THE ADVANCED NUCLEAR 3S EDUCATION AND TRAINING (ANSET) PROGRAM OF TOKYO TECH: (2) 3S EXERCISES

Chi Young HAN, Hiroshi SAGARA, Tatsuya KATABUCHI, Hiroshige KIKURA, Yoshihisa MATSUMOTO, Kenji TAKESHITA, and Koichiro TAKAO, and Satoshi CHIBA

Tokyo Institute of Technology, Tokyo, Japan

ABSTRACT

Tokyo Institute of Technology (Tokyo Tech) has established the Advanced Nuclear 3S (Safety, Security, and Safeguards) Education and Training (ANSET) program in 2017. The ANSET program provides students with an advanced 3S curriculum (3S Lectures, 3S Exercises, and 3S Internships), which educates them in 3S expertise, insight and leadership, and practical skills. This paper introduces four exercise courses of the program. “Nuclear Non-proliferation and Security Exercise” course is designed to deepen the understanding of important physics and technology in nuclear non-proliferation and security. Students perform uranium enrichment determination using non-destructive assay, numerical simulations of shock wave impact on structural materials, and physical protection exercises and studies at an exercise field and nuclear facilities. “Environmental Dynamics of Radioactive Material” course is intended to have students build an emergency response capability to nuclear and radiological disaster such as nuclear accidents or nuclear terrorism. It offers an intense immersive experience that includes simulation, analysis, and evaluation of the atmospheric dispersion of radioactive materials. “Radiation Disaster Response Exercise” course aims to have students build an emergency response and crisis management capability, teamwork, and communication skills needed to adequately respond to radiation disasters caused by nuclear security events. It provides an intense immersive experience that includes planning and implementing detection, verification, and retrieval of unknown nuclear and radioactive materials as a radiological emergency response assuming hypothetical nuclear security events. This course includes gamma-ray source identification, neutron source detection, uranium enrichment determination, and radiological emergency response. “Nuclear Disaster Response Exercise” course is designed to help students understand the progress of nuclear accidents in nuclear power plants through practicing simulation of transient events, design-basis accidents, and severe accidents using a nuclear power plant simulator and find lessons from the Fukushima nuclear power plant accident on nuclear security. It aims to cultivate a comprehensive thinking ability so as to respond to beyond-design-basis accidents in both viewpoints of nuclear safety and security.

INTRODUCTION

In 2017, Tokyo Tech has established the Advanced Nuclear 3S (Safety, Security, and Safeguards) Education and Training (ANSET) program [1], supported by the Nuclear Regulation Authority (NRA) of Japan. The ANSET program aims to foster the next generation of leaders who have an expertise in nuclear safety, security, and safeguards, and can take the lead in 3S-related decision-making. This program is 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. Building on Tokyo Tech’s nuclear engineering program, the ANSET program provides students with an advanced 3S curriculum (3S Lectures, 3S Exercises, and 3S Internships), which educates them in 3S expertise, insight and leadership, and practical skills. **Figure 1** shows an overview of the program. The curriculum is systemized to organically integrate nexus among 3S, and provide more practical hands-on exercises to build response capacity to social needs of nuclear security. This paper describes the objectives and outline of the four exercise courses in the ANSET program.

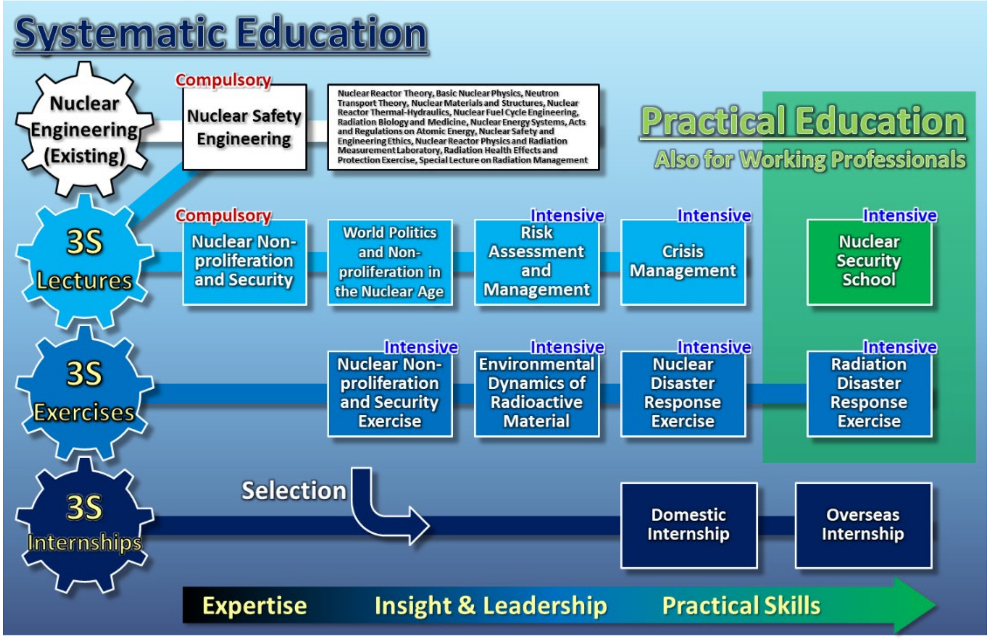

Figure 1. Overview of the ANSET Program

NUCLEAR NON-PROLIFERATION AND SECURITY EXERCISE

This course is designed to deepen the understanding of important physics and technology in nuclear non-proliferation and security. Students perform uranium enrichment determination using non-destructive assay, numerical simulations of shock wave impact on structural materials, and physical protection exercises and studies at an exercise field and nuclear facilities.

Uranium enrichment is a sensitive technology in relation to preventing nuclear proliferation and under international control as a non-proliferation measure. In the uranium enrichment determination (**Figure 2**), students understand the principles of the determination method and the basic techniques used for measuring gamma rays. They measure gamma-ray spectra from a reference uranium sample and subsequently blind uranium samples of different enrichment levels (low and high) using handheld NaI(Tl) scintillation detectors. They determine the uranium enrichment by comparatively calculating the intensity of the 186 keV gamma ray from U-235 and have a discussion on the measurement errors including sample form and size.

After the Fukushima nuclear power plant accident in 2011, the new nuclear regulatory body of Japan, the Nuclear Regulation Authority (NRA) requires additional countermeasures against malicious airplane crash on nuclear power plants as well as enhanced countermeasures for severe accident response. In the numerical simulations of shock wave propagation in structural materials (**Figure 3**), students learn the physical mechanism of structural material damage using the ANSYS Autodyn software. Various case studies are assigned for students to model 3D targets, projectiles, and wave patterns including chemical explosives and simulate the impacts of shock waves on structural materials. Physical properties such as kinetic and explosive energy are discussed to understand shock wave behavior and related structural damage.

Students perform physical protection exercises (**Figure 4**) at the physical protection exercise field [2] of the Japan Atomic Energy Agency (JAEA), equipped with a central alarm station, fences, intrusion detection cameras and sensors, access control systems, contraband detection devices, etc. They experience the physical protection functions (detection, delay, and response) and discuss vulnerabilities and effective physical protection. They also have discussions on insider threat and nuclear security culture. Lastly, students visit the reprocessing and fuel fabrication facilities of JAEA and discuss applied safeguards and security measures with actual practitioners and facility operators.

Figure 2. Uranium Enrichment Determination

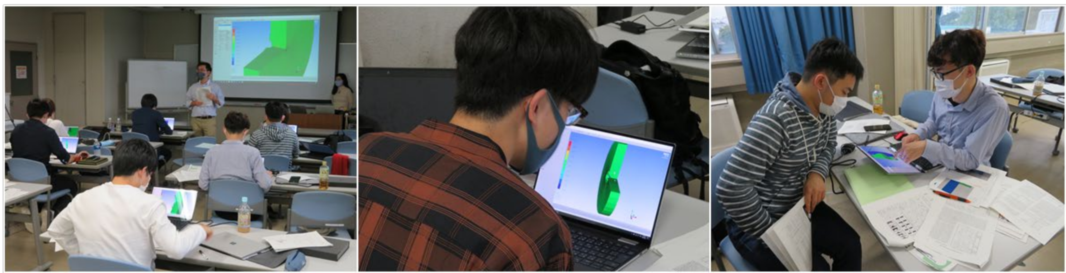

Figure 3. Numerical Simulations of Shock Wave Impact on Structural Materials

Figure 4. Physical Protection Exercises (A Photo Courtesy of JAEA ISCN [2])

ENVIRONMENTAL DYNAMICS OF RADIOACTIVE MATERIAL

This course is intended to have students build an emergency response capability to nuclear and radiological disaster such as nuclear accidents or nuclear terrorism. It offers an intense immersive experience that includes simulation, analysis, and evaluation of the atmospheric dispersion of radioactive materials.

The class lectures deal with radioactive source terms, atmospheric dispersion models, biological effects of radiation, decontamination, and nuclear and radiological disaster response, especially focusing on the Fukushima nuclear power plant accident. The exercises include (1) the small-scale atmospheric dispersion of radioactive materials from nuclear security incidents such as sabotage and radiological dispersal device (RDD) use; calculations using a plume model and a fast field-portable code for emergency response, and (2) the large-scale atmospheric dispersion of radioactive materials from nuclear power plant accidents; simulations using a system for prediction of environmental dispersion.

In the exercise of small-scale atmospheric dispersion (**Figure 5**), students understand the general characteristics of the Gaussian plume model for atmospheric dispersion of radioactive materials. For a better understanding of plume behavior, assuming a hypothetical terrorism scenario involving an RDD, they calculate the atmospheric dispersion using the plume model on an excel spreadsheet and visualize how the plume changes as the result of modifications in atmospheric stability. Students also learn how to use the HotSpot code for emergency response to incidents involving radioactive materials and calculate atmospheric dispersion for various examples of general plume, explosion, and fire. They compare the spreadsheet and HotSpot calculations for the hypothetical terrorism scenario and discuss adequate protection and evacuation of the nearby residents.

In the exercise of large-scale atmospheric dispersion (**Figure 6**), students first understand the formation process of contaminated areas by the Fukushima nuclear power plant accident from measurement and simulation data. They learn how to use the WSPEEDI-II code [3] for prediction of the environmental dispersion of radioactive materials and the public exposure. Assuming a hypothetical nuclear accident at the Fukushima nuclear power plant, different weather conditions are assigned to each student, who performs two simulations of a reference and his or her own scenarios and compares both simulation results in dispersion, deposition, and exposure. The reference scenario is based on the weather conditions at the time of the Fukushima nuclear power plant accident, and the course provides students with a case that has different weather conditions than were present at the accident in 2011. This case is based on wind fields and rainfall events, because atmospheric dispersion strongly depends on wind fields, and rainfall events considerably influence their depositions on the surface. The scenarios include typhoons passing through Japan and the rainy season of Japan with a typical weather pattern that would lead to different features of dispersion and deposition. Students also have discussions on adequate protection and evacuation of the public in the nuclear accidents from their calculation and evaluation results.

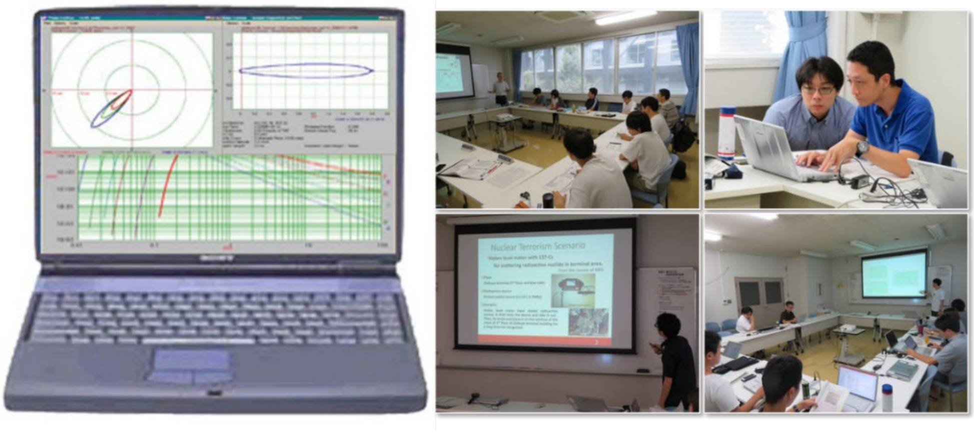

Figure 4. Atmospheric Dispersion of Radioactive Materials by Nuclear Terrorism

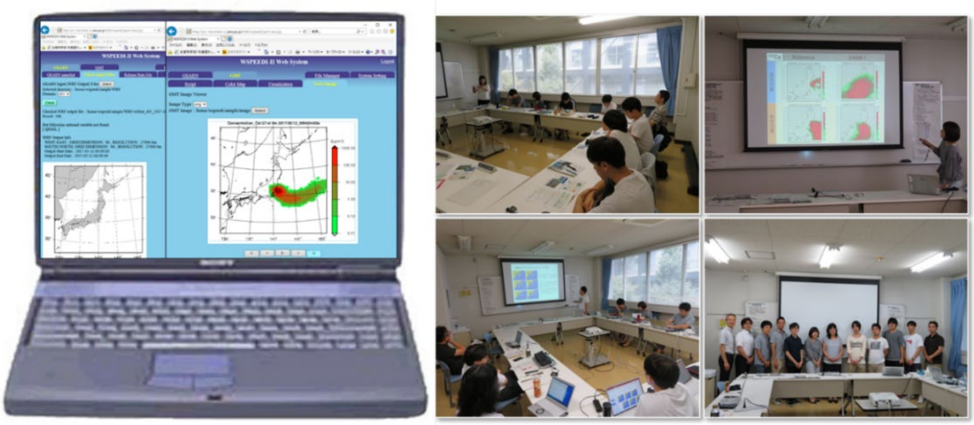

Figure 6. Atmospheric Dispersion of Radioactive Materials by Nuclear Accidents

RADIATION DISASTER RESPONSE EXERCISE

This course aims to have students build an emergency response and crisis management capability, teamwork, and communication skills needed to adequately respond to radiation disasters caused by nuclear security events. It provides an intense immersive experience that includes planning and implementing detection, verification, and retrieval of unknown nuclear and radioactive materials as a radiological emergency response assuming hypothetical nuclear security events where a general disaster response is difficult.

This course consists of four exercises. “Gamma-Ray Source Identification” exercise (**Figure 7**) is designed to acquaint students with the principles of gamma-ray measurement, analysis of gamma-ray spectrum (resolution, calibration, background, photopeak area, statistical error, detection efficiency, nuclide identification, radioactivity, etc.), and how to use gamma-ray detectors; HPGe detector, NaI(Tl) detector, and $LaBr_3$(Ce) detector. They practice to detect, locate, identify, and recover gamma-emitting isotopes indoors using gamma handheld radioisotope identification devices.

In “Neutron Source Detection” exercise (**Figure 7**), students are acquainted with the principles of neutron measurement, characteristics of detectors (gamma-ray sensitivity, n-γ discrimination, etc.), and how to use neutron detectors; He-3 proportional counter (and polyethylene for neutron moderation) and liquid scintillator. They practice to detect, locate, and recover a Cf-252 neutron source indoors using a handheld He-3 detector.

“Uranium Enrichment Determination” exercise (**Figure 8**) provides a direct application and experience of gamma-ray spectrometry. It is also intended to foster a better understanding of efficiency and resolution of scintillation and semiconductor detectors. They use the NaI(Tl) handheld detector and HPGe detector cooled with liquid nitrogen. They compare the determination results and discuss interference peaks, shielding, and measurement effectiveness.

“Radiological Emergency Response” exercise (**Figure 9**) is designed to give some practice of radiation disaster response. Assuming a hypothetical terrorism incident involving a radiological exposure device (RED), as a first responder to the radiological emergency, students locate, verify, and retrieve unknown virtual radiation sources outdoors. They use a radiation detection simulator [4] on smartphone (a mobile application) using the Wi-Fi and GPS functions. The simulator presents a radiation dose level at the user location for virtual gamma sources that are designated in advance. Students are missioned in teams to make a radiation field map for an unknown RED, to locate the unknown RED and estimate the dose level, to estimate potential candidate radioactive materials and their radioactivity, to design evacuation area and plans, and lastly to evaluate responder's exposure.

Figure 7. Gamma-Ray Source Identification and Neutron Source Detection

Figure 8. Uranium Enrichment Determination

Figure 9. Radiological Emergency Response

NUCLEAR DISASTER RESPONSE EXERCISE

This course is designed to help students understand the progress of nuclear accidents in nuclear power plants through practicing simulation of transient events, design-basis accidents, and severe accidents using a nuclear power plant simulator and find lessons from the Fukushima nuclear power plant accident on nuclear security. It aims to cultivate a comprehensive thinking ability so as to respond to beyond-design-basis accidents in both viewpoints of nuclear safety and security.

The class lectures cover plant safety systems and functions, an overview of severe accidents to threaten the integrity of reactor containment vessel, the progress of the Fukushima nuclear power plant accident, and its analysis results. Students learn about severe accident behaviors and accident management.

The simulation exercises (**Figure 10**) include operation of plant major components (control rods, pumps, pressurizer, turbine, etc.), plant start-up and shutdown, normal operation, and simulation and management of design-basis accidents and severe accidents (the Fukushima nuclear power plant accident and its similar accidents; station blackout, reactor water injection failure, etc.) using the plant simulator of the Japan Atomic Power Company (JAPC). Students understand the differences between design-basis accident and severe accident behaviors. They also visit the Tsuruga nuclear power plants of JAPC to experience and discuss the importance of interface design between nuclear safety and security systems and operations (**Figure 11**).

Figure 10. Severe Accident Simulation (Source: http://www.dojo.titech.ac.jp)

Figure 11. A Visit to the Tsuruga Nuclear Power Plants (Source: http://www.dojo.titech.ac.jp)

CONCLUSIONS

Since 2017, more than 500 students have taken the courses of the ANSET program and 25 students, who met the requirements of the curriculum, have received the certificate of curriculum completion as an evidence to show their expertise in this field. The hope for this program is to contribute to the human resource development in the next generation with a capability to prevent, prepare for, and cope with nuclear accident, nuclear terrorism, and nuclear proliferation.

ACKNOWLEDGMENTS

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