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Physical Protection of Nuclear Facilities Quarterly Progress Report January - March 1981

Leon D. Chapman, Editor

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PHYSICAL PROTECTION OF NUCLEAR FACILITIES
QUARTERLY PROGRESS REPORT
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PHYSICAL PROTECTION OF NUCLEAR FACILITIES
QUARTERLY PROGRESS REPORT

January-March 1981

Contributors

Sharon L. Daniel
Louann M. Grady
Charlene P. Harlan
Mildred S. Hill
Bernie L. Hulme
Richard D. Jones
Mark Richardson
Suzanne L. K. Rountree
Dallas W. Sasser
Desmond Stack
G. Bruce Varnado
Richard B. Worrell

Leon D. Chapman
Editor

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QUARTERLY PROGRESS REPORT

January-March 1981

SUMMARY

In-House Activities

The vital area analyses of operating reactor facilities continued during this quarter. Vital area analyses were performed on seven pressurized water reactor (PWR) facilities and two boiling water reactor (BWR) facilities. Additional work in this area included use of example problems to extend the method for maintainability analysis of nuclear reactors using the Simulation Language for Alternative Modeling (SLAM). SLAM is also being employed in the development of a generic reactor personnel flow model used to investigate facility personnel flow and potential bottlenecks caused by queueing of personnel.

An investigation of the methods which can be used to define optimal security officer response strategies also continued this quarter. Integer programming techniques have been applied to two example problems to determine response strategies which would best protect the facility against sabotage acts. Comparison of results has provided insight into security officer deployment tactics. The same technique is also being applied to a generic nuclear reactor facility.

Modification of the Automated Region Extraction Algorithm (AREA) program of the Safeguards Automated Facility Evaluation (SAFE) method also continued this quarter, and a procedure file for SAFE that uses a pathfinding routine to find the minimum time path between all pairs of targets (up to 45) in a facility has been written and partially tested. The Brief Adversary Threat Loss Estimator (BATLE) Graphics code has also been modified to allow the user to select which side is observed for the dependent variable and which side is affected by the independent variable(s) in an engagement.

Contractual Support

Contractual support continued to be provided this quarter by Science Applications, Inc. (SAI) and Pritsker & Associates, Inc. SAI continued their work on the expansion and revision of generic sabotage fault trees (GSFTs) and the analysis of the insider reactor sabotage problem.

Pritsker & Associates, Inc. has essentially completed their efforts on development of a graphical input/output (I/O) package for the SAFE/SNAP (Safeguards Network Analysis Procedure) interface, including completion of the commands for the graphical input editor (GIE) of the SNAP operating system (SOS). A general review of the status of this project and its culmination is included in the body of this report.

FACILITY CHARACTERIZATION

In-House Activities

Vital Area Analyses

The vital area analyses of operating reactor facilities continued during this quarter. This work is being performed jointly by Los Alamos National Laboratory and Sandia National Laboratories, Albuquerque (SNLA) under sponsorship by the U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards (NRC/NMSS) and the Office of Nuclear Regulatory Research (NRC/RES), respectively. Analyses were performed on BWR Nos. 14 and 15 and on PWR Nos. 24 through 30.

Maintainability Analysis of Reactors

The investigation of the dynamic dependence of reactor systems on component availability continued this quarter. The analysis of reactor maintainability is being pursued as a means of incorporating time-dependent phenomena, such as run failure and repair activities, into reactor systems analysis of the insider problem. The SLAM simulation language is being used for this study. As part of this investigation, a small example problem was developed to extend the method for the maintainability analysis of nuclear reactors using SLAM. It is anticipated that four closely related problems, each of which incorporates a more detailed analysis of the same system than the preceding problem, will be addressed.

Reactor Personnel Flow

Work continued during this quarter on a generic reactor personnel flow model that employs SLAM. Investigation into reactor facility layout, particularly with regard to personnel flow, operating and emergency procedures, and potential bottlenecks has begun. The model should provide insight into the effects of security officer locations at times of alert, security infractions, bottlenecks at portals, etc., as well as pinpointing likely locations for queueing caused by personnel flow through the facility. This, in turn, should provide dynamic input for determining security officer response strategies.

Contractual Support

SAI, La Jolla, California, continues to provide assistance in the expansion and revision of the GSFTs developed by SNLA. The SAI contract is being extended to allow the development of pipe segment fault logic procedures for determining system level failures. This work will include the generic fault tree modules necessary for electrical system fault trees, control system fault trees, actuation system fault trees, and various component support system fault trees.

EVALUATION METHODOLOGY

In-House Activities

Optimization of Security Officer Response

The investigation of optimal security officer response strategies continued during this quarter. Initial results, which were obtained using a linear programming method, strongly indicated the desirability of employing an integer programming technique to obtain integer allocations. Noninteger results tended to cluster around 0.5, making it difficult to round to integer values with confidence.

Consequently, an integer programming technique was applied to an example problem to obtain integer allocations for differing response strategies. Different strategies for facility protection which were examined included (1) assignment of one security officer to every facility vital area, (2) assignment of one security officer to every cut set of vital areas, (3) limited vital area cut-set coverage, including corridors, and (4) limited vital area cut-set coverage using aggregate corridors or aggregate inside and outside areas. Parameterizing the number of security officers gave insight into security officer deployment tactics which provided different strategies for physical protection. The importance weights for the various doors and corridors leading to the targets were altered for one response strategy. This shifted the deployment locations and emphasized the necessity of a relative numerical ranking for all vital areas. Comparison of the results for three different response strategies highlighted their respective optimal objective function values, as measured by importance weights of vital areas with security officer assignments. Calculated values for the ratio of the objective functions to security force size for fixed numbers of security officers approached a limiting value, which can be used as a yardstick for comparison of results.

The integer programming technique was also applied to a second example problem. Comparison of the results for two stragegies for facility protection--assignment of one security officer to every vital area and assignment of one security officer to every cut set of vital areas--provided further knowledge on the use of differing security officer deployment tactics. Again, for the case in which one security officer was assigned to every cut set of vital areas, alteration of the importance weights for the various doors leading to the targets shifted deployment locations.

Current efforts in this area are focused on application of the integer programming technique to a generic nuclear facility. When completed, this application should provide insight into problems that may arise in the definition, solution, and application of security officer deployment methods.

Automation of System Evaluation

Computer Code Modifications -- Work continued on conversion of the AREA program (part of the SAFE methodology) to run on the Tektronix 4054. The only routines that still remain to be converted are those that accept user input on the stairwell regions and those that renumber the regions. An improvement was made to the algorithm in AREA that determines whether two line segments intersect. This resulted in a 30% to 40% reduction in run time for those cases tested.

A procedure file for SAFE has been written which uses a pathfinding routine to find the minimum time path between all pairs of targets (up to 45) in a facility. The pathfinding routine can be run without user interaction, thus allowing unattended execution during non-prime-time hours. The routine has been tested using an example data set; it has not yet been tested using actual facility data, however.

BATLE Graphics -- The independent and dependent variables available in BATLE Graphics have been modified to allow the user to select which side is observed for the dependent variable and which side is affected by the independent variable(s) in the engagement. The independent variable options for the two-dimensional and three-dimensional plots available in BATLE Graphics are

1. Weapon used,
2. Posture,
3. Exposure while firing,
4. Exposure while reloading,
5. Delay, percent time spent not firing,
6. Proficiency of firer,
7. Firing degradation due to firer's posture,
8. Firing degradation due to target illumination,
9. Tactic used,
10. Number of combatants on the force,
11. Time between reinforcements to the force,
12. Range of engagement, and
13. Time into engagement.

The dependent variable options include

1. Probability of side win, i.e., probability that zero opponents survive,
2. Probability that the expected number of combatants on a side is k, for k = 1, 2, 3,...,
3. Expected number on a side,
4. Ratio of expected number to initial number,
5. Ratio of expected number on a side to expected number on opponent's side, and
6. Probability of engagement termination.

The user must select either a two-dimensional or a three-dimensional plot and the independent variable(s) and dependent variable desired. The user must also indicate which side is to be observed for the dependent variable, the side affected by each independent variable (except for the choices of range and time-into-engagement), and a time-into-engagement value when the dependent variable is to be observed. The default assumption is that all combatants on the side are affected during the entire engagement by the independent variable(s). However, the user will be able to single out individuals and certain events, if so desired. In addition to the plot requested, the user will have the option of plotting the dependent variable value at steady state and time-to-steady-state as a function of the independent variable(s) chosen.

Documentation -- A general flow diagram, a detailed flow diagram for each subprogram, and a glossary of parameter names, variables, arrays, and files in the BATLE code have been added to the "BATLE User's Guide," which is currently undergoing final review.

Technology Transfer

Several requests for copies of existing safeguards evaluation codes were received by SNLA during this quarter. In response to one request, a magnetic tape of the BATLE program and its subroutines has been sent to Dynatrend, Inc; SNLA has asked to be kept informed by Dynatrend, Inc. of its use of BATLE. Also, magnetic-tape copies of the programs and subroutines for SAFE, SNAP, and the Matrix Analysis of the Insider Threat (MAIT) code have been forwarded to Rockwell Hanford Operations. Copies of available user's manuals for these programs were also provided. Representatives of Rockwell Hanford Operations visited SNLA in February for a demonstration of SAFE and a briefing on SNAP and then again in March for the purpose of learning how to use SAFE; they made use of the Graphical Representation through Interactive Digitization (GRID) program for facility digitization. Hanford intends to use SAFE to study the effectiveness of the safeguards system at one of its own facilities.

Contractual Support

Insider Reactor Sabotage Analysis

A draft report by SAI on the insider reactor sabotage analysis problem was delivered to SNLA this quarter and is currently being reviewed prior to publication of the final report. A presentation which covered the highlights and final results of this study was given to NRC personnel in Washington, D.C.

SAFE/SNAP Application Development

During this quarter, Pritsker & Associates, Inc. essentially completed their efforts on development of a GIE for the SOS. The following description of the progress reported by Pritsker & Associates, Inc. reflects not only the NRC-sponsored work on the input/output graphics capability for SNAP but also related work on the SAFE/SNAP interface, which is sponsored by the Naval Surface Weapons Center

(NAVSWC), and provides a general review of what has been accomplished as well as what still remains to be done.

All of the executive level commands for the SAFE/SNAP interface (shown in Table 1) are now operational. The READ and WRITE overlay processors that were originally planned as separate overlays have been incorporated into the executive processor.

Table 1

Executive Commands

Command	Function
ADENTRY,LIBR=R1,ENTRY=R2	Creates an entry
ADSITE,LIBR=R1,SITN=R2,PASS=R3	Creates a site
ADSCEN,LIBR=R1,SCNR=R2	Creates a scenario
ASSIGN,FILE=R1,LIBR=R2	Assigns a library file
CLOSE,FILE=R1,RETA=R2	Closes a library file
CREATE,FILE=R1,PASS=R2,MAXR=R3	Creates a library file
CURRENT,LIBR=R1	Prints the current entry
DELETE,LIBR=R1,ENTI=R2,RETA=R3	Deletes a site or entry
EDIT,ENTR=R1	Calls the graphical editor
GENERATE	Calls the SAFE-to-SNAP translator
GET,ENTI=R1,R1,R1,...	Gets entries from a library
LINK,LIBR=R1,SCNR=R2,ENTR=R3,R3,...	Links entries to a scenario
LIST,ENTI=R1,LIBR=R2,FSTA=R3,PASS=R4	Lists contents of a library
OPEN,FILE=R1,MAXR=R2	Opens a library file
QUIT	Stops execution
READ,FILE=R1,ENTR=R1,REWI=R3,PURG=R4	Reads a text file into a library
RENA,LIBR=R1,OLD=R2,NEW=R3	Renames an entry
RUN,LIBR=R1,SCNR=R2,FILE=R3,TRCE=R4, R5,BATL=R6	Calls the run processor
SAVE,ENTI=R1,R1,...,CONN=R2,RETA=R3	Saves an entry in a library
SELECT,LIBR=R1,ENTI=R2,PASS=R3	Makes an entry current
SOG,ENTR=R1	Calls SNAP trace graphics
UNLINK,LIBR=R1,SCNR=R2,ENTR=R3,R3, R3,...	Unlinks an entry from a scenario
WRITE,FILE=R1,ENTR=R2,REWI=R3, RECO=R4,R5	Writes a text file

The SAFE-to-SNAP translator (STST) is also operational, and debugging has been completed. The STST commands are shown in Table 2. STST allows the user to read SAFE data files and create an equivalent SNAP facility entry. Targets to which SAFE has generated paths can be displayed as can the paths themselves. The user can select a path that he wants generated automatically; STST will create a SNAP guard and adversary data entry for the selected path. The user can do this as often as he desires for each path SAFE has generated. In addition, if SAFE is run again with different options (minimum time, minimum detection, deterministic, stochastic, etc.), the new paths generated can be read into the facility; guard and adversary entries can then be created for these new paths. Furthermore, if only a SNAP analysis is being performed, a facility entry can be created by digitizing the facility and using SAFE procedures up to but not including the path-finding algorithms. This will expedite creation of the SNAP facility model, and the user can then create his own guard and adversary entries with the SNAP GIE.

Table 2

STST Commands

Command	Function
GENADVERSARY,PATH=R1,ENTRY=R2, FACILITY=R3	Generates an adversary entry
GENFACILITY,ENTRY=R1	Generates a facility entry
GENGUARD,PATH=R1,ENTRY=R2,FACILITY=R3	Generates a guard entry
PRPATHS,TARGET=R1,FACILITY=R2	Prints paths to a target
PRTARGETS,FACILITY=R1,NEW=R2,TYPE=R3	Prints target for which there are paths

User interactive input to the system is in the form

command,prompt=response,prompt=response...

Command and prompt names are significant to four characters. Some prompts have default responses and need not be given if the default is satisfactory. If only the command name is typed with no prompts, the user will be questioned interactively for all prompts. If some but not all prompts are given on the same line as the command, then the user will be queried only for the remaining prompts which have no defaults. Thus, a beginning user can be queried for all prompts, and an experienced user need not look up the prompts for an infrequently used command. Furthermore, typing CANC for any prompt name or response will cancel the current command (CANC is analogous to a BREAK key).

Examples of the use of the executive and STST commands are shown in Figures 1, 2, and 3.

```
  ENTER COMMAND
? open file=w1   <------- open a previously created library

  ENTER COMMAND
? assign file=w1
    FILE W1        IS NOW A WORKING  LIBRARY.

  ENTER COMMAND                                   select SHIP as current site
? select enti=ship pass=shippas <------                          internal error trap
 *ERROR IN  VPASL-        NO PASSWORD VALIDATION,KODE=    4 <--- which will be
    INVALID PASSWORD ENTERED.  PLEASE RE-ENTER THE COMMAND        suppressed

  ENTER COMMAND                                          user friendly error
? select enti=ship pass=shippass                          message

  ENTER COMMAND
? gene <-- ---------- invoke SAFE-to-SNAP Translator

  ENTER COMMAND
? prtargets faci=facl-2 new=n type=stoc <------ print previously generated targets
1
   TARGET NODES FOR-/SHIP    -FACL-   2/-

        SNAP LABELS    SAFE LABELS
           T606           606

  ENTER COMMAND
? prpaths targ=t606 faci=facl-2 <-- ----print the paths to target T606


   TARGET=(T606, 606)
    PATH NUMBER=  1  STOCHASTIC   /MIN INTER PROB    =   .9003
      (B417, 417)
      (X059,    0)   <---------------- added SNAP space nodes
      (B432, 432)
      (S061,9003)   <------------------ SAFE pseudo nodes
      (B411, 411)
      (X022,    0)
      (B604, 604)   <-------------------- SAFE barrier nodes
      (X060,    0)
      (B607, 607)
      (X061,    0)
      (T606, 606)

   ENTER COMMAND
   ?
```

Figure 1. Interactive Input--Example 1

```
                                        ┌───generate a SAFE equivalent
                                        │   adversary entry
 genadversary path=1 entry=adv-2 faci=facl-2
                    ADDED ENTRY -/SHIP    -ADV -    2/- ON WORKING LIBRARY

 DISTRIBUTION CODES
          1-DETERMINISTIC
          2-UNIFORM
          3-TRIANGULAR
          4-NORMAL
          5-LOGNORMAL

 ENTER CODE FOR BARRIERS
? 2

 ENTER CODE FOR SPACE TRAVERSALS
? 3

 DENG CREATED WITH ALL DEFAULT PARAMETERS

 ENTER NUMBER OF ADVERSARIES AND WEAPON
  TYPE(HG,SG,SA,FA,SM)
? 3 fa

 ENTER PROFICIENCY AND TIME OF ARRIVAL
? 50 o.   <──────────────────────────── mistake, entered "oh" for zero

    IMPROPER NUMERIC FIELD          <─────── free format error trap
  FREE FORM ERROR FIELD UNDERLINED IN RECORD  17
    50 O.
       --

    CORRECTLY RE-ENTER BAD FIELD AND REMAINDER
? 0.

 ENTER RANGE AT TARGET(0 TO 500 METERS)
? 4
```

Figure 2. Interactive Input--Example 2

```
list enti=* fsta=y  <-------------- list contents of working library
1

     FILE STATISTICS FOR WORKING LIBRARY
          FILE NAME                        =  W1

          UNIT NUMBER                      =         1
          MAX RECORD NO. ALLOWED           =       INF
          NO. RECORDS CURRENTLY IN LIBRARY =       430
          NO. OF RECORDS CURRENTLY UNUSED  =         0
          NO. OF RECORDS AVAILABLE         =       INF

    SITE    (PASSWORD)  SCENARIO       ENTRY
    ----------------------------------------------
   *SHIP
                             1
                                       GUA -    1 }       these were created
                                       ADV -    1 }  <--- previously and belong
                                       FACL-    2 }       to Scenario 1
                        (UNLINKED)
                                       ADV -    2
                                                ^
  ENTER COMMAND                                 \---- this was created in Example 2
                                                      and currently belongs to no
?  quit                                                scenario
     .414 CP SECONDS EXECUTION TIME.
 /
```

Figure 3. Interactive Input--Example 3

Development of the utility, basic, and modular commands for the GIE was also essentially completed during this quarter. All of the utility and basic commands are operational. Six of the basic command names were changed to facilitate their use and to make their syntax consistent. The convention now used for editing nodes and branches is to specify node or branch, depending on which symbol is to be edited, prefixed by A for add, C for change, D for delete, or M for move. In addition, the ADDSTAT command name was changed to ASTAT, and the PRINT name was changed to PSTAT.

The basic commands included in the GIE are ABRAN, ANODE, CBRAN, CNODE, DBRAN, DNODE, MBRAN, MNODE, SKETCH (edits FACILITY diagrams), ASTAT (adds STAT entries), DSTAT (deletes STAT entries), MODE (edits STAT entries), and PSTAT (prints STAT entries).

The utility commands included in the GIE are DRAW, EDIT, FACL, PAGE, RESTART, SCREEN, TEXT, VIEW, ZOOM, and QUIT.

Initial versions of all the modular GIE commands were completed during this quarter, and editing of the adversary detection networks was implemented. The PATH command, which is considered the cornerstone of most of the modular GIE commands, was among the first completed, paving the way for completion of the remaining modular GIE commands. Of the other commands, the ALARM command creates network sections which can be linked to guard path networks in order to facilitate simulation of various responses to alarms, and the ATTACK command links adversary path segments to create complete adversary networks. These two commands greatly expand the user's ability to prepare complete guard and adversary subnetworks rapidly. The PATROL command creates a network section for patrols and automates the task of creating one-directional and bi-directional guard patrol segments. The recently implemented MERGE command constructs a network segment to merge groups of forces, allowing these forces to be assembled one-at-a-time, two-at-a-time, etc.

Two subeditors (ATREE and TEXT) within the GIE were also completed. ATREE contains a family of commands for editing the adversary detection devices. The functions permitted are adding, deleting, and linking and unlinking devices from the adversary detection network. The TEXT command is used to edit parameter sets, ENGAGEMENT cards, PENG cards, and DENG cards; these SNAP statements have no graphical representation. TEXT provides interactive responses for displaying, replacing, adding, and deleting these statements.

Other work accomplished this quarter includes

1. Addition of a general defaulting capability to the GIE. Previously, it was necessary to enter an explicit response for each prompt. Now, however, for most fields on most nodes, a carriage return will supply a default value. Included in this capability are system-generated node labels for the ANODE (add a node) command.
2. Improvement of the DNODE (delete a node) command to permit a list of nodes to be specified.

3. Resolution of the few remaining differences in command syntax between the GIE and the rest of SOS.
4. Improved internal efficiency of the GIE through modification of an internal scanning program.
5. Removal of the automatic redraw feature of the GIE. The user must now specify DRAW to have the network drawn. This modification improves responsiveness since the user can specify several commands that set options before having the screen redrawn; previously, the screen was redrawn after each option selection.
6. Correction of several minor bugs and the addition of arrowheads to network branches.

Also, the SOS was changed from the overlay loader to the segmented loader on the SNLA Network Operating System (NOS). This allows more flexible memory management and reduces compatibility modifications which might be needed if the system is used on another computer. Segmentation has allowed the executive, GENERATE, RUN, and graphical editing processors to be run together for the first time in a single computer job.

The SOS permits considerable flexibility in the generation of facilities and paths for use by SNAP. The procedure involves reading the SAFE-generated data files to input the digitized facility description and adversary paths determined by SAFE. The facility and the paths are read independently; therefore, the following combinations are possible:

1. Execute SAFE completely. Read the facility and adversary paths into SOS and automatically generate SNAP guard and adversary subnetworks for any or all of the paths determined by SAFE.
2. Run SAFE again with new pathfinder options and read only the new paths into SOS. Create SNAP guard and adversary subnetworks using the newly read paths and the previously read facility.
3. Digitize the facility using the GRID program and the intelligent capability of the Tektronix 4054. Transfer the digitized information to the NOS and use SAFE procedures UAREA and UPREP. Do not run the SAFE pathfinders. Use SOS to read the facility but no paths. Create guard and adversary subnetworks with the GIE. This procedure uses the "smart" capabilities of the 4054 and some of the SAFE programs to prepare a SNAP representation of the facility. If only a SNAP analysis is performed, the effort needed to create the SNAP facility subnetwork is substantially reduced.

Work still to be completed in the next quarter includes final implementation of the RUN processor, which creates SNAP data cards from internally stored SNAP entries. The RUN command automatically produces the input data card file for SNAP from the internal library representation of the model. The RUN command has been implemented and is operational for SNAP models created with the GENERATE commands;

that is, RUN will correctly produce SNAP data input for models created from SAFE data. Final debugging of RUN with general models involving decision branching, flags, etc. (elements not present in SAFE emulation networks) was completed this quarter.

The design of a data transfer module which will become part of the RUN command processing has also been completed. Use of the PATH command in the GIE creates calls to the SNAP user function. The user function needs access to data that are internally generated by SOS. A specialized internal user function to perform this task will be written and incorporated into SNAP, and the RUN command will produce the extra data cards to be read by this internal user function. It is expected that this data transfer module will be implemented in April.

Other work scheduled for April includes continuation of minor clean-up activities, modification of the SNAP Output Graphics processor to accommodate multiple runs, and completion of user documentation for SOS. In addition, a test of SOS capabilities is being performed on a hypothetical facility. This application, while simple, will be the first complete operational test of SOS and should point out any minor errors which need to be corrected.

A demonstration of the capabilities of the SOS was given to SNLA representatives by Pritsker & Associates, Inc. in their Albuquerque offices on 18 March 1981 and will be repeated for NRC representatives in the near future.

SNAP

A list of SNAP "quirks" and problems was compiled during this quarter, and several of these problems were resolved. In addition, the current version of SNAP does not incorporate all of the data input changes specified in the new documentation. In April, the data input will be made compatible with existing documentation and the new BATLE module will be thoroughly tested. An updated, fully documented version of SNAP will soon be available, and the revised edition of the "Users's Guide for SNAP," SAND80-0315, will be available in July 1981.

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