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Physical Protection of Nuclear Facilities Quarterly Progress Report January - March 1980

Leon D. Chapman, Editor

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PHYSICAL PROTECTION OF NUCLEAR FACILITIES
QUARTERLY PROGRESS REPORT
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Sandia National Laboratories
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PHYSICAL PROTECTION OF NUCLEAR FACILITIES

QUARTERLY PROGRESS REPORT

January-March 1980

Contributors

Jim A. Allensworth
David E. Bennett
Sharon L. Daniel
Dennis Engi
Louann M. Gra[illegible]y
Charlene P. Harlan
Mildred S. Hill
Bernie L. Hulme
Richard D. Jones
Constantine Pavlakos
Dallas W. Sasser
Desmond Stack
David R. Strip
G. Bruce Varnado
Richard B. Worrell

Leon D. Chapman
Editor

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January-March 1980

SUMMARY

In-House Activities

In-house activities this quarter were principally related to facility characterization or evaluation methodology tasks. Facility characterization activities concentrated on the vital area analyses of operating reactor facilities, which are being performed jointly with the Los Alamos National Scientific Laboratory (LANSL) for the U.S. Nuclear Regulatory Commission (NRC). In addition, existing computer codes for rank ordering of vital areas were extended by the addition of subroutines to allow calculations of approximations to the importance measures. Several new approximation methods applicable to the vital area ranking techniques were also examined.

Evaluation methodology efforts this quarter concerned primarily the Safeguards Automated Facility Evaluation (SAFE) methodology and the Brief Adversary Threat Loss Estimator (BATLE) model. In support of a study on design concepts for sabotage protection, the SAFE methodology was applied to the Standardized Nuclear Unit Power Plant System (SNUPPS) facility. Alternative SNUPPS facility designs were also analyzed using SAFE.

Documentation of the SAFE methodology is approaching completion. The initial draft of Volume III of the SAFE Users Manual is still being prepared, and new sections are being added.

At the request of the NRC, modifications have been made to the new BATLE model, and the model is being refined. A version of BATLE which allows a user to vary combinations of input parameters and study the corresponding simulation results was also completed this quarter. This new BATLE version was used to perform sensitivity studies; the data generated by these sensitivity studies will be included in a forthcoming BATLE user's guide.

Work also continued this quarter on SEADIF, an interface program which will be used to combine SAFE and the Safeguards Engineering and Analysis Data-Base (SEAD).

Contractual Support

Contractual support related to the physical protection of nuclear facilities work was provided by Science Applications, Inc. (SAI), Management Group, Inc. (MGI), and Pritsker & Associates, Inc.

SAI continued to assist in the facility characterization efforts to expand and revise the generic sabotage fault trees (GSFTs) developed by Sandia National Laboratories, Albuquerque (SNLA).

MGI has been involved in the development of tactical response procedures for use by participants in the Multiple Integrated Laser Engagement System (MILES) experiments. MGI is also developing a technique for categorizing nuclear fuel cycle facilities in terms of site-specific tactics and procedures.

Pritsker & Associates, Inc. provided support in a number of areas related to the Safeguards Network Analysis Procedure (SNAP). Work was begun this quarter on the development of a SAFE/SNAP interface, the purpose of which is to automatically produce SNAP models which emulate the results obtained with SAFE. A preliminary graphics model which provides graphical traces of SNAP scenarios was also developed. Continued work on the implementation of the new BATLE model into SNAP has also required the development of new procedures to handle the arrival of reinforcements and the modification of force characteristics.

In the application of SNAP, initial modeling of the Site-X facility was completed this quarter and four scenarios were run. Initial results were presented to the NRC. Documentation on the Site-X application is being prepared as is a report on general SNAP modeling techniques.

FACILITY CHARACTERIZATION

In-House Activities

Vital Area Analyses

The vital area analyses of operating reactor facilities, which are being performed jointly with LANSL for the NRC Office of Nuclear Material Safety and Safeguards (NRC/NMSS), continued as the major activity during this quarter. Analyses for two boiling water reactors (BWRs) and two pressurized water reactors (PWRs) have been completed. In addition, changes were received and analyses rerun for eight BWRs and five PWRs.

A paper entitled, "A Boolean Approach to Common Cause Analysis," was presented by R. B. Worrell and D. W. Stack, Org. 4414, at the 1980 Annual Reliability and Maintainability Symposium, which was held in San Francisco, California, on 22 to 24 January 1980.

Rank Ordering Vital Areas

Work continued this quarter on the development of vital area ranking techniques. Existing computer codes were extended by the addition of subroutines to calculate approximations to the importance measures. This extension allows the ranking program to work with extremely large fault trees while using only small amounts of computer time. An algorithm to aid in further modularization is being developed.

A briefing on importance measures for ranking vital areas was given to staff members from the NRC Office of Regulatory Research (RES) and NRC/NMSS. Discussions covered the concepts of vital area ranking, basic research problems, and the application of vital area ranking techniques using existing software.

Several new approximation methods applicable to the vital area ranking techniques were examined during the past quarter. This study was prompted by the fact that existing literature on this subject relies upon rare events to justify the approximations. This is often not the case in safeguards applications; therefore, a new approximation technique is required.

Contractual Support

Generic Sabotage Fault Tree Development

During this quarter, SAI continued to provide assistance in the expansion and revision of the GSFTs developed by SNLA. These revisions are being made in order to improve the utility of the trees and to reduce analyst time required for their application. The revised trees developed in this task will be logically equivalent to the ones currently in use but will be structured to enhance applicability.

Three members of the SAI staff visited Sandia on 17 and 18 January to discuss and review the current status of this work. The discussion included

1. Extension of the generic trees to include the capability of risk and safety assessment,
2. Review of the revised PWR and BWR treetops,
3. Changes to the loss-of-coolant accident (LOCA) and transient sabotage fault trees, and
4. Review of the forms for the component fault tree questionnaires and analyst's instructions.

Staff members from Sandia visited SAI in La Jolla, California, on 21 and 22 February to discuss and review the current status of the GSFT work.

COMPONENT FUNCTIONAL PERFORMANCE CHARACTERIZATION

Contractual Support

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Guard Response Tactics for Engagement Experiments

MGI is currently working on the development of tactical response procedures for use by participants in the MILES experiments. Since the facilities used for these experiments resemble fuel-cycle facilities, the generic response procedures that are developed may be appropriated for operational fuel-cycle facilities. In addition, a number of site-specific tactics and procedures are provided to assist in the formulation of a technique for categorizing facilities. This categorization should serve as an aid to the analyst in determining adequate guard tactics and procedures to counter potential adversary attacks on a site-specific basis. However, it is felt that an in-depth study of each site will be necessary to define the appropriate tactics for each facility. Recommendations for implementation of the tactics will be presented in a final report.

Five hypothetical adversary attack scenarios and their interaction with a set of hypothetical facilities have been described. First, simulations of the adversary scenarios are run for hypothetical facilities which employ incorrect guard procedures and which, in all likelihood, would result in adversary success. These scenarios are followed by an analysis which explains the adequate guard procedures for countering the adversary attack scenarios.

MGI is also developing a technique for categorizing nuclear fuel-cycle facilities in terms of site-specific tactics and procedures. This technique should be useful in determining a particular facility's ability to counter adversary attack scenarios. Simulation of specific scenarios against a facility will allow an analyst to determine whether or not the security system at the facility has established tactics or procedures capable of countering the specific threat defined in the scenarios and, if it has not, which tactics or procedures should be added to the security system to provide the necessary safeguards.

EVALUATION METHODOLOGY

In-House Activities

Automation of System Evaluation

SAFE Applications -- During this quarter, the SAFE methodology was applied to the SNUPPS reactor facility in support of the study on design concepts for sabotage protection. The baseline SNUPPS facility design and some alternative designs have been examined. Following the initial analysis of the baseline design, the component performance data for the baseline case were reviewed and additional analyses performed.

An alternate physical facility layout was digitized during February. Three different physical protection system configurations were specified for the alternate design, and a complete SAFE analysis was performed for each configuration. A third facility layout, which contains a minor addition to the baseline facility, has also been analyzed. Once these analyses have been completed, the results for all designs will be compared and documented.

SAFE Documentation -- Preparation of Volume III: "Example Application" of the SAFE Users Manual continued during this quarter. New sections have been incorporated and existing sections are being reviewed.

Computer Code Modifications -- The new BATLE model was described to NRC staff members on 17 January 1980. At the request of NRC, the following modifications were made to the new code:

1. A new output file was created for BATLE which contains the probability densities generated each time the probability of battle termination increases by 0.1. The user has the option to output this file, if desired.
2. BATLE contains an editor written in FORTRAN that can be used to quickly modify a previous scenario in preparation for rerunning the model. This option enables the analyst to make various changes to the scenario and to observe the effect of these changes, e.g., different weapons, better cover, new ranges, etc., on the battle outcome. This FORTRAN editor is being modified, using a menu approach, to facilitate user interaction.
3. Proficiency in firing accuracy has been included as an input parameter, while the number of months since last trained parameter has been deleted.

The new BATLE model is being refined, and sensitivity studies have been performed in order to provide information to be included in a user's guide to BATLE. A condensed version of this documentation was completed in February for inclusion in the SAFE Users Manual, which is currently being prepared.

A version of BATLE which allows the user to vary combinations of parameters and study the corresponding results was completed in February. This version allows the user to generate results that can be plotted manually to facilitate sensitivity analyses. It is expected that this new code will serve as the core of BATLE Graphics, an interactive computer version of BATLE.

The principal utility of BATLE lies in its use as a technique for examining the effects of varying the security force size and strategy on the probability that a postulated security force will defeat a given adversary force. To illustrate this capability, several example sensitivity studies are presented in the following paragraphs. The inputs used in these examples are fictitious and were chosen solely for illustrative purposes.

First, a fixed scenario for BATLE is set up. Initially, the conditions for the battle are the same for both sides:

1. Number of guards and adversaries -- three each,
2. Weapon type -- semiautomatic rifle,
3. Posture -- prone,
4. Exposure during firing -- 20%,
5. Exposure during reloading -- 0%,
6. Delaying tactics -- none,
7. Proficiency -- average, and
8. Firing degradation due to firing posture or target illumination -- none.

Since both sides are identical in this fixed scenario, the probability that the guard force will defeat the adversary force is 50%, regardless of the range of the battle. However, varying the guard characteristics without making changes to the adversary force characteristics does affect the outcome of the battle.

Figures 1 through 5 illustrate the effects of various parameters on the probability of a guard win. In Figure 1, the probability of guard win as a function of range is plotted for all five possible weapon types (SA = semiautomatic rifle; FA = fully automatic rifle; SM = submachine gun; SG = shotgun; HG = handgun). In Figure 2, the probability of guard win is plotted as a function of guard exposure while firing for two, four, six, and eight guards. In Figure 3, the probability of guard win is plotted as a function of guard posture for two, four, six, and eight guards. In Figure 4, the probability of guard win at a range of 10 meters is plotted as a function of the number of guards in the battle for each weapon type available. The same parameters used in Figure 4 are plotted in Figure 5 but for a range of 50 meters rather than 10 meters.

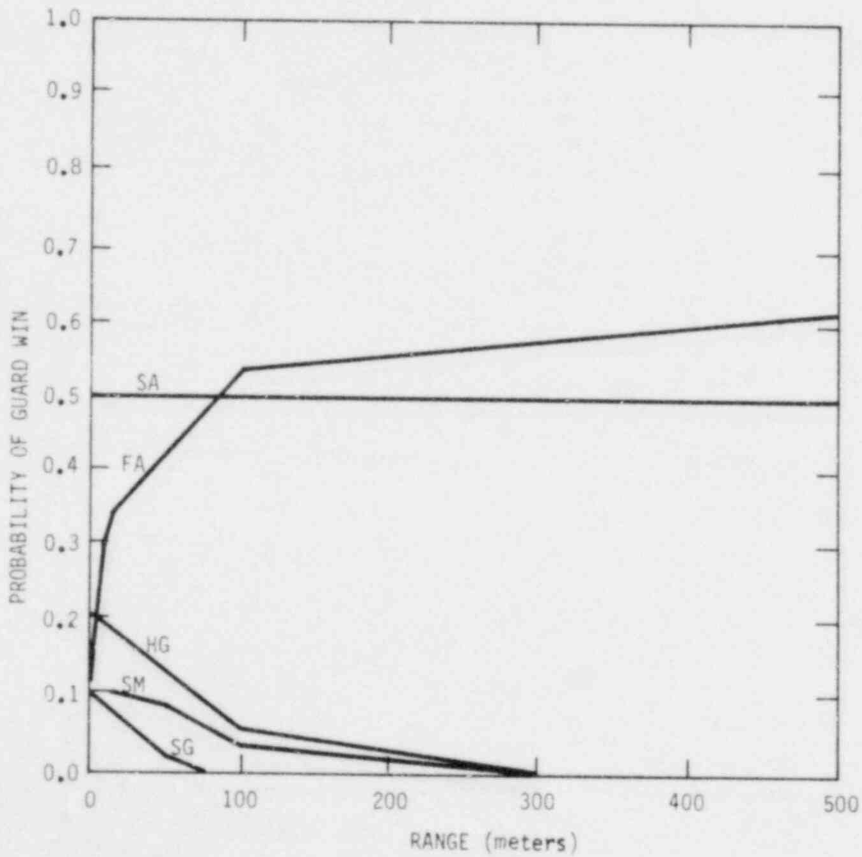

Figure 1. Probability of Guard Win as a Function of Range and Weapon Type

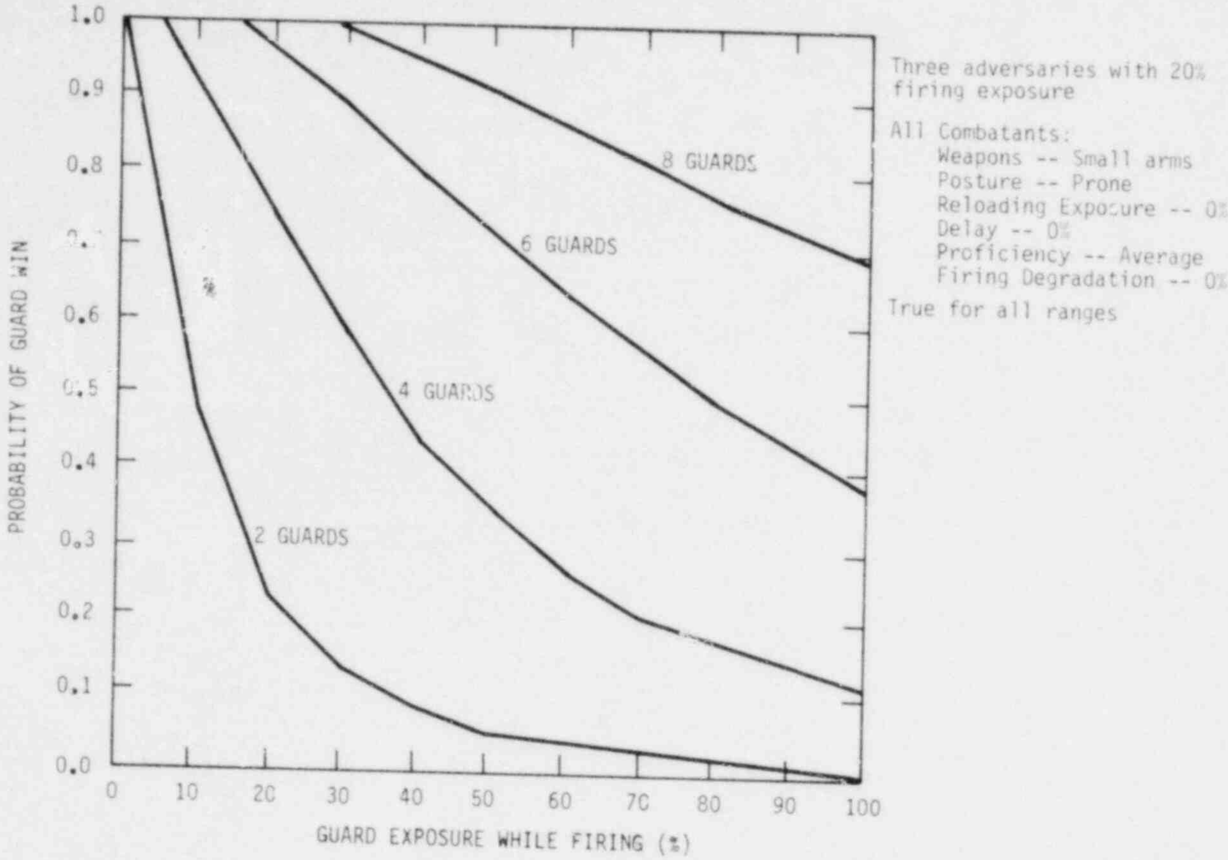

Figure 2. Probability of Guard Win as A Function of Guard Exposure while Firing and Number of Guards

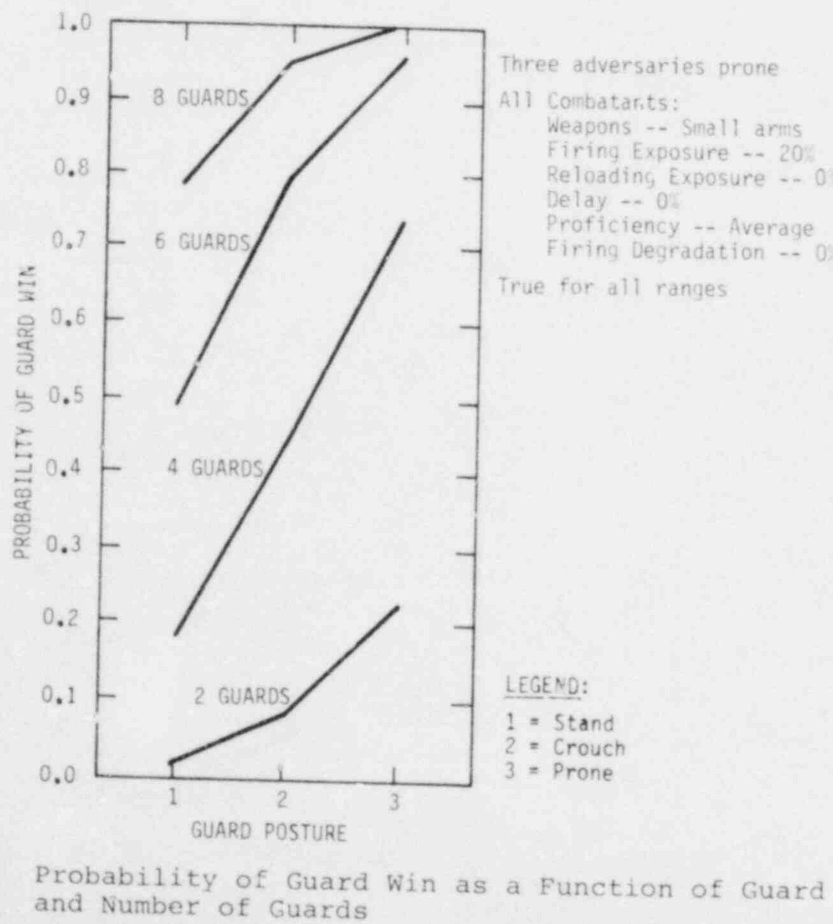

Figure 3. Probability of Guard Win as a Function of Guard Posture and Number of Guards

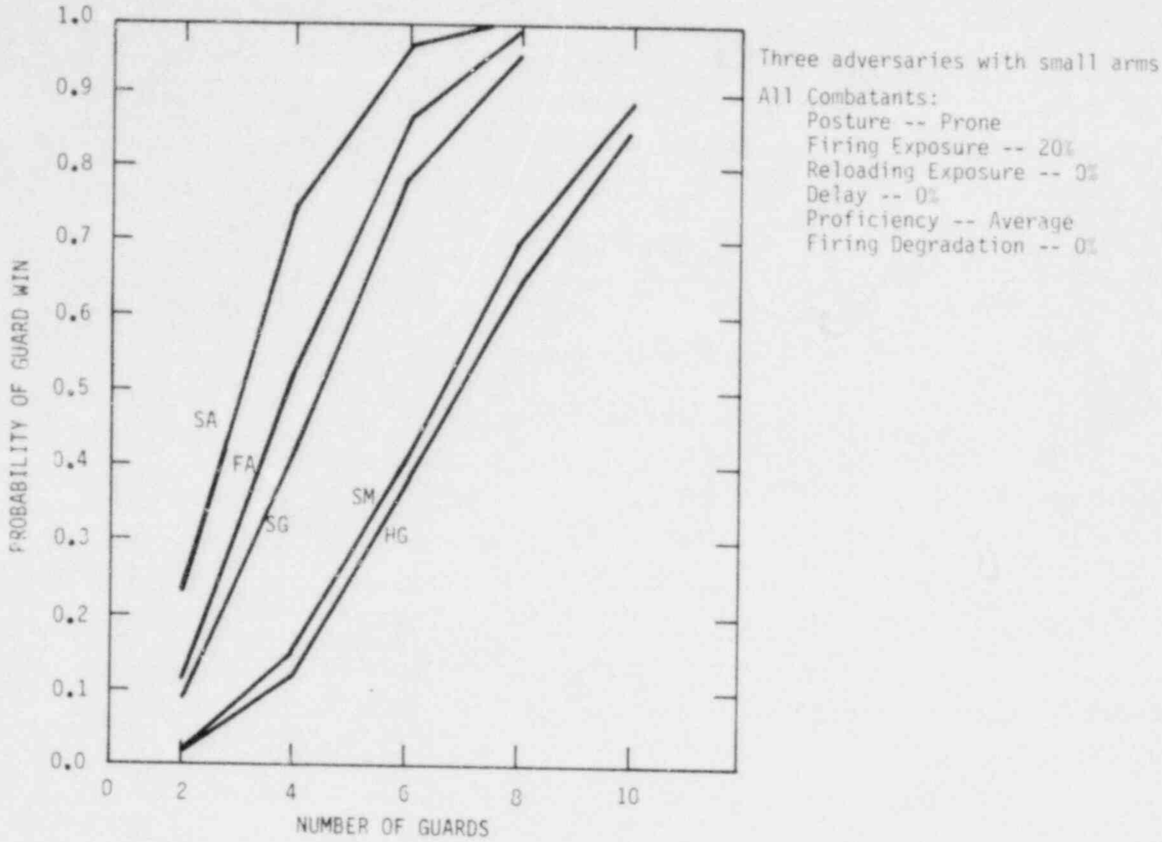

Figure 4. Probability of Guard Win at 10 Meters as a Function of Number of Guards and Weapon Type

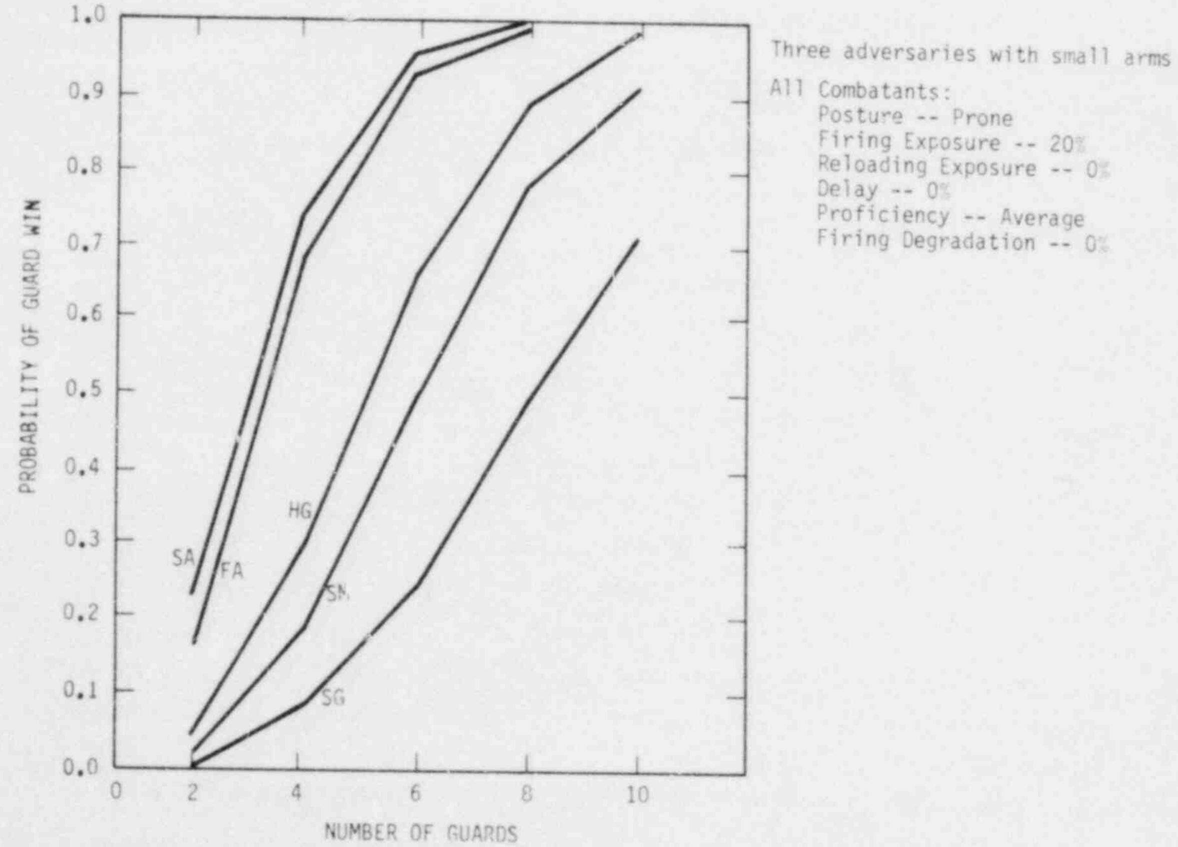

Figure 5. Probability of Guard Win at 50 Meters as a Function of Number of Guards and Weapon Type

SAFE/SEAD Interface -- Also this quarter, work continued on an interface program, SEADIF, which will combine SAFE and SEAD. Although both SEAD and the SAFE interface load onto the computer separately, when combined, a large array structure for the combined program must be accessible by SEAD. The result is too large to load; therefore, overlays are being used to segment portions of the SEAD program.

Contractual Support

SNAP Application Development

SAFE/SNAP Interface -- Work on a SAFE/SNAP interface was begun by Pritsker & Associates, Inc. in March 1980. The initial effort has been directed toward a review of the SAFE procedure in order to determine requirements for the interface software. It appears that some design changes to SNAP will facilitate creation of a unified SAFE/SNAP methodology. In particular, the SAFE facility representation module is being considered for direct incorporation into SNAP.

The intent of the SAFE/SNAP interface is to automatically produce SNAP models that emulate the results obtained from SAFE. (Preliminary tests with a simple SNAP model have been successful in duplicating the SAFE results.) These automatically generated models will form the basis for more extensive analyses and scenario modifications using SNAP.

The current conceptual design of the SAFE/SNAP interface includes the following capabilities:

1. Direct use of the SAFE facility representation module,
2. Automatic generation of SNAP networks to emulate the guard and adversary scenarios produced by SAFE,
3. Interactive programs to create and edit SNAP guard and adversary networks at a computer terminal, and
4. Certain design additions to SNAP to facilitate modeling security force routing and alarm response.

Graphics Input/Output -- A preliminary graphics module was developed this quarter which provides a graphical trace of SNAP scenarios using the Tektronix 4014. This module has proved useful in debugging SNAP models, as well as for illustrating the outcome of particular SNAP scenarios. The graphics module has been demonstrated to the NRC, and the preliminary graphics program has been updated in response to comments received from Sandia and NRC personnel. These changes facilitate the use of the graphics package and also clarify the graphical output. Preliminary design work was also initiated on the identification of graphics modules which will be required in conjunction with the SAFE/SNAP interface.

Implementation of the New Version of BATLE -- Implementation of the BATLE model into SNAP continued this quarter. Although the new version of BATLE is statistically equivalent to the analytical BATLE model, the transition to discrete-event simulation has required the development of new procedures to handle the arrival of reinforcements and the modification of force characteristics.

The first of these new procedures focuses on the development of a simulation-based process for the computation of casualty rates. This development necessitated the estimation of various engagement parameters which are provided analytically in BATLE. Average outcomes are statistically equivalent to those produced by BATLE.

The second new procedure involves the development of techniques which allow the user to control discrete changes in engagement characteristics. The status of an individual's engagement characteristics may vary both independently of or in conjunction with the individual's location. This flexibility was accomplished by the addition of engagement "nodes" which may be linked together to represent changes in engagement status conditions. This capability allows the user to predefine discrete changes in conditions in much the same way as is done in BATLE.

The implementation of the new BATLE model has been accomplished through the addition of 33 new subroutines and program functions. In addition, modifications were made to 20 of the existing routines. The resulting input requirements are not completely compatible with either of the two previous engagement models; however, only minor modifications will be required to execute the more basic scenarios.

The new BATLE model will be used in the analysis of the four Site-X scenarios that were run using the previous version of the BATLE model. A comparison of results between the two engagement models will be made.

New statistical output has been designed and implemented to provide information on the characteristics of engagements in SNAP using the new BATLE model. This output will provide statistical information on the nitial status of engagements and on the status of engagements as time progresses. The purpose of the new output is to extract data from engagements as they occur in SNAP and allow the user to use these data to perform a further analysis with the analytic version of the BATLE model available in SAFE.

Output related to the initial status of engagements provides the analyst with information on the frequency of occurrence of guard and adversary attributes at the initiation of an engagement. Information generated during the progression through an engagement will be reported for average guard and adversary attributes over discrete time intervals.

Application of SNAP to Site X -- Initial modeling of the Site-X facility was completed during January 1980, and all four scenarios were run to provide preliminary analysis information concerning the outcome of each scenario. These initial results were presented to the NRC at a recent working session devoted to discussion of the status of the Site-X facility models.

Modifications to the Site-X model which were requested by the NRC included the following:

1. Modify the SNAP insider scenario to make the insider unarmed,
2. Provide the adversary cover with firepower from the parking lot for the insider scenario,
3. Move the guard outer defensive location from the northeast corner of the facility to a more prudent interior point, and
4. Incorporate the new features of the BATLE model into the SNAP analysis.

When completed, the final results of the Site-X study with the above modifications will be presented to the NRC. In addition, a report on the Site-X application is currently being prepared.

Documentation -- In addition to the Site-X report, a document that discusses general SNAP modeling techniques is being prepared. This report will present standard procedures for building SNAP networks to model frequently encountered safeguards system components such as guard patrols, response to alarms, and communications.

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