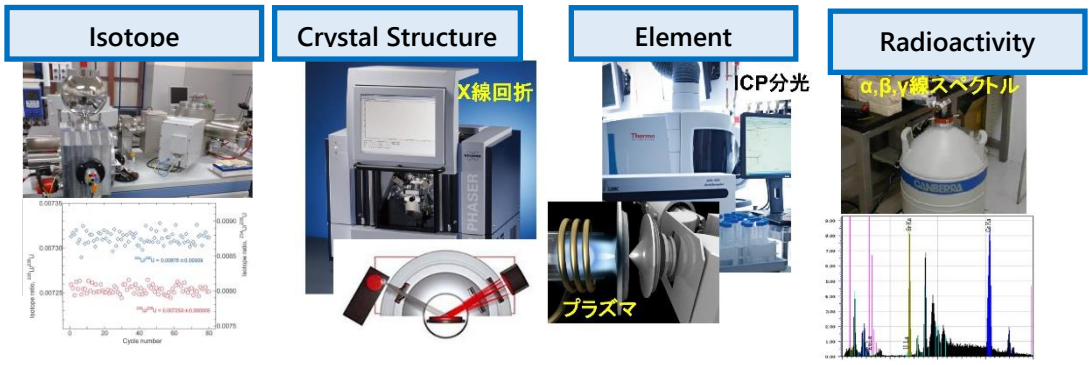

Figure 2. Fundamental Chemical Analysis Experiments for Nuclear Security and Safeguards

- **Experiments for Material Engineering in Nuclear Non-proliferation and Decommissioning (*NEW!*)**

Students learn the basic principles of physical properties evaluation for solid materials required to nuclear forensics for nuclear security and to decommissioning of nuclear reactors using the text as well as to. Students also learn fundamentals of handling non-sealed radioisotopes, contamination tests and decontamination, exposure prevention of exposure etc.

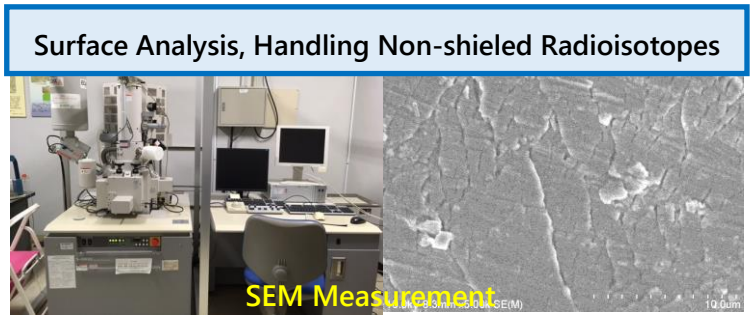

Figure 3. Fundamental Material Analysis Experiments for Nuclear Security

- **Nuclear Plant Cyber Security Exercise (*NEW!*)**

This course offers students to study the fundamentals of cyber security, its impact to the nuclear power plant safety, and its management & control practically with table-top exercises and nuclear power plant operator training simulator provided by Mitsubishi Heavy Industries (MHI).

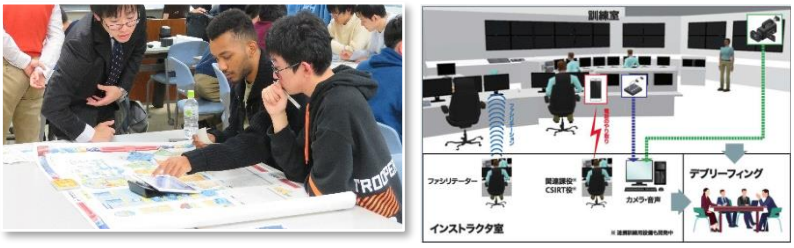

Figure 4. Nuclear Power Plant Cyber Security Exercise at MHI (Left: Table Top Exercise, Right: Practical Exercise with Nuclear Power Plant Operation Training Simulator)

- **Nuclear Plant Physical Security Exercise (*NEW!*)**

This course offers students to study the fundamentals of physical protection system design and the impact of radioactive material release by numerical simulation of hyper-velocity projectile or shock-wave impact to the structure material, and local dispersion of radioactive material.

Figure 5. Nuclear Plant Physical Security Exercise (Left 2 figs: Hydro-dynamics Simulation Results of Experiment [7] and Simulation, Right 2 figs: Scenery of Exercise by Numerical Simulation)

- **Nuclear Disaster Response Exercise (*NEW!*)**

This course offers students to study the detection and retrieval of nuclear and radioactive materials in hypothetical radiation disasters by gamma-ray and neutron measurement emitted by sealed sources as well as huge source by Pelletron accelerator. Hypothetical nuclear disaster response is also trained with field work by using virtual radioactive source and detectors with application working on smart phones. Environmental dynamics simulation is also used to study on preparedness to the large-scale nuclear disaster. A part of the lecture will be opened to the outside university students in year 2024 and 2027 hosted by ANSET-CP program.

Figure 6. Nuclear Disaster Response Exercise (Left: Hypothetical nuclear disaster response, Center: Detection and Retrieval of Sealed Radioactive Materials, Right: Pelletron Accelerator in Tokyo Tech)

- **Nuclear Reactor Physics, Radiation Measurement and Nuclear Security Laboratory**

This course offers students 3 elements; reactor physics experiments, radiation measurement experiments and nuclear security experiments. As for nuclear security experiments, operating principles of uranium enrichment measurement by gamma-ray spectrometry and its application to nuclear security and safeguards are treated.

- **Experiment on Thermalhydraulic and Severe Accident Engineering**

Concerning Thermalhydraulic measurements using ultrasonic waves, after learning measurement principles and techniques, students will learn measurement skills through experiments. Students will learn the basics of robot control, and through transport experiments for robots designed for reactor measurements done after a severe accident, they will acquire basic skills as a robot engineer.

(3) INTERNSHIPS

The internship courses are to deepen understanding of the 3S expertise, insight, and leadership learned from 3S Lectures and Exercises, and promote practical skills through working experiences in 3S fields at NRA Japan, Students receive a full financial support from the ANSET-CP program.

- **Domestic Internship**

The destination of domestic internship includes NRA Japan, the Japan Atomic Energy Agency (JAEA), and the Japan Nuclear Fuel Limited (JNFL). Students experience domestic nuclear safeguards at NRA Japan, nuclear safeguards and security at Uranium Enrichment Plant and Reprocessing Plant of JNFL, at Plutonium Fuel Production Facility, TRP Decommissioning Center, and Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN) of JAEA. Student also have chance to visit the Nuclear Material Control Center for domestic nuclear safeguards.

- **International Internship**

The destination of overseas internship includes the International Atomic Energy Agency (IAEA), the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Two to three selected students participate in the international internship for 3 – 6 months every year. Tokyo Tech have made the agreement on the internship between IAEA in 2020, and this frame work enhanced the internship procedure much effectively. Due to the successful experience for both sides, the agreement will be renewed in May 2023 to change the three-year duration period to indefinite for more stable and long-term intern sending.

Figure 6. International internship (Left: at IAEA, Right: at UNSCEAR [8])

(4) 3S RESEARCH PROJECT

This project offers students to promote the individual research project to deepen expertise through 3S relating research activities, by supporting students' research planning, achievement, and publications financially.

CONCLUSIONS

The newly developed ANSET-CP program in Tokyo Tech was introduced and its challenges and best practices of 3S education were shared and discussed. Since the program has just started in 2022 for 5 years, updated results will continue to be reported in future.

ACKNOWLDEGEMENT

This program is supported by the NRA Japan.

REFERENCES

1. Nuclear Engineering Major, Tokyo Tech official website at http://www.ne.titech.ac.jp/en/index.html
2. Hiroshi Sagara, "Advanced Nuclear 3S Education and Training – Overview and Curriculum," International Nuclear Security Education Network (INSEN) 2018 Annual Meeting, July 9-13, Vienna International Center (2018).
3. Chi Young HAN, Shuichiro EBATA, Hiroshi SAGARA, Satoshi CHIBA, Yoshihisa MATSUMOTO, Noriyosu HAYASHIZAKI, Masako IKEGAMI, Akira OMOTO, Kenji TAKESHITA, Tatsuya KATABUCHI, Hiroshige KIKURA, and Koichiro TAKAO, "THE ADVANCED NUCLEAR 3S EDUCATION AND TRAINING (ANSET) PROGRAM OF TOKYO TECH," Proceedings of the INMM 61st Annual Meeting, July 12-16, 2020.
4. Hiroshi SAGARA, Chi Young HAN, Satoshi CHIBA, Yoshihisa MATSUMOTO, Noriyosu HAYASHIZAKI, Masako IKEGAMI, Akira OMOTO, Kenji TAKESHITA, Tatsuya KATABUCHI, Hiroshige KIKURA, and Koichiro TAKAO, "THE ADVANCED NUCLEAR 3S EDUCATION AND TRAINING (ANSET) PROGRAM OF TOKYO TECH: (1) OVERVIEW OF YEAR 5," Proceedings of the INMM & ESARDA joint Annual Meeting, August 2021.
5. Chi Young HAN, Hiroshi SAGARA, Tatsuya KATABUCHI, Hiroshige KIKURA, Yoshihisa MATSUMOTO, Kenji TAKESHITA, and Koichiro TAKAO, and Satoshi CHIBA, "THE ADVANCED NUCLEAR 3S EDUCATION AND TRAINING (ANSET) PROGRAM OF TOKYO TECH: (2) 3S EXERCISES." Proceedings of the INMM & ESARDA joint Annual Meeting, August 2021.
6. ANSET-CP official website at http://www.zc.iir.titech.ac.jp/anset-cp/jp/
7. M. Katayama, S. Kibe and S. Toda, "A NUMERICAL SIMULATION METHOD AND ITS VALIDATION FOR DEBRIS IMPACT AGAINST THE WHIPPLE BUMPER SHIELD," International Journal of Impact Engineering, Vol. 17, pp.465-476, (1995).
8. UNSCEAR internship site at https://www.unscear.org/unscear/en/about-us/internships.html