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Leon D. Chapman, Editor

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PHYSICAL PROTECTION OF NUCLEAR FACILITIES
QUARTERLY PROGRESS REPORT
July-September 1978

Leon D. Chapman
Editor

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PHYSICAL PROTECTION OF NUCLEAR FACILITIES

QUARTERLY PROGRESS REPORT

July-September 1978

Contributors

Kenneth G. Adams
David E. Bennett
Harold A. Bennett
Sharon L. Daniel
Dennis Engi
Louann M. Grady
Mildred S. Hill
Bernie L. Hulme
Richard D. Jones
Christine A. Morgan
M. Teresa Olascoaga
Nestor R. Ortiz
Dallas W. Sasser
Amado A. Trujillo
G. Bruce Varnado

Technical Staff Members
of Sandia Laboratories

Leon D. Chapman
Editor

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SUMMARY

Major activities during the fourth quarter of FY78 included (1) the vital area analysis of operational reactors and characterization of the Standardized Nuclear Unit Power Plant System (SNUPPS), (2) the algorithm development of a new pathfinding computer code, (3) the completion of contractor-supported work for the component generic data base, (4) the refinement of tests related to human parameters modeling, and (5) the addition of improvements to and demonstration of the Safeguards Automated Facility Evaluation (SAFE), Safeguards Network Analysis Procedure (SNAP), and Fixed-Site Neutralization Model (FSNM) methodologies.

Vital area analyses have been completed for five pressurized water reactors (PWRs) and one boiling water reactor (BWR). The analysis of a second BWR continues. In addition, the characterization of the SNUPPS is nearly completed. The standardized SNUPPS design will be used in the construction of five identical facilities which are being built by four different utility companies. The SNUPPS design will also be used as the test bed in other study areas, e.g., demonstration of the SAFE methodology.

Several studies within the component functional performance characterization area are nearing completion or were completed during this reporting period. The SRI International portion of the generic component data-base model has been completed and efforts are now being made to provide FORTRAN interfaces for the Safeguards Engineering and Analysis Data-Base (SEAD) which contains this information. The characterization of human parameters for neutralization models and testing programs is also nearing completion. Work in this area has concentrated on the refinement of the stress tolerance test and the establishment of possible locations for field testing of the test program developed by Applied Psychological Services (APS).

Improvements have been made to several existing evaluation methodologies. Program additions and updates to the SAFE algorithm and an improvement to the

user interface with SAFE have been made. The additions include a new stochastic Pathfinding Simulation (PATHS) model, and the Brief Adversary-Threat Loss-Estimator (BATLE) model. In addition, some improvements or changes have also been made to SNAP and FSNM.

A tutorial on the FSNM was conducted during September. This tutorial was attended by various Sandia staff members and representatives from the NRC Office of Regulatory Research (NRC/RES) and the NRC Office of Nuclear Material Safety and Safeguards (NRC/NMSS). A demonstration of the use of the model to simulate an NRC Guard Tactics Simulator (GTS) scenario was also performed.

FACILITY CHARACTERIZATION

In-House Activities

The vital area analyses of operational reactor facilities continued during this quarter. This work, which is part of a joint effort with Los Alamos Scientific Laboratories (LASL), is being performed for the Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation (NRC/NRR). In general, the analyses have produced the following results for each facility studied:

1. A fault tree plot,
2. A list of event sequences which would lead to a successful sabotage,
3. A list of Type I and II vital areas,
4. A list of event sequences which occur within Type I vital areas, and
5. A list of event sequences which occur in pairs or triples of Type II vital areas.

To date, the analyses for five pressurized water reactor (PWR) facilities have been completed; the analysis for the second boiling water reactor (BWR) facility is in progress.

The characterization of the Standardized Nuclear Unit Power Plant System (SNUPPS) is nearing completion. Four utilities are presently constructing five identical SNUPPS units. This standardized design will be used as a test bed for the demonstration of the Safeguards Automated Facility Evaluation (SAFE) methodology and as the baseline design in the Nuclear Power Plant Design Concepts for Sabotage Protection Program. During August, a briefing was given to personnel from the NRC Office of Regulatory Research (RES) and NRC/NRR. The briefing included familiarization with the facility and illustrations of how the information developed in the characterization will be used in the design study. During September a visit was made to the SNUPPS project office in order to discuss the SNUPPS design and obtain more detailed information than is available in the Safety Analysis Reports (SARs).

During this quarter, a new standard version of the computer code SANDIA-ORIGEN was developed. This code is used for reactor fuel irradiation/radioactive decay calculations. Computer core requirements have been reduced significantly and the new mass storage routine allows the code to run on most CDC computers

(6400, 6600, 7600). A copy of the code has been provided to Prof. L. Meem, Department of Nuclear Engineering, University of Virginia, for use in the Sandia-funded program on nuclear fuels and proliferation risks.

Contractual Support

Dikewood Industries

Dikewood Industries continued to support the facility characterization of the SNUPPS facility during this quarter. Through the use of the generic sabotage fault tree (GSFT) methodology, nearly all of the detailed sabotage fault trees have been developed and drawn on the computer and are currently being reviewed. Five system descriptions have been written and will be available shortly; these descriptions include the auxiliary feedwater system, the emergency electric power system, the residual heat removal system, the reactor protection system, and the primary coolant system boundary.

Falcon R&D

During this quarter, Falcon R&D began the development of generic fault trees for complex cooling systems. The previous generic fault trees were for single-loop cooling systems without cross-connections to redundant, parallel loops. The application of the single-loop tree to systems with redundant trains and numerous cross-connections became exceedingly complex and unmanageable for real facility cooling systems. Many simplifying assumptions had to be made to generate reasonable fault trees, e.g., treating large blocks of piping and valves simply as black boxes and assigning one or more vital locations as appropriate. The new methodology will hopefully allow a better and more detailed fault tree description of piping and valves in complex cooling systems. Also during this quarter, work continued on refinement of the generic component fault trees.

PATH-GENERATION/SELECTION METHODOLOGY

In-House Activities

ADPATH Code

A single code which finds either theft or sabotage paths (or both) from a network which represents a facility is under development. This code, called Adversary Paths (ADPATH), uses a computational scheme based on the previously developed subroutine SFORD, which uses a variant of Ford's method to compute shortest paths in a network. The details of the algorithm have been fully developed. ADPATH has been coded and is now being debugged and tested.

The network model is a directed graph called a facility digraph. Each barrier (and boundary) penetration point is represented by a pair of nodes, one on each side of the barrier, and two oppositely directed arcs between them. These arcs are weighted with the delay time and the detection probability associated with penetration of the barrier in each direction. Within each region of the facility, each pair of barrier nodes is joined by a pair of oppositely directed arcs whose weights reflect the time and detection probability for traveling from one location to another. Each target is represented by a pair of nodes and a single arc weighted with the time and detection probability associated with either the destruction of target or the removal of protected material from the target location. There are arcs from each barrier node in a region to the first node of each target in the region and arcs from the second node of each target back to each barrier node. Thus, the paths in the facility digraph represent all the physical routes that a thief or saboteur might use based on a given set of targets and barrier penetration points. Alarmed barriers and targets are indicated by the assignment of nonzero detection probabilities to the appropriate nodes in the digraph.

The user of ADPATH may find sabotage and/or theft paths for an adversary who is either an insider or an outsider. For each sabotage target, a guard response time to the target is given. For theft problems, a guard response time to each off-site node is given. In addition, the starting points for the adversary are specified. The adversary path computed for each target has the property of (1) minimizing detection probability from the set of starting nodes up to a

locus of points at a guard response time away from the destination and (2) minimizing time from the locus to the destination. For sabotage problems, the destination is a target. For theft problems, the destination is off-site but the theft path must pass through a target.

COMPONENT FUNCTIONAL PERFORMANCE CHARACTERIZATION

In-House Activities

Generic Component Data-Base Modeling

Major accomplishments for this reporting period included the development of prototype FORTRAN interfaces which provide interactive browsing access to the BARRIER module of the Safeguards Engineering and Analysis Data-Base (SEAD). In addition, a definition tree for the SENSOR module has been appended to SEAD, and a retrieval capability has been demonstrated on a very limited SENSOR data base.

Other activities included the on-going piecemeal transcription to punched cards of the qualitative data tables of performance indicators compiled by SRI International and preliminary studies of prototype schemas for the GENERIC module of SEAD.

Contractual Activities

Generic Component Data-Base Modeling

During this reporting period, emphasis was placed on completion and editing of data for Task I of the SRI International contract and on preparation of the data in computer-usable form (under Task II) for entry-control, assessment, and communication equipment. Work under Task I on the generic data base has been completed. Administrative review by Sandia of the draft report, a prerequisite for publication, is in progress.

As part of the work on Task II, sets of data tables for entry control, assessment, and communications have been forwarded to Sandia along with explanatory, unpublished, text.

Printing and distribution of the final SRI International reports and implementation of an automated GENERIC data-base module will be accomplished at Sandia Laboratories. Therefore, no further reports will be issued on the SRI International work, which now can be considered as completed.

Neutralization

Human Parameters -- Work on the stress tolerance test was completed by Applied Psychological Services (APS). The Autogenic 3000 Skin Feedback Dermo-graph is used to measure stress. Time stress is induced by means of the mirror tracing task, which uses the Automatic Scoring Mirror Tracer manufactured by Lafayette Instrument Company. By the end of this quarter, the test had been fully designed and verified on three subjects. The results of these tests are encouraging.

A meeting was attended at Allied-General Nuclear Services (AGNS), Barnwell, South Carolina on 17 August to discuss the possible use of members of the AGNS security force as subjects for tests developed by APS. Attendees at this meeting included representatives from Sandia Laboratories, APS, and staff from the security and personnel organizations at AGNS. The APS tests were described and questions regarding them answered. AGNS personnel were receptive to the idea of the proposed tests.

APS has inquired into the possibility of using police officers as subjects for testing. The Philadelphia Police Department has indicated a willingness to cooperate in this effort. The Philadelphia police force uses the equivalent of SWAT teams and, therefore, would be ideal for these studies. Other police forces have also indicated a willingness to cooperate with APS in these tests.

The integration of human effects parameters into the Sandia Brief Adversary-Threat Loss-Estimator (BATLE) model was completed during this quarter. A report which describes the logic, sensitivity tests, and results was completed by APS. Minor changes to the report have been made by Sandia and the final report should be published in October.

Security Officers -- Discussions were held between members of the Sandia Barrier Technology Division, who are involved in work on Physical Protection Systems for the Department of Energy, and members of the Safeguards Methodology Development Division. These discussions centered on work related to the human component of physical protection systems. The training/evaluation program for transportation security officers developed by Missouri Southern State College (MSSC) was reviewed. In addition, current efforts in the evaluation of the human component of physical protection systems at nuclear sites were discussed. Specific interest was expressed in future Sandia efforts to extend the MSSC training/evaluation program to include fixed-site security officers.

A meeting was also held with the Sandia security organization to discuss the MSSC training program. A copy of the complete training package was given to security personnel and a request for comments was made.

Portions of the training program for security officers who accompany shipments of special nuclear materials (SNM) has been published by NRC as NUREG-0465 and distributed for comments. This training program was developed by MSSC under contract to Sandia Laboratories for the NRC Office of Standards Development. The document which outlines the rationale of the MSSC training program has been prepared for publication as a Sandia Laboratories report. This document, in conjunction with the NUREG-0465 draft, will provide complete documentation of MSSC efforts in the area of training of security personnel who accompany SNM shipments.

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EVALUATION METHODOLOGY

In-House Activities

Model Development

EASI -- An improvement to the legibility of the hard-copy output for the Estimate of Adversary Interruption (EASI) Graphics code has been implemented. This improvement provides better output reproducibility which will facilitate the preparation of good quality graphics for documentation and visual aids. Also, the document EASI Program Improvements for HP-67 and TI-59, SAND78-0506, was released in September.

FESEM -- The interactive version of the Forcible Entry Safeguards Evaluation Model (FESEM) has been modified to eliminate the problem of write-over on cathode-ray tube terminals. The FESEM output is now temporarily interrupted whenever the page is full of printing and the user is prompted to make a copy, if desired, and clear the page.

Automation of System Evaluation

Perhaps the best procedure for judging the usefulness of the Safeguards Automated Facility Evaluation (SAFE) methodology is through its application by NRC staff members or other analysts to specific facilities. These individuals are the most logical people to evaluate the form and format of the information provided by SAFE and to provide needed feedback on the usefulness of the methodology and output. Thus, most of the SAFE analyses performed during this quarter were done by NRC staff members on an example facility. In addition, a nuclear facility designed by Oak Ridge National Laboratory (ORNL) was also analyzed. An earlier design of this ORNL facility had been analyzed using SAFE and the results of this earlier analysis were incorporated into the design to produce the modified facility studied during this quarter.

SAFE Methodology Additions and Improvements -- Besides improvements to the user interface with SAFE which resulted from user's comments, several additions and updates to the SAFE algorithms have also been made. For example, two new functional modules have been added. One of these new modules is the stochastic pathfinding simulation model, PATHS. PATHS provides a third pathfinding routine

to supplement the KSPTH and MINDPT routines already included in SAFE. The other new module is the BATLE model. This model allows the user to estimate the probability of neutralization along a path. Therefore, the SAFE user can now calculate the probability of interruption, the probability of neutralization, and the probability of system win.

A modification was also made of the MINDPT and PATHS pathfinding algorithms in order to allow any node of the facility graph to be the terminal (last) node of paths found by MINDPT or PATHS. Previously, only target nodes (for a sabotage threat) or outer boundary nodes (for a theft threat) could be terminal nodes.

One present deficiency of SAFE is that the user must devote a great deal of time to manually identify regions and barriers within a facility. Much thought has been given to the possible automation of the entire process of region identification. To date, there has been little success with this approach. Some interactive approaches to the problem are being considered which may result in a suitable compromise.

SAFE Documentation -- The preparation of documentation for SAFE is proceeding in two phases. The first phase is the amendment of the computer codes in order to make them more efficient, to have them conform with ANSI Standard FORTRAN, and to internally document the programs with comments. The second phase is to prepare users' manuals. There will be two goals in the preparation of this documentation: (1) the philosophy behind the SAFE methodology and the algorithms used in the SAFE programs will be explained, and (2) a set of clear, user-oriented instructions for an analyst who wishes to perform a SAFE analysis will be provided.

Neutralization

Fixed-Site Neutralization Model -- Corrections and changes have been made to the Fixed-Site Neutralization Model (FSNM). Emphasis was placed on the conversion of FSNM from its original AMDAHL format to a format compatible with the Sandia CDC 7600 computer. To date, the FSNM, the PLEX preprocessor, and associated utility routines have been placed in the NOS time-sharing system, and a complete compilation has been made for editing purposes. The corrected files will be copied onto magnetic tape for check-out on the CDC 7600.

The FSNM has been estimated to require 300K octal words on the 7600 computer. The maximum small central memory available on the 7600 is 160K octal words. The common array, ITEM, in FSNM uses 41,900 decimal words. This

translates to a little more than 100K octal words. Since 1200K octal words are available, it appears probable that FSNM will go onto the 7600 computer with very little change since the common can be assigned directly to large core memory.

Contractual Support

Safeguards Network Analysis Procedure

Based on a review of the literature on gaming, an evaluation of the uses and benefits of a gaming capability in Safeguards Network Analysis Procedure (SNAP) was completed. The advantages frequently cited by the proponents of gaming include (1) the training and motivational value of games, (2) the improved model validation that is achieved since the analyst is permitted to participate in the execution of the model, and (3) the incorporation of complex human decisionmaking processes within the model. The primary disadvantage of gaming is the increased time and cost of model execution.

Design and coding of a subset of the SNAP interactive module were also completed during this quarter. This coding has been integrated into a copy of the current version of SNAP. Although only a small subset of the gaming features are included, it is anticipated that the demonstration module will illustrate the potential uses of gaming in SNAP models.

Coding implementation and debugging activities also included the development of new engagement combining procedures. With the completion of this development, it is now possible for several forces to be simultaneously involved in the same engagement. In addition, forces may now join an ongoing engagement, and the arrival of a force at a particular location in the facility may now trigger the merging of two previously separate engagements into one larger engagement.

Extensive application and testing of SNAP have been initiated. Two separate applications have been formulated through the use of the NRC Guard Tactics Simulator (GTS) facility. These applications have been designed to reflect scenarios which arose in the board game which was demonstrated during August. These applications will serve to illustrate the applicability of SNAP to GTS scenarios, to test the new capabilities, and to provide a vehicle for discussion and identification of new capabilities.

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TECHNOLOGY TRANSFER

A tutorial on the FSNM was conducted on 21-23 September. In addition to Sandia staff members, the tutorial was attended by R. Zimmerman of the NRC Office of Regulatory Research (NRC/RES) and R. Gramann, J. Ennis, B. Medelsohn, and B. Hatter of the NRC Office of Nuclear Material Safety and Safeguards (NRC/NMSS). The tutorial included a comprehensive description of the PLEX and data preprocessors as well as a module-by-module overview of FSNM process logic. The final day of the tutorial was spent on a demonstration of the use of the model to simulate an NRC/GTS scenario.

Computer codes for the Forcible Entry Safeguards Effectiveness Model (FESEM) and the Insider Safeguards Effectiveness Model (ISEM) have been transferred to NUS Corporation, a private consulting firm in Rockville, Maryland, and to Savannah River Laboratory. In addition, the Estimate of Adversary Sequence Interruption (EASI) Graphics code was also provided to NUS Corporation. Technical guidance and support for the implementation of these codes was provided by Sandia personnel. Also, a technical demonstration of the application of SAFE, FESEM, and ISEM was given to members of NRC/NMSS.

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Attn: G. Molen
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