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SAFEGUARDS AND SECURITY MODELING FOR ELECTROCHEMICAL PLANTS

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Safeguards and security design for reprocessing plants can lead to excessive costs if not incorporated early in the design process. The design for electrochemical plants is somewhat uncertain since these plants have not been built at a commercial scale in the past. The Separation and Safeguards Performance Model (SSPM), developed at Sandia National Laboratories, has been used for safeguards design and evaluation for multiple reprocessing plant types. Materials accountancy and process monitoring data can provide more timely detection of material loss specifically to protect against the insider threat. While the SSPM is capable of determining detection probabilities and examining detection times for material loss scenarios, it does not model the operations or spatial effects for a plant design. The Presagis STAGE software is able to model force-on-force exercises with 3D models of a facility. This software, then, can be used to model operations and response for various material loss scenarios. The purpose of this work is to discuss the integration of the SSPM model data with the STAGE software to provide a more complete analysis of diversion scenarios to assist plant designers.

I. INTRODUCTION

Safeguards and security design for nuclear fuel cycle facilities in the past were two separate activities that led to two distinct systems. This leads to a more expensive design process and yields plant monitoring systems that do not fully take into account the plant data that are available. Given the high costs of safeguarding and securing nuclear facilities today, safeguards and security must be taken into account early in the design process to optimize costs while providing robust protection systems.

The concept of safeguards and security by design fits into the larger concept of Safety, Safeguards, and Security by Design, or 3SBD. However, this work is only focused on the interface between safeguards and security in electrochemical reprocessing facilities.

Although nuclear facilities are designed to be robust against outside attack, insiders can pose a security risk due to their knowledge of the facility and protection systems. Materials accountancy data, in the safeguards systems, can provide information to help protect against a theft or diversion scenario by an insider adversary.

Furthermore, the traditional safeguards system can track if material goes missing, but does not track how material would leave a plant in the event of a diversion scenario. The physical protection system is designed in part to detect and respond to unauthorized removal of material from a facility. Thus, in order to completely analyze a diversion scenario, both the materials accountancy and physical protection systems as part of the facility design and operation should be evaluated. The purpose of this work is to describe that integration both from the modeling standpoint and for the purposes of designing integrated plant monitoring systems in the future.

II. BACKGROUND

The integration of safeguards and security has been evaluated for the past few years as part of the Materials Protection Accounting and Control Technologies (MPACT) program in DOE NE.[1,2] This work initially evaluated aqueous reprocessing facilities, but currently electrochemical processing facilities are being examined. The Separation and Safeguards Performance Model (SSPM) has been used as the basis for the safeguards modeling in this work.

Past work has also evaluated the integration of materials accountancy administrative procedures with the physical protection system to improve detection and response against the insider threat.[3] This work takes into account operator actions and human reliability data in responding to off-normal plant conditions. The past several years of research have led to the current path, which is described below.

II.A. SSPM

The SSPM is a transient reprocessing plant model based in the Matlab Simulink platform.[4] Currently UREX+, PUREX, and Electrochemical (EChem) models exist. The Echem model tracks all elemental mass flow rates, as well as the total salt flows and inventories in an electrochemical processing facility. Unit operations are designed to mimic actual operations including inventory tracking and bulk material transfers. Assumptions are used for separation efficiencies, but integration with chemistry models is also possible.

Although the mass tracking is required as the model base, the main purpose of the SSPM is to simulate materials accountancy and process monitoring measurements. The user can customize the uncertainties at these measurement points. All of the measurements are used to calculate an inventory difference (ID). Error propagation is used along with a Page's Test to set alarm conditions for detecting material loss. The SSPM includes the following capabilities:

- Spent fuel source term library
- Mass tracking of elements 1-99 and bulk solid/liquids
- Tracking of heat load and activity
- Customizable measurement points
- Automated calculation of ID and error propagation
- Alarm conditions and statistical tests
- User-defined diversion scenarios

II.B. STAGE Model

The Presagis STAGE software was chosen to model the physical protection system. STAGE provides a framework to create end-to-end scalable force-on-force combat simulations. It allows for a complete 3D model of a facility to be designed along with the design of physical protection elements. These elements may include sensors or personnel.

The STAGE model provides the ability to complete the modeling of a diversion scenario since it can model the material removal from the facility and the response of the physical protection system. Figure 1 shows an example building model using STAGE with entities shown in blue.

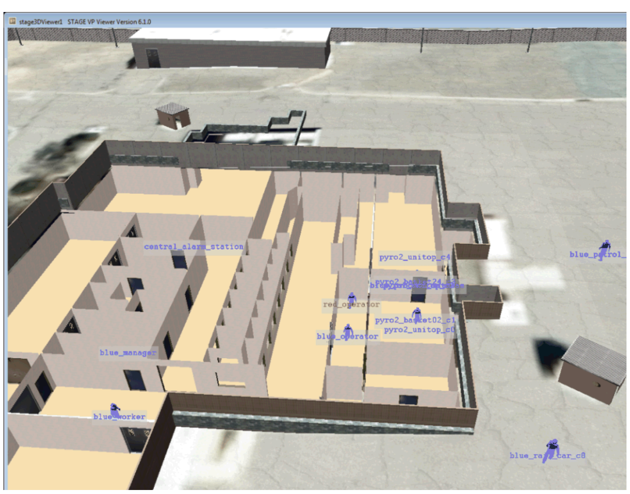

Fig 1. Example building model in STAGE.

III. INTEGRATION ARCHITECTURE

The overall goal of this work is to examine how/if incorporation of safeguards data will augment a physical protection system against the insider threat. Specifically this work is focused on an insider attempting to steal nuclear material. An insider may have intimate knowledge of a facility and so can circumvent physical protection elements easier than an outsider. However, the materials accountancy system is much more difficult to beat.

The concept of 3SBD does not necessarily mean that all plant protection systems need to be completely integrated. In fact, it is more efficient to design plant monitoring systems that only have access to the data they need. In this case, the safeguards system can provide data to the physical protection system, but the information flow is one-way.

The SSPM was setup to model specific material loss scenarios. Multiple iterations of the model allowed for a determination of the probability of detection as a function of time, which depends on when the diversion starts and stops. These data will then be used as an input to STAGE for the 3D modeling of the same diversion scenario. Figure 2 shows an example of a probability of detection profile for a protracted diversion that started at hour 500 and ended at hour 2700. Before hour 600, the probability of an alarm is very low, but soon after there is a likely chance that an alarm would be indicated. STAGE will use these data once per day with a random number generator to determine if an alarm will be indicated.

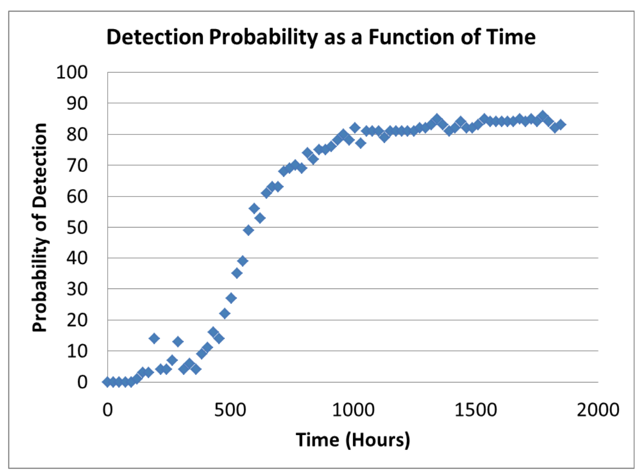

Fig. 2. Example probability of detection profile

Although an alarm might be indicated, human operations often determine what action is necessary. False alarms are a possibility and expected, so an administrator will need to do an assessment of the alarm to determine if it appears real or not. Human reliability will play a factor here, and this area will be explored more in future work. These administrative procedures may or may not lead to an escalation of the facility's security posture.

The STAGE model will be setup with two modes of operation. In the "Normal" state, the operators, guards, administrators, and physical protection elements have one set of behaviors. As long as no materials accountancy alarms occur and material is not detected leaving the facility, the plant will operate normally. If a materials accountancy or physical protection system alarm is indicated, an "Alert" state will lead to different behaviors. For example, administrators may check to see where the problem occurred; guards may converge on the area of interest; or entry control points would go into tighter screening procedures.

To model this, the same material loss scenario as modeled in the SSPM will also be setup in STAGE, but with the added information of how an insider adversary is going to remove material from the facility. The data from the SSPM can change the state of the facility.

The material balance is only calculated once per day, so to save running time, the STAGE model will be setup to perform that material balance check once every 24 hours, and then jump to the next day. If an alarm is indicated, or if material starts being actively removed from the facility (whichever comes first), the model will transition into real-time operation until either the diversion attempt is caught or material is removed from the facility. STAGE can be set up to run through multiple iterations to determine the probability of successfully defeating the insider adversary.

In an actual facility design, the alarm data from the safeguards system would directly be used to inform both administrators and physical security responders. The probability of detection profile shown here is used to help with the modeling and allows both the SSPM and STAGE models to be run independently.

IV. DISCUSSION

When the STAGE model is ready for analysis, an insider theft scenario will be compared both with and without integration. The case 'without integration,' as currently practiced will only rely on the physical protection system elements for detecting material removal from the facility. The case 'with integration' will utilize the materials accountancy system to trigger alert states. This comparison will likely show differences between detection and response times.

This work will be highly dependent on the assumptions made regarding the particular diversion scenario and physical protection elements. This modeling and simulation effort provides an approach to explore the ability of an insider adversary to defeat or circumvent the material accountancy and physical protection systems. In addition, the integration of the SSPM and STAGE modeling tools provide an approach for evaluating facility designs and gaining insights for design and operations of integrated plant monitoring systems.

IV. CONCLUSIONS

The initial goal of this work was to develop the integration architecture, but much more modeling detail is required before specific scenarios can be run. Future work will develop the diversion scenarios and test the concept of integration in more detail.

The integration described here provides a simple approach to integrate data from both the SSPM and STAGE codes. This approach allows both models to be run stand-alone, and is logical since the information flow is one-way. Future work can examine direct integration of both codes if that would be useful.

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