Developing Interactive Means to Teach Nuclear 3S Topics

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Abstract

In 2014 Sandia National Laboratories (SNL) developed a tabletop exercise to help students apply Nuclear Safety, Security, and Safeguards (3S) principles to a hypothetical nuclear facility. In the tabletop each of the three topics were broken out so that participants could learn about security, safety, and safeguards individually before negotiating a facility design including all 3S elements. After five years of the first iteration of the tabletop, Sandia staff updated the tabletop exercise to make it more modular and represent the wide variety of threats that facilities may potentially face. By dividing the tabletop exercise into modules, students have gained a better understanding of the interplay between the 3S systems and how they have complimentary and competing aims. This paper will introduce the impetus for the 3S tabletop exercise and summarize Sandia's use of the exercise over the last five years. After discussing lessons learned from running the tabletop with multiple audiences, this paper will describe how such exercises meet the need for creative applications to help students understand 3S principles. The effectiveness of Sandia's 3S tabletop will be examined in terms of comparing the qualitative tabletop exercise outcomes, as well as investigating the advantages and disadvantages between the original and current forms of the exercise.

Introduction

Nuclear safety, security, and safeguards each represent an important part of the nuclear energy industry with their own histories, requirements, and specialists. However, in recent decades there has been a push to understand how each of the 3S topics complement and detract from one another. In pursuit of this goal, and in an attempt to help students of the nuclear 3S topic area understand these unique idiosyncrasies, Sandia National Laboratories developed a tabletop exercise to help students apply Nuclear Safety, Security, and Safeguards (3S) principles to a hypothetical nuclear facility.

In the first iteration of the 3S tabletop, participants learned about security, safety, and safeguards in a lecture series before negotiating a facility design including all 3S elements. This exercise proved effective in helping students understand areas in which nuclear safety, security, and safeguards blend together well, and where they come in conflict in their application. However, after five years of the exercise application, SNL staff updated the tabletop exercise to make it more modular and represent the wide variety of threats that facilities may potentially face. This includes the need to balance budget with additional safety and security measures. In making

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[1] *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.*
SAND No. 2019-XXXX

these changes, Sandia lecturers are able to customize the exercise to participants of all backgrounds. By dividing the tabletop exercise into modules, students have gained a better understanding of the interplay between the 3S systems and how they have complementary and competing aims.

This paper will examine a brief history of nuclear safety, security, and safeguards, as well as the development of the 3S concept. We will then provide an overview of the development of the exercise, the changes made to make the exercise more modular, and the results and qualitative differences in the learning outcomes due to the changes. Finally, we will explore potential future developments that could be used to further develop and improve upon this exercise.

3S Overview

The concept of nuclear 3S is relatively new within the nuclear energy industry. The 3S concepts: safety, security, and safeguards generally developed separately and were typically reactive to world events such as the Chernobyl accident, the 9/11 attacks, and the discovery of Iraq's clandestine WMD program in the early 1990s. While each pillar of the 3S topic area has many years of history, the pillars have often developed independently and not in coordination with one another. The distinct outline of each area has required careful examination when attempting to implement safety, security, and safeguards in unison. At times the three pillars can be complementary and work together, while other aspects of these very distinct areas lead to idiosyncrasies that require special attention to solve. In this section, we will further explore the history of each of the 3S pillars and understand how they came together under the 3S concept.

The concept of nuclear safety has existed from the inception of nuclear power. Beginning as early as 1953, the first civilian reactor featured a containment building around the reactor. Shortly thereafter the IAEA was established with a limited mission to improve nuclear safety. This led to the development of core safety concepts from 1957 to 1967 that included the mandate that nuclear power plants cool the core of the reactor, control the chain reaction, contain the nuclear material, and practice defense-in-depth. Despite the development of these safety best practices, nuclear accidents at Three Mile Island in 1979 and Chernobyl in 1986 motivated the international community to further develop safety standards.[2] For many years nuclear safety has been a core concern for the nuclear industry. A nuclear accident anywhere in the world has the potential to derail or set back the nuclear energy industry for many years. Because of this, nuclear safety issues have generally been a significant concern and are typically considered as reactors are being built.

Like nuclear safety, nuclear security has a long history. However, unlike nuclear safety, nuclear security has not always been a consideration for nuclear power plants beginning with their construction and can, at times, be an afterthought. It was not until 1975 that the IAEA published Information Circular 225 (INFCIRC/225), "The Physical Protection of Nuclear Material." INFCIRC/225 has remained the main source of guidance on nuclear security practices since it was created. The document has gone through five editions the most recent of which is sometimes

[2] Pierre Tanguy, "Three Decades of Nuclear Safety." *IAEA Bulletin*. 1964. https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull30-2/30202085157.pdf

referred to as Nuclear Security Series 13.[3] However, other key international events have led to additional thinking on nuclear security. For example, the end of the Cold War brought about new challenges to nuclear security that led the IAEA to create the Illicit Trafficking Database and Physical Protection Advisory Service in 1995. In addition, the 9/11 terrorist attacks led to additional measures to prevent terror attacks at nuclear facilities. This includes the first IAEA Nuclear Security Plan and the Nuclear Security Fund in 2002 and the 2004 United Nations Security Council Resolution 1540 which addressed WMD terrorism. Finally, the nuclear accident at Fukushima, Japan in 2011 led the international community to recognize the nexus between nuclear security and nuclear safety.

Finally, nuclear safeguards have been an important part of the nuclear power industry since the creation of the International Atomic Energy Agency (IAEA). In the 1950s and 1960s, early IAEA safeguards focused solely on ensuring that trade of nuclear plants and fuel did not contribute to proliferation. The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was signed in 1968, limiting nuclear weapons to the five existing nuclear weapons states and applying safeguards to all nuclear material possessed by non-nuclear weapons states. This give the IAEA a stronger mandate and more authority. In the 1990s, promoted by the discovery of the Iraqi nuclear weapons program and other world events, the IAEA reviewed the existing safeguards system and expanded the legal basis for IAEA safeguards.[4]

In the early 2000s, the concept of the nuclear 3S was brought to the forefront in a number of IAEA documents. These documents pushed the idea that, in order to be truly effective, nuclear safety, security, and safeguards needed to fully address their complementary and competing aims. The goal of better understanding and implementing the 3S structure in unison has proved difficult due to organizational factors. Often, when safety is included in facility design but security and safeguards are an afterthought, the competing aims overwhelm the efficacy of the 3S system and one element ends up being prioritized. The understanding of how difficult it can be to effectively deploy a fully integrated 3S system and trying to express these difficulties in 3S lectures ultimately led SNL staff to develop a hands-on exercise to demonstrate to students how to overcome competing aims and amplify the complementary aspects of 3S systems.

History of the Exercise

In 2014, SNL staff began developing the original version of the 3S tabletop exercise. Inspired by a security focused exercise from Booz Allen Hamilton, the group from Sandia saw an opportunity to develop an exercise that would meet the needs of students attending courses hosted by Sandia on nuclear security, safety, safeguards, or the 3S system.

SNL instructors saw students struggling with the integration of 3S concepts and believed a hands-on example would help students to better understand the application of an integrated 3S system. In order to facilitate this exercise, SNL instructors would provide a series of lectures on

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[3] "Nuclear Security Briefing Book." *King's College London*. 2016. https://www.kcl.ac.uk/sspp/departments/warstudies/research/groups/csss/pubs/Nuclear-Security-Briefing-Book-2016-edition/2016NSBB---Final-Version.pdf

[4] "The Evolution of IAEA Safeguards." *The International Atomic Energy Agency*. Vienna, 1998. https://www-pub.iaea.org/MTCD/Publications/PDF/NVS2_web.pdf

the basic tenants of nuclear safety, security, and safeguards, and an overview of the integrated 3S system. Then, participants were given a poster-sized map of a hypothetical facility and a number of nuclear safety, security, and safeguards elements to place on the systems to build their own nuclear 3S system. Sandia staff used this iteration of the nuclear 3S exercise for five years—running it many times with international and domestic audiences with positive results and feedback. The exercise seemed to help the participants more fully grasp the competing aims and complementary aspects of 3S systems as they grappled with the need to place doors, equipment, and requirements upon their facilities.

Changes to Become More Modular

Revising the exercise to a modular format required separating out the safety, security, and safeguards sections which were combined in the original format of the exercise. Untangling these sections involved outlining potential safety, security, or safeguards considerations for participants when designing a facility. Facilitators also created an exercise section focused on the integration of each of the three components, asking participants to keep in mind both the competing and overlapping goals of each 3S aspect.

The course schedule was also altered to support the new modular approach to the exercise. In the first section of the course, participants received lectures on state systems for accountancy and control, safeguard measurement principles, techniques, and processes, and tamper indicating device use and requirements. Participants then completed the safeguards module of the 3S exercise. The second section of the course featured an overview of nuclear safety, significant accidents and lessons learned, case study discussion on Three Mile Island, Chernobyl, and Fukushima, and modeling and simulation to reduce research risk. This lecture series was followed by completion of the safety module of the 3S exercise. In the third section of the course, participants received an overview of nuclear security, physical protection systems, nuclear security culture and case studies, insider threat, and cyber security, followed by the 3S exercise security module. Finally, participants engaged in lecture and discussion on IAEA 3S perspectives and were asked to apply knowledge gained from the previous three sections of the course in an integrated safety, security, and safeguards 3S exercise.

The facilitators considered potential tradeoffs to the new exercise approach. For example, while teaching safety, security, and safeguards separately would likely allow participants to more fully understand the goals of each aspect of 3S, this approach could also make eventual 3S integration during the final portion of the exercise more difficult. Ultimately, facilitators determined this issue could be partially mitigated by ensuring instruction on each 3S element was taught in context of the overall 3S model.

Results of Modular Approach

Use of the modular exercise resulted in mostly positive learning outcomes for participants of the 2018 3S course. During conversation with facilitators and group presentations, participants demonstrated robust understanding of the overlapping goals of 3S principles. For example, participants quickly identified that the two-person rule was potentially useful for both security and safety purposes. In the final presentation of a facility incorporating all three elements of 3S,

each of the groups included a two-person rule in the reactor and explained why this measure could help to decrease the likelihood of safety incidents and insider theft or sabotage. Similarly, participants correctly identified that radiation detection monitors can serve as a useful tool for both security and safeguards, preventing both external adversaries and the host nation from stealing or diverting nuclear material.

Participants also demonstrated more limited understanding of the tradeoffs between different 3S elements. During the lecture series, one of the facilitators pointed out that an emergency exit door would be helpful to have in a reactor for safety purposes, but potentially problematic to security outcomes. In the final presentation of a 3S facility, all three groups applied this principle within the reactor and to other sensitive areas of the facility.

Additionally, participants in the 2018 course identified and incorporated 3S measures beyond the materials provided to them by facilitators, demonstrating creativity in pursuing 3S goals. While participants fully utilized equipment and tools provided in the exercise packet, they also brainstormed other potentially useful methods for addressing safety, security, and safeguards considerations. For example, one group incorporated emergency procedure lists in their facility to enhance safety protocol.

Despite receiving separate lectures on each element of 3S, participants struggled at times to distinguish between 3S aspects. In particular, participants demonstrated a tendency throughout the course to conflate security and safeguards and failed to fully grasp the differing goals of the two principles. For example, participants were provided the option to place both a CCTV camera (for security) and a secured surveillance camera (for safeguards) in their facility. Several participants assumed both cameras were used for security purposes and/or questioned the necessity of employing two types of video surveillance equipment. In another example from the course, participants presenting safeguards measures for their facility explained that the measures were intended to deter an adversary, an explanation more appropriate to describe security. This issue could be mitigated in the future by more clearly outlining the goals of safeguards and its comparison to security in the lecture material.

The modular version of the exercise received positive feedback from participants. An end-of-course evaluation was administered to each of the seven participants of the 2018 3S course. In response to the statement “the tabletop exercise was an effective tool to demonstrate the importance of 3S concepts,” six participants selected “strongly agree” and one participant selected “agree.” In a free response section of the evaluation which asked participants to identify the most valuable aspect of the course, three participants referenced the exercise directly. One participant described the exercise as a “great learning experience,” while two others noted its value in summarizing and applying 3S principles.

Conclusion

The modular approach to the 3S exercise resulted in mostly positive learning outcomes for participants. Separating the exercise into modules allowed participants to explore both the competing goals of 3S components and opportunities for integration within a nuclear facility. During presentations and discussion with facilitators, participants demonstrated knowledge of

the overlapping goals of 3S components and showed creativity in applying 3S principles to facilities within the exercise. Participant feedback on the exercise was also overwhelmingly positive, with all seven participants considering the exercise an "effective tool" in the instruction of 3S concepts.

Future iterations of the exercise may consider introducing additional considerations to support learning objectives on the relationship between 3S elements. One possibility for further exploration is the introduction of resource constraints. Facilitators could provide exercise participants with a budget for each facility and assign dollar amounts based on real-world costs to security, safeguards, and safety equipment. Applying resource constraints would force participants to more closely examine tradeoffs between aspects of 3S and to prioritize the measures judged to be most important to the successful operation of the facility. However, there are also several challenges to this approach. Determining appropriate costs for safety, security, and safeguards measures would be time consuming, particularly if facilitators plan to base these costs on real-world equipment prices. Additionally, the cost of some measures is not clear-cut. For example, implementing a two-person rule would likely entail costs associated with an increase in manpower, but calculating these costs is dependent on a variety of factors such as hourly wage and hiring expenses.

Another possible addition to the exercise is the introduction of threat scenario(s) for the facility. Providing participants with information about a threat or threats to the facility would allow participants to identify which safety, security, and safeguards measures are most appropriate to mitigate a given hazard. Additionally, applying a threat scenario to facility design could help participants to better understand how 3S principles can work together to prevent negative outcomes for the facility. To this end, facilitators have developed three potential threat profiles for use within the exercise based on threats from a religious extremist group, radical anti-nuclear activists, and rebels involved in a destabilizing civil war. These scenarios may be applied to future iterations of the exercise.