AVERT 4 Universities (A4U) Program Support to the Pennsylvania State University

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ABSTRACT

The AVERT 4 Universities (A4U) program by ARES Security Corporation (ARES) provides access to the AVERT software suite at no charge to educational institutions for inclusion in their curriculum. AVERT is an established suite of all-encompassing software solutions for the entire life cycle, from design to operations, of physical security systems. AVERT transforms physical security planning and assessment from a dependence on the qualitative judgement of subject matter experts to a science based on a 3D digital twin, physics-based quantitative modeling, simulation, and artificial intelligence. Building on a partnership established in 2016, ARES provided the Pennsylvania State University (Penn State) with AVERT for use in the fall 2020 Nuclear Security System Design (NucE 442) class, one of five core courses in Penn State's graduate nuclear security education program covering threat, security system design, detector technologies, and global policies. AVERT enables instructors to demonstrate and students to explore a wide range of theft and sabotage scenarios with the ability to rapidly test the impact of changes to any and all aspects of the environment, threat, and protection systems. Simple models are used for demonstrating core concepts while complex models allow students to integrate concepts and demonstrate a comprehensive attainment of course learning objectives through a series of hands-on exercises and a final design challenge project in which students use AVERT to apply "what if" scenarios to assess different security configurations and prioritize investments in system improvements. The use of industry-leading Security Risk Assessment (SRA) software enhances student achievement of learning objectives while also providing experience with a tool actively used by used by 65% of commercial nuclear plants in the U.S. as well as many industrial, corporate, and government organizations. The industry partnership also provides students with the opportunity for engagement with professionals in the field, broadening their educational experience and extending their network. This paper will introduce the A4U program, discuss the Penn State experience with deploying and using the tool for both resident and online instruction, lessons learned, and student feedback.

INTRODUCTION

ARES Security Corporation (ARES) is the world leader in Security Risk Assessment (SRA) software. ARES Security's flagship product, AVERT, is an established suite of all-encompassing software solutions for the entire physical security life cycle from design to operations. AVERT transforms physical security planning and assessment from a dependence on the qualitative judgement of subject matter experts to a science based on a 3D digital twin, physics-based quantitative modeling, simulation, and artificial intelligence. The AVERT software suite is actively

used by 65% of U.S. commercial nuclear plants, along with industrial, corporate, and government organizations and has a proven track record of effectively assessing and optimizing security systems and identifying subsequent cost savings. As best stated by the ARES CEO, Ben Eazzetta, "ARES Security is proud to help save lives and improve security against violent threats such as active shooters for large corporations, government agencies and critical infrastructure."

ARES is committed to supporting the education of tomorrow's leaders. As such, ARES is pleased to introduce ARES' AVERT 4 Universities (A4U) program. The A4U program provides the commercial AVERT Physical Security (AVERT-PS) software to public universities, at no charge, to be included in their curriculum. Along with educating and providing the minds of the future with world class commercial software, ARES appreciates interacting with and getting feedback from innovative students to continue to enhance and improve the software. ARES has been fortunate enough to have been working with the Pennsylvania State University (Penn State) since 2016, providing access to the AVERT-PS software and support from ARES professionals. This paper provides an overview of AVERT-PS, a description of the A4U program, and a summary of the Penn State experience with the A4U program in support of nuclear security education.

AVERT-PS OVERVIEW

The AVERT-PS software is the primary software tool provided to Universities under the A4U program. AVERT-PS is a unique Security Risk Assessment (SRA) software used to evaluate physical security posture, perform Vulnerability Assessments (VAs) and facilitate training of the facility along with providing the capability to visualize, quantify, assess and optimize security posture. This solution's holistic and integrated approach, delivers accurate, measurable, and repeatable assessments of physical security design and operations. The AVERT-PS software system provides asset owners and security analysts with the capability to make security system investment decisions based on quantitative, physics and engineering based models. AVERT-PS's intuitive user interface can quickly create a realistic 3D Digital Twin model of the facility that includes interior and exterior features or structures, access points and entrances, natural features, and the placement of both offensive tactics (i.e., active and passive barriers and detection tools) and defensive tactics (i.e., guards and deterrence systems).

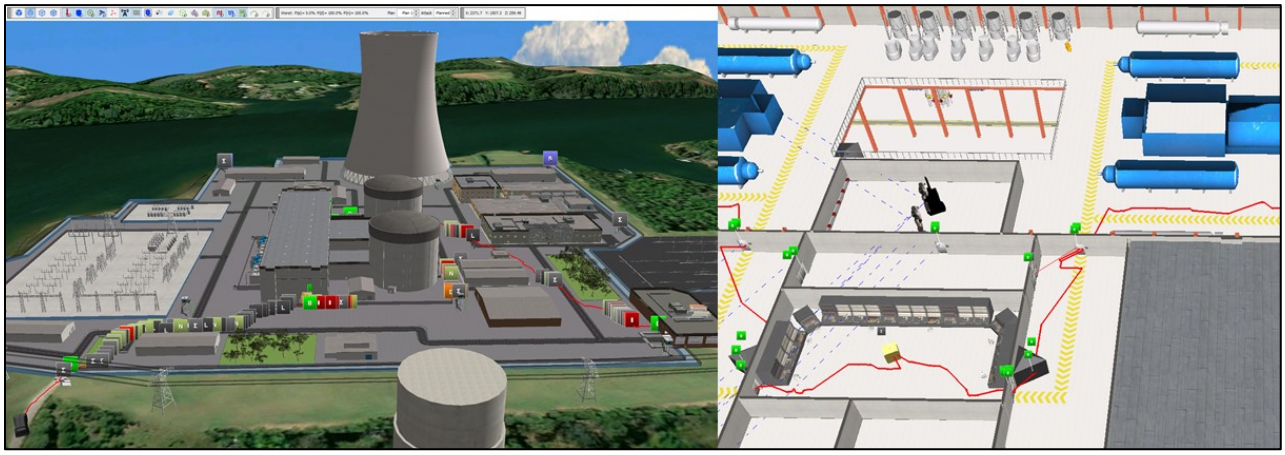

Figure 1. AVERT-PS 3D Digital Twin model of a hypothetical nuclear power plant, site and interior details.

Once the site is modeled, the solution uses proven modeling and simulation technology along with Monte Carlo simulations to evaluate the comprehensive security design. AVERT-PS utilizes an ARES exclusive automated pathing algorithm to determine the various pathways of adversaries, responders, and even natural hazards. The AVERT-PS simulations are very fast running, so thousands of simulations, with multiple variations, can easily be performed. Through the use of enhanced reporting and output tools, all of the generated data can easily be mined and presented in easy to use and understand reports.

The AVERT-PS assessments provide the organization with a complete understanding of the facility's security posture and response to address vulnerabilities and optimize configurations for both effectiveness and costs. The parameters can easily be changed within the model to address a wide range of security system configurations, threats, and targets. Once the vulnerabilities and pathways have been identified and analyzed, a baseline assessment has been established. This baseline assessment can then be compared to variations of the security posture such as changing and testing new modeled sensors, systems, and procedures. Through the evaluation of various "what ifs", a quantified assessment of a site's existing and potential new/revised security posture can be performed. This quantitative approach provides a cost-effective means to continually assess risks and optimize security effectiveness within budget. The result is a thorough understanding of a site's return on investment. AVERT-PS clients have identified a wide range of cost savings, while maintaining or improving security posture.

Reducing existing security posts is the most common cost reduction identified using AVERT-PS in this process. The industry average cost to maintain a security post is approximately $575K per year (with a cost range of $375K-$1200K per year). Assuming an average facility lifetime of 25+ years, a single post reduction can result in an overall net present value (NPV) of $6M or more. Typically, multiple post reductions are identified during an AVERT-PS assessment project. Post reductions of 1-3 posts, with limited capital investment, and upwards of 14 posts with capital investment have been achieved. In such cases where capital investments are used to generate additional staff reduction, AVERT-PS is used in the design and justification of the capital investments to ensure minimum spending, optimizing design while improving or maintaining effectiveness.

AVERT 4 UNIVERSITIES (A4U) PROGRAM

ARES is committed to supporting the education of tomorrow's leaders through direct collaboration with leading institutions of higher education. Through the AVERT 4 Universities (A4U) program, ARES works with universities to provide the AVERT-PS software to be included in their curriculum. The A4U program provides students with the unique experience of using world class commercial software actively used by 65% of U.S. commercial nuclear plants, along with industrial, corporate, and government organizations with a proven track record of effectively assessing and optimizing security systems and identifying subsequent cost savings.

The A4U program provides universities with the AVERT-PS software; a complete set of user documentation; a module-based training curriculum consistent with the same material used to educate commercial clients, including lecture presentations and lab exercises; support by ARES exerts to assist in installation, preliminary training, and to answer questions; ARES experts as guest

lecturers for introduction and special topics; and end of the semester review of lessons learned and areas for software improvement with the instructor and students to collect valuable constructive criticism and expose the students to professional situations.

The A4U partnership in curriculum can extend beyond nuclear security to other disciplines such as architecture and business, and A4U provides other opportunities for faculty and students to apply AVERT-PS in support of research or to explore innovations in modeling and simulation. ARES experts can assist with review and provide guidance on publications or presentations for students and faculty pursuing R&D projects at the university in which AVERT-PS is used.

A4U AT THE PENNSYLVANIA STATE UNIVERSITY

The Nuclear Security Education Program at Penn State

The Ken and Mary Alice Lindquist Department of Nuclear Engineering in the College of Engineering at The Pennsylvania State University formally introduced a nuclear security option in its nuclear engineering master's program to ensure the continued security and safety of nuclear enterprises. Nuclear security education program (NESP) courses were first offered in 2011 with a Nuclear Security master's degree option formally offered to students starting in the Fall of 2018. This unique master's degree program is designed to educate and train the next generation of nuclear security experts who can actively contribute to improving nuclear and radiological security around the world. Development of the Penn State NESP and Nuclear Security master's degree program option was supported by a grant from the United States Department of Energy and the National Nuclear Security Administration (NNSA) in collaboration with Massachusetts Institute of Technology and Texas A&M University. The nuclear security program at Penn State combines the technical, societal, and policy aspects of nuclear security with experience using state-of-the-art technologies through 5 core courses:

- NucE 441, Nuclear Security Threat Analysis and Assessment: Assessing non-state/rouge-state capabilities and intentions to target nuclear and radiological facilities and supply lines.
- NucE 442, Nuclear Security System Design: Science and engineering associated with the design, evaluation, and implementation of systems to secure nuclear and radiological facilities, materials, and supply lines.
- NucE 542, Source and Detector Technologies for Nuclear Security: Theory and technology behind detectors, sensors, and source technologies including portal monitors and field deployable radiation detection systems.
- NucE 543, Nuclear Security Education Laboratory: Hands-on experience using radiation detection systems, sensors, devices and source technologies for nuclear security.
- NucE 544, Global Nuclear Security Policies: Introduction to global policies and laws for nuclear security that are intended to provide a secure environment for the pursuit of legitimate nuclear activities.

AVERT-PS in NucE 442, Nuclear Security System Design

NucE 442, Nuclear Security System Design, provides students with the opportunity to learn how to think with a security perspective such that they can design and evaluate systems to deter, detect,

interdict, and respond to threats to the security of nuclear and radiological facilities, materials, and supply lines. The AVERT-PS modeling and simulation tool provides a robust virtual environment in which students can gain direct, hands-on engineering design experience where they apply knowledge gained through a variety of texts, online modules, lectures, and practical exercises. NucE 442 is available to both undergraduate and graduate students in resident programs at University Park and online programs via Penn State World Campus as a technical elective or as one of 5 core courses required for students pursuing the Nuclear Security master's degree option.

ARES Security partnered with Penn State in 2016 to develop the first offering of NucE 442 with AVERT-PS used by students for the course final project. In 2020 the course was significantly updated and relaunched with support from ARES security and the latest version of the AVERT-PS software and support for continued online content development provided by Pacific Northwest National Laboratory (PNNL). The AVERT-PS modeling and simulation environment is now used throughout the entire course to improve the achievement of learning objectives:

- Analyze motivations and capabilities of adversaries and be able to characterize a Design Basis Threat (DBT) that can be used to perform a threat-informed security evaluation.
- Describe and explain the operation of detection, delay, and response technologies.
- Understand how to complete a performance evaluation of detection, delay, and response technologies.
- Evaluate insider threats to nuclear and radiological facilities and incorporate the insider threat in a DBT.
- Formulate different response strategies (including deterrence, denial, containment, pursuit, and recapture) for different facilities and considering on-site and/or off-site response.
- Understand the unique security required for the transportation of nuclear materials, smuggling of nuclear materials, and protection of major public events.
- Apply engineering principles to redesign the security system of a nuclear facility to provide defense-in-depth with balanced protection that minimizes security risk to an acceptable level while controlling costs and impacts to safety and safeguards.

AVERT-PS is one of four key components of NucE 442 course content. The first component is the primary textbook: *Design and Evaluation of Physical Protection Systems, 2nd Edition* by Mary Lynn Garcia. Structured around the Design and Evaluation Process Outline (DEPO) for physical protection systems developed by Sandia National Laboratories (SNL), this text complements the second component which is a series of online modules and lectures based upon content from the SNL International Training Course (ITC) on the Physical Protection of Nuclear Material and Nuclear Facilities. Other sources and guest lecturers support additional special topics such as transport security and major public event security to form the third component. The final component is the AVERT-PS modeling and simulation tool in which students spend the majority of course time with hands-on applications and engineering design work.

The AVERT-PS modeling and simulation software provides students with the ability to virtually experience real-world scenarios, directly applying concepts learned throughout the course. Students are introduced to AVERT-PS during the second week of the semester. The initial introduction is familiarization with and testing access to the AVERT-PS software as well as file saving, storage,

and movement to support future assignments. Students receive an AVERT-PS introductory presentation with question-and-answer time by an expert from ARES Security. Starting in the third week students begin to use AVERT-PS to synthesize reading and lecture materials as they learn to use AVERT-PS through a series of Modules and Labs adapted from ARES Security AVERT-PS training materials. The Modules are detailed explanations of key concepts and how AVERT-PS models are configured, run, evaluated, and modified in the design process. The Labs are hands-on exercises in which students synthesize, analyze, and apply lecture, reading, and Module knowledge in applied scenarios with questions to demonstrate comprehension. Finished model files are submitted for homework, and students respond to questions via quizzes for instructor assessment of achievement of learning objectives. The Modules and Labs build upon each in the series, ensuring students gain confidence in the use of AVERT-PS. The online discussion capability of the university's Canvas Learning Management System (LMS) is used for each Module/Lab as a means for students to collaborate and ask questions as they work; in the early stages of the course the instructor provides most of the support to answer questions, but as the semester progresses students begin to gain the ability to support and answer questions for each other as they explore the assignments. Modules progress from an introduction to how AVERT-PS represents physical protection system (PPS) design, path analysis, and the DEPO methodology to running models and evaluating results followed by a series on detectors, barriers, guards, and adversaries resulting in a fully functional model students can evaluate and modify. This is followed by a series on AVERT-PS reporting and analytic tools to help students synthesize knowledge gained from prior Modules/Labs with the application of knowledge and skills necessary for the final design challenge project.

The NucE 442 course culminates with a final design challenge project in which students use AVERT-PS to apply the security engineering design concepts, principles, and methodologies learned throughout the course and complete a redesign of the PPS for a hypothetical nuclear facility such as the model shown in Figure 1, which is more advanced than that used for the Modules/Labs. Experts from ARES Security provide the model and work with the instructor to configure a variety of scenarios to challenge students in the evaluation and redesign of an existing PPS and given DBT. Scenarios vary from those with opportunities for significant PPS reductions, such as in the number of guards and/or responders, to those where initial performance, probability of effectiveness (P_e), is inadequate and a combination of additional PPS components such as detectors, barriers, or guards might be needed along with other PPS configuration changes.

Students apply the DEPO methodology to the design challenge project, starting with characterizing the facility (the site, PPS, and DBT) and then analyze and evaluate initial PPS performance. Students use a performance-based approach to redesign the security system to provide defense-in-depth with balanced protection that minimizes risk to an acceptable level while controlling costs and impacts to safety and safeguards. Students present their interim redesigned models to the class and produce a final written report of the design changes with an analysis of initial and recurring costs to implement the proposed changes.

Students collaborate via online discussions in the LMS to complete the facility characterization step of the design process. Normally there is at least one World Campus student in the class who has current or past experience working at a nuclear facility; they help lead the discussion and guide

other students in identifying and understanding the physical layout of the facility and purpose of buildings and other components (such as the reactor building, turbine building, and entry control). While many model details are not present, such as reactor components, students enjoy the collaboration, learning, and exploration of the exceptional detail of the AVERT-PS model. Collaboration for the final project continues at the scenario level with online discussions in which students share discoveries about the initial PPS, ideas for re-design, and resulting performance.

The analysis and reporting capabilities of AVERT-PS are particularly useful for students to evaluate the current system, identify performance gaps, develop solution strategies, and analyze the impacts of design changes. Use of these tools enables students to demonstrate comprehension and knowledge of course concepts and produce clear and complete final written reports for the project. Figure 2 shows an example of a basic, summary report of the initial conditions for a final design challenge project scenario with Figure 3 showing the results following an interim design change by the student project team.

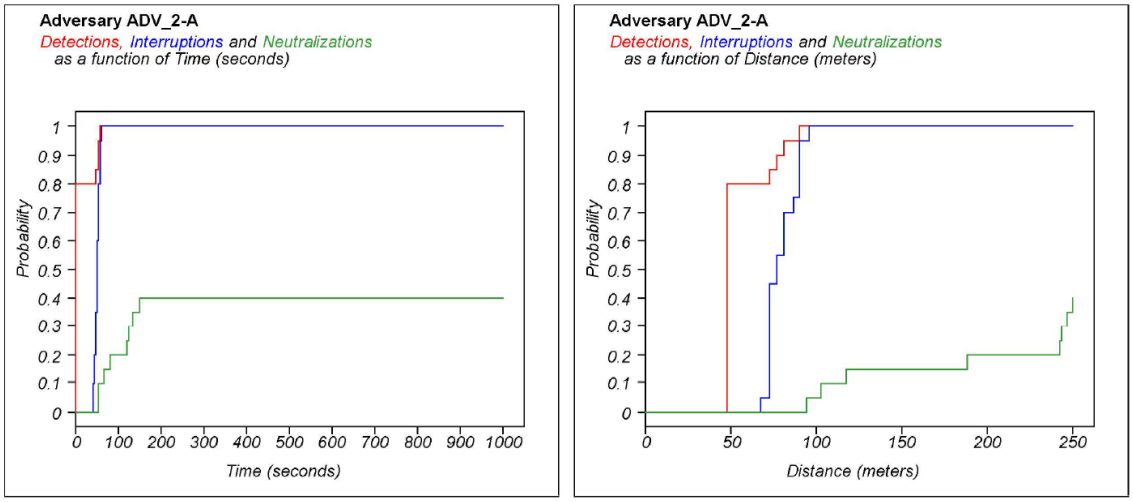

Figure 2. AVERT-PS adversary attack plan report for Probabilty of Detection, Interuption, and Neutralization vs. Time and Distance for final design challenge project initial conditions.

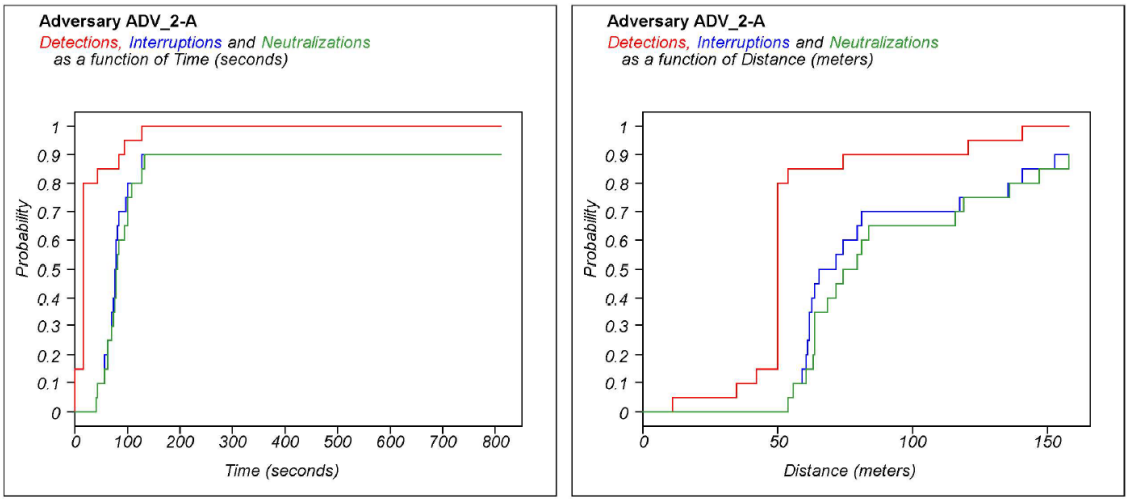

Figure 3. AVERT-PS adversary attack plan report for Probabilty of Detection, Interuption, and Neutralization vs. Time and Distance for final design challenge project following student inertim re-design.

In this case, students were faced with a DBT of two teams of 6 attackers entering the facility shown in Figure 1 from two locations and converging on two objectives (targets) for which the existing PPS provides insufficient protection. The second team is equipped with a vehicle, making neutralization of the adversary team difficult for the existing PPS. Using the Adversary Report in AVERT-PS shown in Figure 2, the student team identified this major gap in PPS performance which they chose to address with three changes: installing an upgraded vehicle barrier, changing the location of one guard, and upgrading that guard's weapons capabilities. The results of model run following these changes is shown in Figure 3; the time and distance gaps between adversary interruption and neutralization are significantly reduced, and the probability of neutralization of the adversary increased from 40% to 90%. Ultimately the student team was able to achieve the required performance objective of $P_e \geq 90\%$ with an overall cost savings by making a few more design changes to the PPS.

The Learning Environment

NucE 442 is delivered in a hybrid environment to accommodate both resident and online students with enrollments usually including an even distribution of undergraduate and graduate students as well as both resident and online students, most of whom are currently working in nuclear or related fields. This diverse enrollment enriches the learning environment with opportunities for students to learn from professionals in the field and for those students to apply their professional knowledge and experience in leadership roles for group exercises and projects. All reading, lecture, and assignment materials are made available to students online via the Canvas LMS with support from Penn State Engineering's Office for Digital Learning (ODL) for course design and delivery in collaboration with the Leonhard Center for Enhancement of Engineering Education. The AVERT-PS software application is made available to students via the College of Engineering (CoE) Virtual Desktop Infrastructure (VDI).

The CoE VDI was developed by the College to enable the use of specialized software for engineering courses and expand student access to resources beyond the limitations of traditional computer lab facilities. The benefits of using a VDI are manifold and particularly important for a specialized, security application such as AVERT-PS. From an IT and support perspective, only one 'machine' needs to be setup and maintained. ARES experts work directly with college IT staff to install, test, and maintain the virtual machine used for the course. To install and test updated versions of AVERT-PS a test virtual machine image, separate from the course image, is used to avoid service interruptions for students actively engaged in the course. From a security perspective, students can run the application but do not have direct access to the software in the VDI; only those IT staff who are provided installation files have access to the complete software. Access to the VDI, and thus the software, can be immediately added or removed by IT staff. From a student perspective, access to the software is platform-independent without the need to purchase computing hardware necessary to meet advanced software specifications or the worry of installation and maintenance of the software and associated working files.

AVERT-PS access and use via the CoE VDI has been very successful with only a few challenges experienced during the first semester deployed in this environment. Although accessing and running the software from a computing perspective is platform-independent, students working from laptops sometimes find it helpful to have access to a larger, high-resolution monitor as well as a

multi-function pointing device (such as a multi-button mouse) to efficiently navigate within AVERT-PS. Latency was rarely a problem even with students working in North America, Asia, and Europe collaborating in a single class. It can take some time for the initial installation and setup of the software and configuration of the machine, particularly for graphics card configuration; however, with a virtual machine environment, this is normally a once-and-done activity.

Enhanced Student Learning Using AVERT-PS for Hand-On Engineering Design Coursework

Use of AVERT-PS in the course enables a highly engaging learning experience. Student completion of the exercises in the Labs ensures achievement of learning objectives, and students are excited to use the actual application for PPS design used by most U.S. nuclear facilities. Care is taken to adapt the ARES AVERT-PS training materials to support the achievement of learning objectives for the course. It is neither the purpose of the course nor a learning objective to learn how to use AVERT-PS. Rather, AVERT-PS is used as an excellent tool for achieving learning objectives throughout the course. Although students rapidly gain remarkable proficiency in the tool, the focus of the course is the application of engineering design principles to nuclear security.

Using AVERT-PS provides expanded opportunities for differentiation, which is particularly helpful in a combined undergraduate/graduate course. Students who want to dive deeper into the course concepts can use AVERT-PS as a tool for exploration. Only a small number of the vast features available in the software are explored in the regular coursework so AVERT-PS offers an opportunity, particularly for graduate students, for more advanced work. Several additional Modules/Labs are included as optional work for students who are interested in learning more about how to build physical models and modify detailed parameters in AVERT-PS. Some students come to NucE 442 with military, law enforcement, or security experience through the Penn State Reserve Officer Training Corp (ROTC) program or are active duty military personnel or veterans attending via Penn State World Campus; however, most students have no security experience. AVERT-PS provides these students with an opportunity to gain an understanding of a wide variety of security equipment and configurations. For those students with security experience, the extensive array of items available in the AVERT-PS model library, and the ability to do detailed configurations allows them to apply their experience in new ways and teach other students.

Student feedback

Students are offered multiple opportunities and methods to provide feedback on their experience with the AVERT-PS software throughout the course in addition to the College and University processes for mid-course and end-of-course evaluations. During the course, the instructor provides several opportunities for feedback during lecture, within assignments, and through online discussions. Within assignments, students are asked for their feedback on both positive and negative aspects of using AVERT-PS in quizzes associated with the Modules and Labs. Up through the first two assignments student feedback includes some challenges with accessing the software and basic acclimation; however, these assignments are specifically designed to uncover and address any initial problems. With basic access and workstation setup problems resolved, students find the software easy to use with an intuitive interface structured for security design, making it an excellent tool to apply concepts learned in class. Students are appreciative of instructor walkthroughs and demonstrations, whether live during lecture or recorded and posted to the LMS in response to

questions. Given this is a certified tool part of a large suite and widely used at many facilities, students appreciate gaining direct experience using and applying a tool they are likely to see in their work as a nuclear engineer in the field and as an added professional skill to include in their resume or CV. Students enjoy the challenge of working to reach performance objectives while minimizing cost impacts (and often are able to reduce costs).

CONCLUSION

The AVERT-PS modeling and simulation tool is widely used within industry and is now being used to educate the next generation of security professionals through the ARES A4U program. A4U has been deployed at Penn State since 2016; one of the authors of this paper was exposed to AVERT-PS under this program and is now a professional at ARES. In Nuclear Security System Design, NucE 442, one of five core courses in Penn State's nuclear security master's degree program, AVERT-PS provides a 3D virtual environment enabling student exploration of a wide range of real-world scenarios with the ability to quickly alter models to test the impact of changes to security systems, directly applying concepts learned throughout the course. Although having no experience with AVERT-PS prior to the course, students are able to immediately begin applying course concepts and are ultimately able to complete a PPS evaluation and redesign for a complex facility all within a 15-week semester (12 weeks during the summer). The AVERT-PS virtual environment provides clear demonstrations of the differences between and challenges of balancing performance-based and prescriptive-based (regulatory) requirements. Deployment of the AVERT-PS software via the Penn State CoE VDI provides platform-independent access to students, rapid and reliable access controls, limited access to proprietary code, and minimal installation and maintenance. The A4U partnership in curriculum can extend to other disciplines and provide other opportunities for faculty and students to collaborate with ARES experts in research using AVERT-PS or related technologies.

ACKNOWLEDGEMENTS

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REFERENCES

1. W. Charlton, C. Marianno, K. Unlu, R. Lanza, G. Kohse, "Designing a Nuclear Security Education Program for the Global Threat Reduction Initiative", Transactions of the American Nuclear Society, Vol. 105, Washington, D.C., October 30–November 3, 2011.
2. K. Unlu, "Establishment of a Master's Degree Program for Nuclear Security at the Penn State University". International Conference on Nuclear Security 2020, 10-14 February 2020.
3. M. Garcia, *Design and Evaluation of Physical Protection Systems, 2nd Edition*, Butterworth-Heinemann, 2007.
4. International Training Course on the Physical Protection of Nuclear Material and Nuclear Facilities, "ITC-28 Resources", Sandia National Laboratories, https://share-ng.sandia.gov/itc/course-materials.html, 2018.