USE OF PHYSICAL PROTECTION

MODELING AND SIMULATION

TOOLS TO OPTIMIZE SECURITY   
FOR NEW REACTORS

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**Use of Physical Protection Modeling and Simulation Tools to Optimize Security for New Reactors**

In 2008, the U.S. Nuclear Regulatory Commission (NRC) issued a policy statement that stressed the importance of considering safety and security requirements together in the new reactor design process, so that security issues (e.g., newly identified threats of terrorist attacks) can be effectively resolved through facility design and engineered security features (*Federal Register*, Vol. 73, No. 199, page 60612, dated October 14, 2008). Incorporating physical security into the designs of new nuclear facilities can avoid future costly retrofits. Numerous commercial- and government-developed physical protection modeling and simulation (M&S) tools exist to help new reactor designers and vendors design physical security elements into their new reactor facilities. Those physical protection M&S tools can perform one or more of several functions related to the design or evaluation of a physical protection program or protective strategy, including facility characterization, adversary pathway analyses, combat simulation, and physical security system effectiveness. The NRC is assessing the appropriate uses of physical protection M&S tools for designing, validating, and modifying physical protection programs and protective strategies associated with new reactors for two primary purposes. First, the NRC wants its security staff to be prepared to review new reactor license applications efficiently and effectively and conduct inspections at new reactor sites that may rely on physical protection programs or elements that have been designed or modified using physical protection M&S tools. Second, the NRC intends to incorporate lessons learned from the assessment into the guidance for industry that it plans to issue within the next 2 years. This paper will describe the details of the approach that the NRC staff is utilizing to form policy for the regulatory oversight of physical protection M&S tools.

## INTRODUCTION

Most operating nuclear power reactors in the U.S. were designed and built without consideration of physical security features in their initial designs. This resulted in costly retrofits to these facilities to enhance security when changes in the threat environment warranted additional security requirements. Since 2006, the NRC has encouraged vendors, applicants, and licensees to integrate physical security attributes into the design of their new nuclear facilities to reduce costs and increase security effectiveness. The AP1000 reactor design (Fig. 1) was one of the first nuclear power reactor designs that included physical security features in its initial design.



Figure 1. Plant Vogtle AP1000

In 2008, the Commission published the Final “Policy Statement on the Regulation of Advanced Reactors,”[1] which reinforced the expectation that security should be addressed through “…facility design and engineered security features, and formulation of mitigation measures, with reduced reliance on human actions.” Additionally, it was stated that “…advanced reactors will provide enhanced margins of safety and/or use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions.” Security‐by‐Design (SeBD) [2] offers a systematic approach to addressing the following issues:

1. late involvement of security in the design process that either led to less security or required expensive redesign and construction costs;
2. a physical protection system (PPS) created with either no consideration of the threat or based only on consideration of the current threat;
3. lack of proper integration between security and operations, safety, and safeguards, leading to inefficiencies that were solved in ways that impacted the effectiveness of the PPS;
4. weaknesses in governance and organizational structures, especially concerning the competent authority and licensee - this would include stakeholders not communicating effectively to one another about how to improve security; and
5. little or no consideration of the facility lifecycle.

These factors have resulted in higher costs to develop and upgrade the PPS to meet the evolving threat and limited the potential for such systems to evolve over time. Implementation of SeBD is intended to provide design features that enable the PPS to remain effective and easier to upgrade when addressing the changing threat environment. The use of physical protection M&S tools can play a crucial role in enhancing SeBD by enabling proactive and automated security risk and vulnerability assessment, and effective design adjustments.

2. OVERVIEW OF PHYSICAL PROTECTION MODELING AND SIMULATION TOOLS

*Purpose*

NRC nuclear power plant licensees and potential applicants for new nuclear reactor designs currently use physical protection M&S tools to optimize their security systems and designs. The evaluation of an existing or proposed facility, including physical layout and PPS design, requires a methodical approach that measures the ability of the PPS to meet defined protection requirements. Physical protection M&S tools enable power reactor licensees and applicants to evaluate their PPS designs against the full spectrum of design basis threat attributes, which is rarely done during security drills/exercises because of the risks to plant or personnel safety. Applicants can use physical security M&S tools to explore the value of SeBD features before deciding to include them in reactor facility designs. Licensees can also use these tools to predict PPS performance or evaluate PPS changes with nominal staff, no risk to plant/personnel safety, and minimal artificialities that typically accompany performance-based security drills or exercises.

*Functions*

The first step when using a physical protection M&S tool is to characterize an existing or proposed facility by building a model of the PPS, including characteristics of the facility. The available physical protection M&S tools can perform pathway analyses, combat simulations, and tabletop exercises based on the model created [3]. Using this model, current M&S tools can be used to: 1) analyse adversary and armed responder pathways to identify critical detection points, 2) visualize/inform potential combat scenarios, 3) calculate PPS effectiveness, and 4) conduct what-if (i.e., cost-benefit) analyses.

*Facility Characterization*

The facility model must accurately depict the spatial orientation of facility structures and equipment; adversary and responder pathways; site topography; delay features; and responder locations and weaponry.

Facility structures and equipment must be accurately situated in the M&S model to facilitate reliable tool output. For example, placing a building at a greater distance than it is actually set from the perimeter intrusion detection and assessment system will falsify adversary/protective force traversal times and produce errors in weapon neutralization. A complete assembly of adversary and responder pathways must be provided in the M&S model to ensure all pathways are considered. For example, leaving out an un-monitored facility feature like a culvert (e.g., drainage pipe) from the M&S model that may be exploited by an adversary, could render an attack interrupted by the protective force when it should have shown that the adversary made it unharmed to a key target location. Site topography information, including contours and elevation data, must also be meticulously detailed in the M&S tool for accurate analysis output. For example, line of site for weapon fire can be skewed by inputting inaccurate site elevation data in the M&S model.

Delay features have spatial and resistance characteristics that must be provided in the M&S tool for realistic outputs. For example, showing a concrete wall that is 2000 pounds per square inch (psi) rated, one meter thick, with no rebar, when at the site it is 5000 psi rated, 1.5 meters thick with 2-centimeter (cm) rebar spaced every 10 cm, will severely impact the delay times assessed by the M&S tool, given the same adversary techniques are applied. Responder locations must be precisely depicted in the M&S tool to establish accurate lines of sight, timelines for the protective force to interrupt an adversary, and protective force survival calculations. For example, an alarm station operator detects an adversary assault at a vital area door; this consequently leads the protective force towards an interruption point. The M&S model output would be inaccurate if the protective force is shown to initiate adversarial pursuit from the wrong starting location. Similarly, specific weaponry data must also accurately be placed in the M&S tool for precise tool analyses. For example, depicting a protective force sniper with a 12-gauge shotgun in the M&S tool will greatly diminish the sniper’s ability to engage long-range targets effectively.

*Pathway Analysis*

Identifying critical detection points enables an analyst to understand the point along an adversary pathway where delay exceeds protective force interruption time with enough time margin to allow for a high probability of neutralization. Several types of adversary paths can be considered in an M&S tool including: a most vulnerable path, a fastest path, and an avoid detection path. The most vulnerable path will demonstrate this adversary pathway as advantageous for the protective force to engage the adversary with a high probability of defeat. The most vulnerable path depicts the critical detection point observed early in an attack scenario. The fastest adversary attack pathway will allow an adversary to defeat a first layer of defense at a site. The critical detection point for a fastest adversary pathway will be located closer to target areas than that of the most vulnerable attack pathways. An avoid detection adversary pathway would show the adversaries taking as much time as is needed to avoid detection before proceeding into target areas, which may be favourable to an adversary attack strategy. The critical detection point in an avoid detection path strategy is observed late in the scenario process.

*Combat Simulation*

Adversary scenario elements include several adversaries, their weapons/ equipment, the number of adversary points of attack, and timing of adversary actions. In addition, responder actions are an important element of the simulation and detail timing associated sensing, assessment, and detection times of the adversary attack; traversal times; lines of fire; and the specific readiness of an actual responder. Visualizing and informing potential combat scenarios serve to educate the applicant or site protective force staff with insights on adversary or protective force actions. Analysts should ensure M&S tools are programmed with a facility’s security plans, protective strategy, and implementing procedures to ensure the simulated response force will behave in the M&S tool consistent with how it is expected to behave in reality. Rules of engagement must also be included into the M&S tool to provide reliable results. For example, local rules of engagement may only permit lethal force after it is determined an adversary has lethal weaponry. In addition, the adversary path strategy (e.g., avoid detection) must be established for each scenario during the M&S runs.

*System Effectiveness Analysis*

Calculating the PPS effectiveness enables users to evaluate how well applicant and licensee protective strategies achieve their performance objectives. The probability of the PPS effectiveness number is an output of the combat simulation tool. A regulatory authority can establish the acceptable criteria for the probability of system effectiveness number that an applicant/licensee must achieve. The probability of PPS effectiveness is never the number one (e.g., 0.90), but rather a realistic number that includes circumstances for which an adversary force will be successful.

*Cost-Benefit (what-if) Analysis*

A what-if analysis enables the most cost-effective protective strategy option to be identified/implemented while maintaining physical protection objectives. Cost minimization can be achieved by utilizing M&S tools to identify lower cost solutions for physical protection capabilities in new reactor facility designs. For example, in a new facility design, interior pathways to target areas can be configured to provide protective force engagement advantages (e.g., few pathways to targets with hardened enclosures in optimum line-of-fire locations). Resource use can be optimized in an existing facility when considering a new threat feature and after identification of potential susceptibilities. For example, if a susceptibility in the access control feature of the personal access portal is found, a list of potential, more sophisticated access control measures could be considered to identify the best cost-effective solution. In the case of a new threat condition, an array of various physical protection measures may be analysed, such as, more capable weaponry, better/more delay elements, and the hardening of target areas to counter an increase in the adversary threat. This analysis of a varying solutions can result in the identification of an optimal, cost-effective solution which maintains the acceptable level of risk.

2. POLICY AND GUIDANCE DEVELOPMENT

The NRC is developing guidance that will describe acceptable methods and best practices for applicants and licensees to consider when using physical protection M&S tools to 1) create physical security plans that comply with applicable NRC requirements, and 2) optimize physical security strategies in nuclear reactor facility design. In [July 2023](https://www.nrc.gov/pmns/mtg?do=details&Code=20230765), the staff engaged with public stakeholders to discuss proposed research which will inform NRC guidance development and to solicit feedback and industry lessons learned. This research will further evaluate the specific uses and capabilities of physical protection M&S tools; assist in guidance development for their uses; and develop/provide training for NRC staff.

Specifically, the guidance development effort will focus on creating a regulatory guide and NUREG document for new reactor applicants and licensees. The proposed regulatory guide will describe the recommended process for using physical protection M&S tools and identify an acceptable standard for PPS effectiveness to demonstrate compliance with the applicable NRC security regulation(s). The planned NUREG guidance document will provide the following types of information associated with specific M&S tools:

* Suitable purpose(s) or function(s), including facility characterization, path analysis, combat simulation, system effectiveness, and what-if/cost-benefit analysis;
* Functional accreditation status;
* Training sources; and
* How an applicant or licensee can obtain the software.

Additionally, the NRC is proposing to develop an inspection procedure for the security oversight of licensee use of physical protection M&S tools to demonstrate compliance with NRC requirements. The objective of this procedure will be to provide NRC inspectors guidance for how to assess key elements of licensees’ processes that rely, at least in part, on physical protection M&S tools to design or optimize their PPS and protective strategies. Accordingly, the inspection procedure will align with the planned regulatory guidance and provide a checklist to aid NRC inspectors in their oversight activities.

Lastly, the research will inform the training of NRC staff to ensure they are familiar with the operation and capabilities of various physical protection M&S tools such that they can provide effective oversight of their use and application. The NRC staff has obtained licenses to use several cost-free, U.S. government-developed and owned physical protection M&S software tools, which will facilitate staff’s familiarization with, and understanding of, those tools capabilities. The U.S. government M&S tools have capabilities like the commercially available physical protection M&S tools being used by NRC power reactor applicants and licensees, and by reactor designers and vendors. The knowledge and insights staff gains from their familiarization with the U.S. government M&S tools will be transferable to the commercially available physical protection M&S tool outputs and methodologies that the staff will encounter during licensing or oversight activities. The physical protection M&S tools, regardless of whether commercial- or government-owned, all rely on realistic input data, accurate facility geometry, and similar algorithms to perform functions and predict outcomes.

4 BENEFITS OF MODELING AND SIMULATION TOOLS FOR APPLICANTS AND LICENSEES

New reactor applicants and licensees can use physical protection M&S software tools to identify and evaluate the SeBD and other security measures to help demonstrate compliance with NRC security requirements across a broad range of areas in the most effective and efficient manner. The security functional areas include access control, administrative controls, responders, delay barriers, deployment strategies, intrusion detection and assessment, communications, secondary power, and weaponry. Importantly, the use of M&S tools provides a repeatable and predictable methodology to evaluate PPS protective strategy designs against the full spectrum of design basis threat attributes with nominal staff, no risk to plant/personnel safety, and minimal artificialities that typically accompany performance-based security drills or exercises. An applicant or licensee will need to always verify the outcome of the tool to ensure that all parts of the completed simulation are realistic. Figure 3 below depicts a new reactor design that the NRC certified in 2020 [4].



Fig. 3. NuScale Power Reactor

The NRC’s development of regulatory guidance for the use of physical protection M&S tools will promote consistency in the application of these tools by applicants and licensees for compliance with NRC’s physical security requirements. As previously mentioned, the regulatory guidance under development will also aid the NRC staff to become familiar or proficient with physical protection M&S tools which could result in consistent, informed, and more streamlined reviews of nuclear power reactor applicant or licensee submittals. Further, the guidance is also a tool to provide NRC staff a method to identify technical issues during licensing reviews that rely on such tools, and informed and effective oversight by NRC staff who review security plan changes.

5 CONCLUSION

Consistent with NRC’s Principles of Good Regulation [5], the informed and correct use of physical protection M&S tools can support timely and efficient execution of its licensing and oversight responsibilities for new reactor physical security. Sophisticated physical protection M&S tools have been developed by both the U.S. government and commercial companies. If these tools are used with accurate facility models, inputs, and other technical specifics, then they can be used to perform accredited functions, including adversary pathway analyses, combat simulations, and calculating the probability of PPS effectiveness. The NRC staff can establish a minimum standard for the expected probability of PPS effectiveness which would meet the NRC regulatory performance objective of adequate protection. If physical protection M&S tools are used correctly, then the NRC, its licensees, and applicants should be able to save resources while designing, assessing, reviewing, or implementing effective and efficient SeBD features or PPS needed to comply with applicable physical security requirements.

References

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[4] NRC, Design Certification- NuScale US600, <https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/nuscale.html>

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