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ABSTRACT

An automated approach to facility safeguards effectiveness evaluation has been developed. This automated process, called Safeguards Automated Facility Evaluation (SAFE), consists of a collection of a continuous stream of operational modules for facility characterization, the selection of critical paths, and the evaluation of safeguards effectiveness along these paths. The technique has been implemented on an interactive computer time-sharing system and makes use of computer graphics for the processing and presentation of information. Using this technique, a comprehensive evaluation of a safeguards system can be provided by systematically varying the parameters that characterize the physical protection components of a facility to reflect the perceived adversary attributes and strategy, environmental conditions, and site operational conditions. The SAFE procedure has broad applications in the nuclear facility safeguards field as well as in the security field in general. Any fixed facility containing valuable materials or components to be protected from theft or sabotage could be analyzed using this same automated evaluation technique.

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Introduction

Concern over the security of nuclear facilities has generated the need for a reliable, time efficient, and easily applied method of evaluating the effectiveness of a safeguards system. Such an evaluation technique could be used by the U.S. Nuclear Regulatory Commission (NRC) to evaluate licensee proposals, to assess the security status of a system, or to design and upgrade nuclear facilities.

An objective physical protection system evaluation and design methodology should include the perspective of both the NRC and the licensee. From the NRC perspective, this methodology should provide a basis for decisions related to the development of regulations or policies. In addition, the methodology could supplement the rationale for a particular regulation and provide a systematic method to make and explain decisions related to compliance with regulations. Alternately, from the licensees' perspective, the evaluation methodology could be used to provide a consistent measurement of the performance of their safeguards systems and a design technique which would allow decisions to be made relative to compliance with regulations or for the upgrading of their physical protection systems.

SAFE Methodology

In response to this express need, an automated approach to facility safeguards effectiveness evaluation has been developed. This automated process, called Safeguards Automated Facility Evaluation (SAFE), consists of a collection of functional modules for facility characterization, the selection of critical paths, and the evaluation of safeguards effectiveness along these paths. SAFE combines these modules into a continuous stream of operations. The technique has been implemented on an interactive computer time-sharing system and makes use of computer graphics for the processing and presentation of information. Using this technique, a comprehensive evaluation of a safeguards system can be provided by systematically varying the parameters that characterize the physical protection components of a facility to reflect the perceived adversary attributes and strategy, environmental conditions, and site operational conditions.

As outlined in Figure 1, the SAFE procedure begins with a blueprint or a layout of the facility. The facility layout module consists of two major parts: characterization and digitization of the facility into a computer compatible representation. One phase of facility characterization is the identification of the locations of vital components and sensitive materials that would be attractive targets for an adversary and the identification of reasonable access points to these areas (Target Identification). The analyst uses the facility layout, a detailed fault tree analysis, and personal knowledge of the facility in this phase. The second phase of facility characterization incorporates the physical characteristics of the facility. This includes such items as barrier locations and access points within the facility (doorways, windows, access shafts, etc.). The third and final phase of the facility characterization process is the identification of physical protection component locations, i.e., the location of alarms, detection systems, guards, roving patrols, etc.

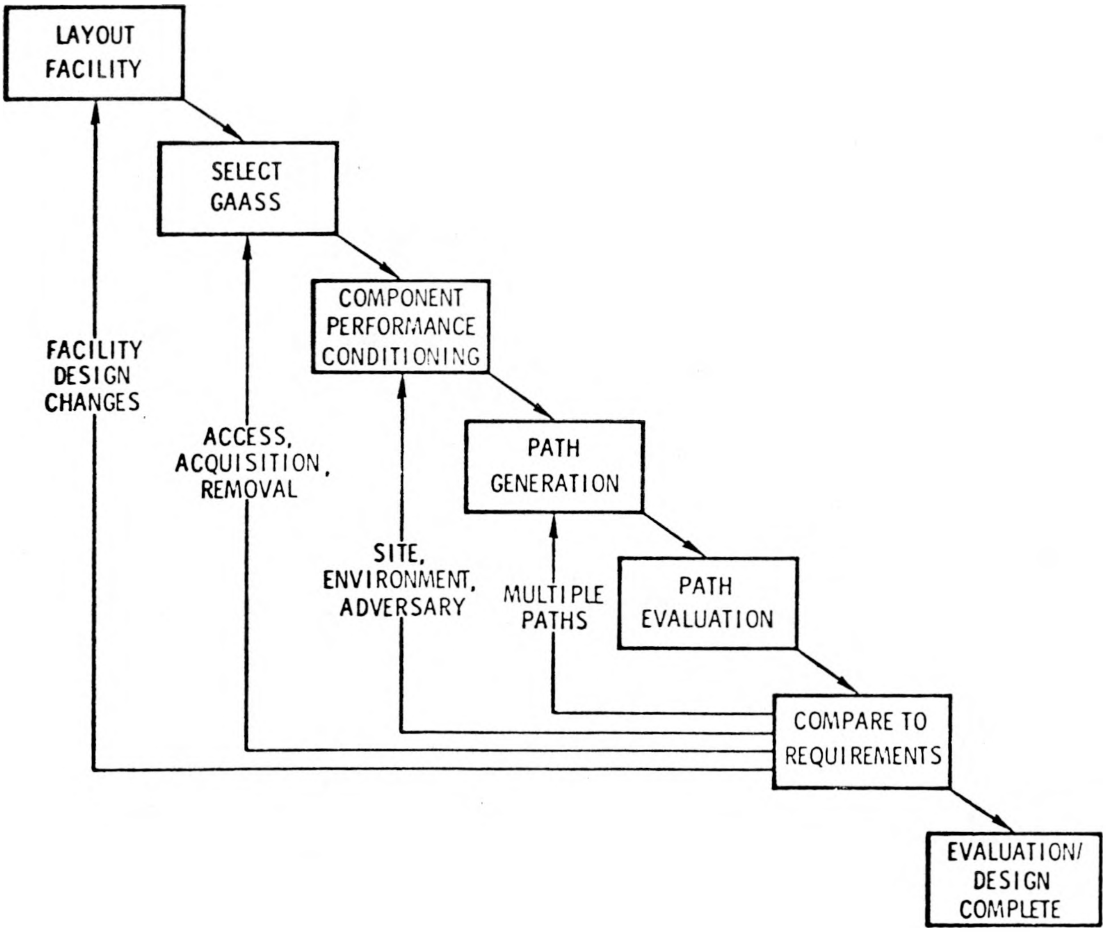

Figure 1. Facility Evaluation/Design Process Using SAFE.

The second part of the facility layout module involves the digitization and organization of the pertinent facility information into a computer usable form. Lines and nodes, which represent facility elements, are identified by X-Y coordinates; nodes are further identified by type, expectation and st ndard deviation of penetration time, and probability of detection. The final output of the facility characterization module is a graph in which nodes represent access points or targets and arcs represent paths between nodes. This representation is used for input to the path selection module in SAFE.

The next step in the application of the SAFE process deals with selecting a Generic Adversary Action Sequence Segment (GAASS) from the three generic segments: access, acquisition, or removal. For adversary actions related to theft, the appropriate GAASS's are concerned with access to, acquisition of, and removal of material. Generic Adversary Action Sequence Segments which are of interest are further investigated or evaluated. Once a GAASS has been selected for evaluation, e.g., a removal segment, the required component performance within the facility can be selected based on three primary conditions: the site operational status, the environmental conditions, and the adversary attributes. **The digital representation of the facility is then input to the path selection module, conditioned on the GAASS and the component** performance that had been selected.

Path selection may be accomplished by several alternative techniques. These techniques are commonly referred to as pathfinding techniques and can be either stochastic or deterministic. SAFE currently uses one of three deterministic measures for pathfinding: (a) a technique that finds the shortest path from a node exterior to the graph to every node in a facility graph (thus minimizing time or detection probability), (b) a technique that identifies up to the kth shortest paths from an exterior node to every node of the graph, and (c) a pathfinding routine based on the "timely-detection" evaluation method (1). The timely-detection method finds paths that initially minimize detection probability and then minimize time. The approach is to select a guard response time locus about the target (minimum time) and to minimize the probability and then minimize time. The approach is to select a guard response time locus about the target (minimum time) and to minimize the probability of detecting the adversary from the facility boundary up to that locus. The output of the path selection is a collection of ordered sets of node identifiers that represent physical paths in the facility. This information is a portion of the input to a path evaluation module.

Path evaluation can be decomposed into two major parts: interruption and neutralization. The path is "evaluated" by first determining the probability that the adversary will be interrupted and then determining the probability that the adversary will be neutralized or defeated by the security force. These two probabilities can be multiplied together to yield the total probability that the physical protection system will be successful in defending against the adversary along the path under consideration.

The Estimate of Adversary Sequence Interruption (EASI) (2) model is an analytical technique which is used in the path evaluation module to compute the probability that the adversary will be interrupted. EASI focuses on the adversary path and requires information related to the probability of detecting the adversary, the time required for assessing the proper response, the probability of communication with the security forces, the delay along the path and the response time of the security force. The output of EASI is an estimate of the probability of adversary interruption along the specified path, i.e., the probability that the security force arrives at a point along the adversary's path prior to the time that the adversary passes through that point.

The Brief Adversary Threat Loss Estimator (BATLE) (3) model is an analytical technique that is used to estimate the probability that the adversary is neutralized by the security force. In addition to the distance between combatants, the information required by BATLE is the type of weapons, the recency of training, the amount of cover, and the number and timing of arrivals of reinforcements for the adversary as well as the security officers. The output of BATLE is the probability that the adversary is neutralized by the security force. This "neutralization probability" is then multiplied by the "interruption probability" to yield the total probability of success of the physical protection system for the path in question.

Capabilities for path interruption evaluation can be utilized in either a single or multipath mode. During a single path evaluation using EASI, the probability of interruption is calculated and the user may request two- or three-dimensional plots which show the probability of the adversary interruption as a function of one or two of the other input variables. Based on the probability of interruption, these graphs illustrate sensitivities related to upgrading the facility. The multipath option displays in tabular form the probability of interruption, the traversal time of each path, and the frequency at which nodes appear in the set of critical paths. The multipath evaluation identifies paths that are particularly vulnerable and thus are candidates for study by more elaborate evaluation modules such as the Forcible Entry Safeguards Effectiveness Model (FESEM) (4) and the Insider Safeguards Effectiveness Model (ISEM) (5). Based on the the results of this evaluation the given facility may be judged to be adequately safeguarded, thereby ending the procedure. However, if there were some deficiencies, changes in the original facility characterization data could be made to reflect upgrades in the system and the SAFE procedure could be repeated.

Summary

The SAFE procedure is an efficient method of evaluating the physical protection system of a nuclear facility. Since the algorithms used in SAFE for path generation and evaluation are analytical, many paths can be evaluated with a modest investment in computer time. SAFE is easy to use because the information required is well-defined and the interactive nature of this procedure lends itself to straightforward operation. The modular approach that has been taken allows other functionally equivalent modules to be substituted as they become available. The SAFE procedure has broad applications in the nuclear facility safeguards field as well as in the security field in general. Any fixed facility containing valuable materials or components to be protected from theft or sabotage could be analyzed using this same automated evaluation technique.

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