SAND2023-05559C

SAFEGUARDS AND SECURITY BY DESIGN FOR ADVANCED REACTORS: AN INTERACTIVE EXPERIENCE

Benjamin B. Cipiti, Alan Evans, Paul Zahnle
Sandia National Laboratories

Claudio Gariazzo
Argonne National Laboratories

Ruth Smith, Anagha Iyengar
National Nuclear Security Administration

ABSTRACT

A special session on Safeguards and Security by Design (SSBD) for advanced reactors was organized for the 2023 INMM/ESARDA Annual Meeting to demonstrate how the SSBD process works in practice. This session utilized 3D models of notional advanced reactor designs to show the effect of design changes affecting both physical security and international safeguards design elements. The session was well-attended with extensive audience engagement.

INTRODUCTION

The move toward smaller, modular, potentially safer nuclear energy sources presents new challenges but also new opportunities to incorporate SSBD early in the design process. Many of the new reactor designs can benefit from an integrated approach in the protection and control of nuclear material. While many advanced reactor vendors do take safeguards and security more seriously during the design process, there continues to be a need to stress the importance of SSBD for the full nuclear community. Cost effectiveness is a key reason to consider safeguards and security regulations early, but it is just one of many considerations nuclear vendors need to take into account in the complete design of a nuclear energy system.

A special interaction session on SSBD for advanced reactors was organized for the 2023 INMM/ESARDA Annual Meeting, held in Vienna Austria. This special session was designed to be an interactive and immersive experience to provide a better understanding of how SSBD works during the design phase. Computer modeling was used to demonstrate how design decisions may be made in the 3D layout of a notional advanced reactor, for both physical security and international safeguards elements. The audience was given a chance to vote on design decisions and then look at overall results of those decisions.

SUMMARY OF SPECIAL SESSION

The special session was attended by 50 participants. Representatives from the National Nuclear Security Administration presented an overview of the goals and challenges of SSBD. Researchers from Sandia National Laboratories provided an overview of both the PathTrace and Scribe3D [1] tools which were used to show examples of Security by Design for notional microreactor and pebble bed reactor facility models. The demonstration included an interactive audience engagement using both modeling and videos to allow the audience to make design choices to meet delay time goals and overall security performance. A researcher from Argonne National Laboratory presented an overview of Safeguards by Design followed by a 3D

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.

immersive environment showing implementation of international safeguards in real facilities. This demonstration ended with visual implementation of safeguards elements in the Scribe3D environment. The audience was highly engaged with several questions and comments during the demonstrations. The session wrapped up with a video on a cyber-physical attack of a notional nuclear plant.

Security by Design

The Security by Design process typically starts with a baseline facility model, floor plan, or site layout which can be used in path analysis tools to design key physical protection delay elements to meet an overall delay time goal. This goal will be a function of the response force strategy which may include reliance on on-site or off-site responders (or some combination). PathTrace is one model that may be used in this initial design phase to determine the more invasive design changes needed for the facility. This design phase may examine barrier thickness, door design and locations, and potential use of active delay features.

The special session used a notional microreactor site layout (see Figure 1) and provided the audience with a choice of design delay times (10, 15, or 30 minutes). The audience was also presented with different barrier choices to meet the goal time. One of the key aspects of this exercise was to show how very invasive changes may only have relatively small changes to overall delay time. This balance in additional barriers (and additional initial cost) versus delay time is one of many tradeoffs a reactor vendor needs to consider in the design of a physical protection system.

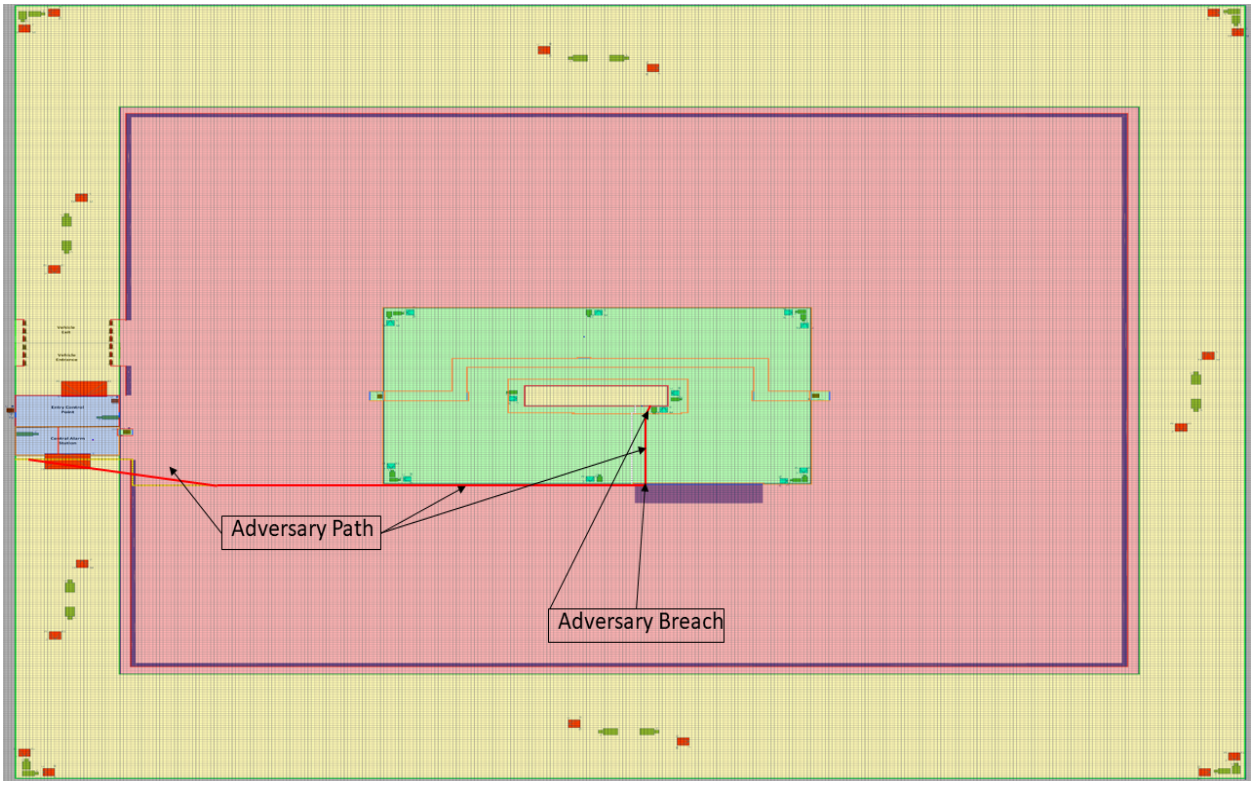

Figure 1. PathTrace Model of a Notional Microreactor [2]

The Security by Design demonstration continued with a Scribe3D model of a notional pebble bed reactor site with three reactor modules. Scribe3D provides a 3D force-on-force modeling environment to examine detection and response force effectiveness for a wide variety of adversary attack scenarios which may include theft or sabotage. Some initial design decisions were provided through a video that highlighted efficient placement of guard towers and unique features like shark cages around entry doors to help improve response force effectiveness. The video demonstrated how line of sight is an important design decision in placement of buildings, doors, and guard towers. Figure 2 shows a screenshot of the video showing overlapping fields of fire for the four guard towers.

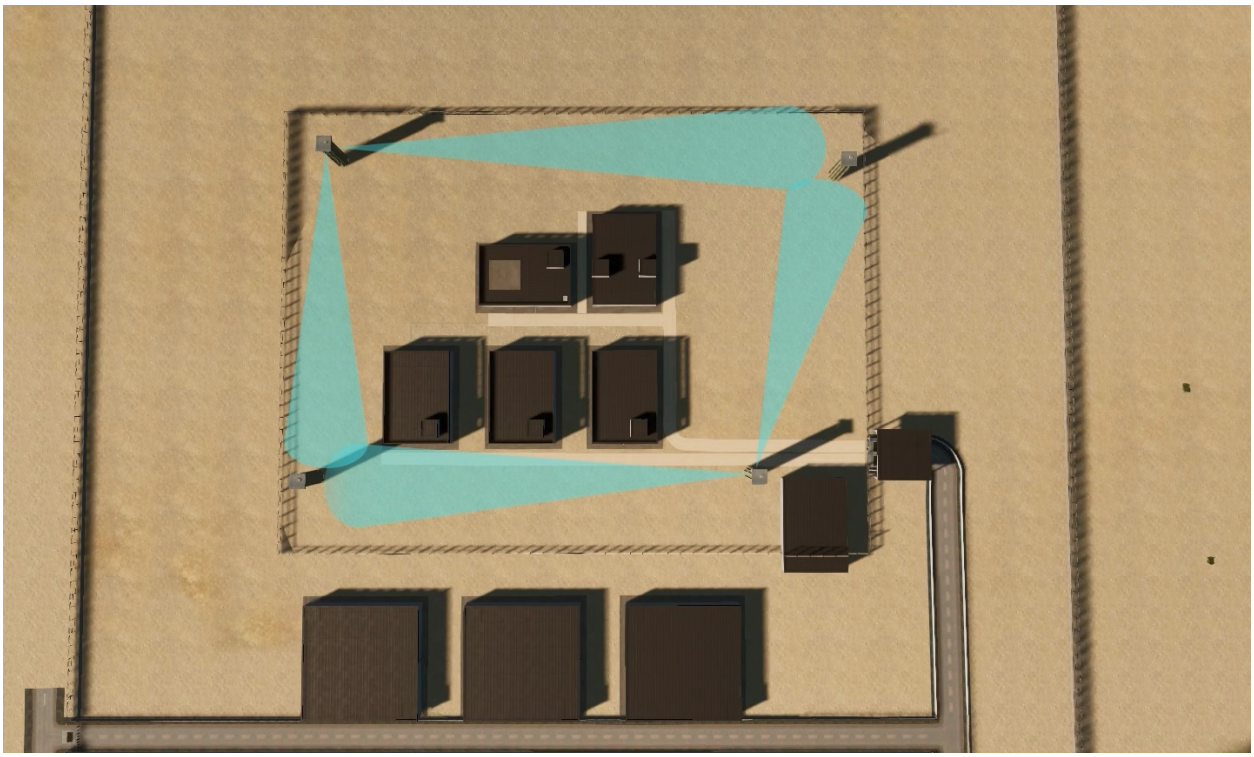

Figure 2. Video Screen Shot Showing Designed Overlapping Fields of Fire

The demonstration continued with an interactive demonstration of the pebble bed reactor model in Scribe3D. The audience was presented with a few design choices for intrusion detection technology and camera location to show the design decisions a security analyst will need to make. Figure 3 shows an example of the Scribe3D model.

Figure 3. Video Screen Shot Showing the Hypothetical Pebble-Bed Reactor

Safeguards by Design

The Safeguards by Design demonstration started with a description of on-line resources that are publicly available showing international safeguards technologies at real facilities around the world. These on-line resources were originally developed as part of international safeguards training during the COVID pandemic (when travel to sites was difficult) and allows the public to see international safeguards technology like cameras and provide a view into these facilities. A screenshot of the web tool is shown in Figure 4, and the reference provides the internet URL to access this resource.

Figure 4: Virtual Facility Tour of the Dukovany Nuclear Plant in the Czech Republic [3]

The Safeguards by Design demonstration ended with a discussion on how the Scribe3D tool can be used to assist in the design and placement of international safeguards elements such as cameras, storage locations, and tags/seals. The presenters noted that this area of work could expand significantly in the research and development space.

AUDIENCE INPUT AND FEEDBACK

The interactive session saw a high degree of audience engagement with several useful comments and questions. The following subsections summarize key points raised during the panel discussion.

Acceptance of Physical Protection Data by the Regulator

The nuclear industry noted that the use of newer physical protection technologies like active delay features may see challenges with the acceptance of performance data by the regulator. The performance data and regulatory acceptance is an important part of making this design process more efficient. Design changes like thicker walls or more robust doors may be easier to get regulatory acceptance than more revolutionary technology choices.

Cost as Part of the Design Decision

The cost of different physical protection technologies or design options is an important part of the design process. The nuclear industry could use more cost data on these technologies.

Multiple Sensors versus Multi-Modal Sensors

There is a potential to lose some information when moving from multiple sensors to a multi-modal sensor that needs to be taken into account. The difference between cameras and guard observation were discussed along with the importance of human reliability.

Scribe3D Modeling Capabilities

The audience had a number of questions about the capabilities of Scribe3D including modeling Unattended Aerial Systems (drones), the ability to model operator actions, and material flow through a facility. These capabilities are included in Scribe3D, although the modeling of material flow will require more integration with other safeguards modeling tools.

Risk-Informed Approaches and the Integration of 3S

Risk-informed approaches are being considered as part of SSBD, but there is a need for more research on the Safety-Security interface. Many of the advanced and small reactors could do more to examine the improved timelines for loss of safety systems and how that will apply to security design.

Cost Advantage of Safeguards by Design

Vendors want to know the Safeguards by Design requirements, but these requirements are not set in stone. The STUK model in Finland provided a good model since Safeguards by Design needs to be done as part of the regulatory process. There are several lessons learned in their repository project in terms of cost savings and where there may have been improvements. A key comment was that SSBD will incur costs by the designer, but the operator will incur costs of any retrofits. IAEA also has some information about the cost of retrofits.

Regulator Independence
Tools like PathTrace and Scribe3D are very intuitive and can help the regulator as well as the designer—the regulator should be part of the process. However, the regulator does need to maintain independence, and this is part of the reason there will always be some uncertainty in the regulatory requirements. Part of the goal is to prepare designers to be flexible for both domestic and international requirements.

CONCLUSIONS

SSBD continues to be a message that must be encouraged with the nuclear industry to help them prevent surprise costs down the road. While the modeling tools demonstrated during this special session are available in the research and development space, advanced reactor vendors should ultimately work with security analysts either internally or within the nuclear industry to begin thinking about security and international safeguards requirements early in the design process.

ACKNOWLEDGEMENTS

SAND2023-05559C, 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.

REFERENCES

1. "Re-imagining Security Through Visualization," Sandia National Laboratories, https://insetools.sandia.gov/, accessed June 21, 2023.
2. A. Evans, A. Neef, B. Stromberg, C. Evans, "U.S. Domestic Microreactor Security-by-Design." Sandia National Laboratories, SAND2021-13779R, October 2021.
3. Dukovany Nuclear Power Plant Aerial View, available at http://virtualniprohlidky.cez.cz/cez-dukovany-aj/, accessed June 21, 2023.