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Safeguards Material Control and Accounting Program: Quarterly Report July-September 1979

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Prepared for
U.S. Nuclear Regulatory
Commission

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FOREWORD

This work was supported by the U.S. Nuclear Regulatory Commission (Office of Nuclear Regulatory Research) under A Memorandum of Understanding with the United States Department of Energy. The NRC FIN number is A-0115.

The scientific editor, Donald R. Dunn, wishes to acknowledge the work of those individuals responsible for each section listed below. In addition, he wishes to express his thanks to Frank Brunotts for editorial assistance.

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ABSTRACT

Activity for the quarter July-September 1979 in the Material Control Safeguards Evaluation Program, conducted for the U.S. Nuclear Regulatory Commission (NRC) at Lawrence Livermore National Laboratory, is summarized. Progress was made in developing a computer-based methodology for identifying vulnerabilities in Material Control and Accounting (MC&A) systems in nuclear fuel-cycle facilities. This progress took the form of deliverables reporting work completed in the Structured Assessment Approach (SAA) methodology, and a Phase II Safeguards Vulnerability Assessment Methodology (SVAM) application to G.E. Vallecitos Nuclear Center. Moreover, SVAM was developed into a computer-based assessment strategy called Safeguards Vulnerability Analysis Program (SVAP). Work continued in assisting the NRC to develop the forthcoming MC&A upgrade rule. Other areas of activity reported on here are aggregated systems model development, adversary modeling, and components performance.

1.0 INTRODUCTION

In the second quarter of FY79 the Nuclear Regulatory Commission (NRC) redirected the Lawrence Livermore National Laboratory (LLNL) Material Control Safeguards Evaluation Program into two main areas: (1) continued development of an automated, computer-based methodology for assessing the vulnerabilities of Material Control and Accounting (MC&A) systems of fuel-cycle facilities, and (2) assistance in the development of guidance for the forthcoming MC&A upgrade rule.

The automated assessment methodology effort was further redirected in the third quarter to specifically develop and deliver the Structured Assessment Approach (SAA), Levels 1 through 4, computer codes and documentation within the FY79 time frame. The SAA work was pursued and supported as directed so that it initially could be applied by the NRC to test compliance to the Part 73 Fixed Site Physical Protection upgrade rules. We were able to achieve our objectives and delivered to the NRC the SAA computer codes and draft documentation consisting of four volumes.[1]

On the other hand, Task 1 of the LLNL program plan was to do a Phase II analysis of Facility X, a fuel-cycle facility, using our Safeguards Vulnerability Assessment Methodology (SVAM). A Phase I analysis for Facility X had been accomplished in January 1979 based only upon the information currently available at the NRC and upon assumptions approved by the NRC. Documents reporting on the Phase I analysis have been delivered. The basis of a Phase II assessment was to include visits and detailed discussion with facility personnel. Our goals to visit Facility X early on were not successful due to delays outside the control of LLNL. We, therefore, chose to develop the SVAM tool further to prepare better for a Facility X visit and for the subsequent analysis of the Facility X data. Eventually, under the NRC's direction, the planned Facility X Phase II assessment was dropped (August 1979) and in its place we did an assessment of G.E. Vallecitos Nuclear Center (VNC). While awaiting approval for entrance into Facility X, we were able to evolve SVAM into a computer-based assessment strategy called

Safeguards Vulnerability Analysis Program (SVAP). Thus, at the end of this quarter we provided in draft form two main deliverables associated with Task 1: (1) Assessment of VNC (draft information), and (2) SVAP methodology and documentation.[2-4]

SAA and SVAP are complementary tools; SAA does have the flexibility to yield a broader assessment than SVAP but at the expense of requiring far more input data. For example, SAA can assess scenarios which allow an adversary threat to penetrate walls, material process pipes, etc., whereas SVAP only allows normal facility entry/exit points. These characteristics may make SVAP more appropriate for field use in examining existing facilities, while SAA could be used to examine and influence the safeguards designs of new facilities. Both the SAA and SVAP contributions for this quarter are discussed in Section 2 of this report.

Sections 3-6 summarize the tasks which have been in support of the MC&A upgrade rule development. Section 3 describes results of a systematic evaluation and critique of the current NRC material accounting regulations. The basis of the study was the development and subsequent analysis of a minimal material accounting system primarily gleaned from the requirements imposed by regulations.

Section 4 reports on using the Aggregated Systems Model (ASM) to do a value-impact (V-I) analysis for the VNC safeguards system. In response to NRC feedback on this effort, LLNL demonstrated in a broader manner the application of V-I analysis of safeguards rules for systems performance specified at several levels: components or procedures, subsystem, the facility, etc. Draft reports of our V-I methodology and its application to the VNC were presented to the NRC on schedule in late September.[5,6]

Section 5 discusses our work to characterize the insider threat to nuclear safeguards by looking at security data from analogous industries. The objectives of this effort are being met and no plans presently exist to extend it into FY80. Results of this work also were delivered on schedule.[7]

Section 6 describes our limited investigation into the use of process monitors as Special Nuclear Materials (SNM) loss indicators for the concentrator and precipitator unit processes at Facility X. In this one instance two LLNL engineers were permitted to spend one-half day at Facility X in July reviewing their concentrator and precipitator unit processes. A draft report for this effort was delivered on schedule in late September.[8]

2.0 ASSESSMENT METHODOLOGY DEVELOPMENT

2.1 STRUCTURED ASSESSMENT APPROACH

D. Freeman, A. Parziale, C. Patenaude, D. Ross, I. Sacks*

This section presents methodological and application developments which have been achieved over this quarter for SAA. Most of the development work for this quarter was devoted to finalizing the SAA Version 1 user-oriented computer program package, including the debugging of the package using Faciity X Phase 1 data and the application of the package to a full-scale hypothetical fuel-cycle facility (HFCF).

The remainder of this section discusses the SAA documentation[1] which was delivered in draft form to the NRC at the end of September 1979. The basic organization of the SAA documentation is shown in Fig. 1, and includes the following four volumes:

Volume I: The Structured Assessment Approach Version 1 Analysis Package, Executive Summary.

Volume II: The License Submittal Document Content and Format for Material Control and Accounting Assessment.

Volume III: The Structured Assessment Approach Applied Demonstration of Output Results.

Volume IV: The Structured Assessment Approach Version 1 Computational Analysis Package.

Volume I, the executive summary, provides an introduction to the SAA, its basic design philosophy, its data input requirements, and the types of outputs which result from an SAA analysis of an MC&A system. Volume I also provides a general overview of SAA and is intended to guide the reader to the in-depth discussions presented in Volumes II, III, and IV.

Volume II presents the requirements for the data which a license applicant should submit to the NRC for analysis along with data format requirements.

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*Consultant.

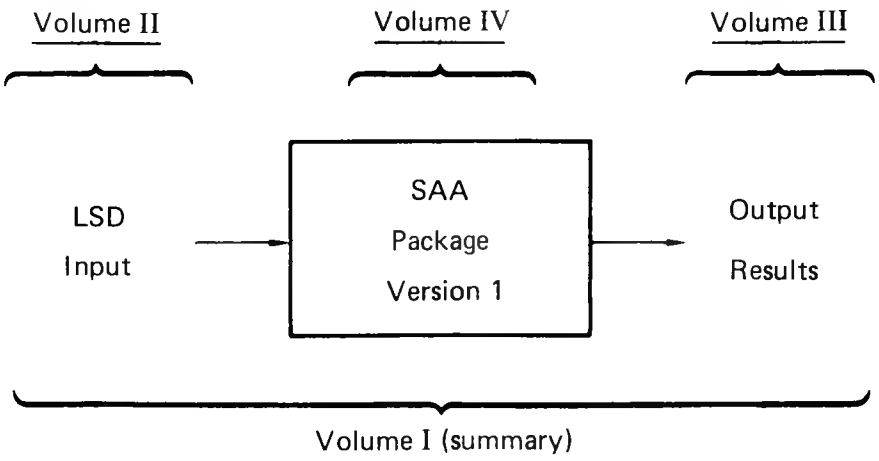

FIG. 1. Organization of documentation.

These data are requested in the form of a License Submittal Document (LSD); Volume II presents an example of the data construction process applied to the HFCF. Volume II is intended to serve as an NRC user's manual to aid in the construction of the LSD so as to meet future upgrade rules.

A description of the assessment package output for each stage of the SAA analysis for the HFCF is presented in Volume III, which is intended as a guide to assist the NRC license reviewer in the interpretation of SAA analysis results.

Volume IV presents the computational aspects of the SAA assessment package, including technical descriptions of the analyses and current computer program flowcharts and listings.

2.2 SAFEGUARD VULNERABILITY ANALYSIS PROGRAM (SVAP)

M. Dittmore, F. Gilman, W. Orvis, P. Wahler

2.2.1 New Developments

We recognized the need for a formal and simple guide to assist an analyst in entering facility data into the Tektronix 4051 computer for processing prior to a SVAP analysis on a main frame computer like LLNL's CDC 7600. The concept of a data-gathering handbook was then formalized and the handbook's

structure was devised. The handbook provides a checklist for the analyst to follow while gathering data and guides him through the steps necessary to put that data into a suitable form for entry into a 4051 computer.

Two disk drives were received for the 4051 computer this quarter and the SVAP input codes were modified to utilize them. This system upgrade resulted in a tenfold increase in data entry speed.

The 4051 codes were further modified to make the data entry operation more user-oriented. Ambiguous and unclear instructions had been found in the codes; these were corrected and improved.

A procedure for analyzing accounting systems was conceived, formalized, and incorporated into the SVAP analysis codes.

A set of three documents describing SVAP, all in preliminary drafts, was prepared and delivered:[2-4]

- The Executive Summary
- The Data-Gathering Handbook
- The SVAP User's Manual.

2.2.2 Applications

During the quarter we conducted an assessment of the MC&A system of the advanced fuels lab at G.E. Vallecitos. The acquisition of the data and completion of the data handbook was done by two people in one week. About eight hours were spent at the facility. The Vallecitos staff expressed their appreciation for the ease with which this assessment was carried out. Draft information on this assessment has already been delivered to the NRC.

Our experience in the Vallecitos analysis revealed deficiencies in the data handbook which have since been corrected. We now plan to submit the improved

handbook to the Vallecitos staff for filling out without any help from the LLNL staff. This will test our anticipation whether the handbook can be filled out by a facility's staff.

Data entry into the computer, data validation, consistency checks, and the actual running of the assessment programs for our Vallecitos analysis took about one man-week. The results were reviewed with the Vallecitos staff, who were in general agreement with the findings. It was during this review that the deficiencies in the handbook mentioned above were identified. After the review the Vallecitos management was enthusiastic about the procedure and expressed a desire to be able to implement SVAP on their own.

3.0 MC&A UPGRADE RULE SUPPORT

P. Alesso, J. Huebel, J. Lim, R. Sanborn, R. Thatcher

The purpose of this task is to systematically evaluate and critique the current material accounting (MA) regulations. To evaluate the MA regulations a generic, minimal material accounting system model is being developed which reflects the requirements, both explicit and implicit, specified by the regulations and by accounting systems in general. To critique the MA regulations this minimal system will be analyzed by an adaptation of the fixed-site safeguards assessment methodology.[9] The analysis identifies vulnerabilities inherent in the current MA regulations.

To motivate development of a minimal material accounting system, we first constructed models of specific MA systems. In particular, the MA systems at Facility X and at VNC were modeled using logic diagrams.

The logic diagram for VNC consists of a three-step sequence of comparison, threshold test, and response. Three submodels were used to accomplish this sequence; they were models of the reference system, measurement system,. and the limit of error system, respectively. Boolean equations were derived from the logic diagram for the VNC MA system. The equations were solved by the SETS[10] computer code for the falsification vulnerabilities and the collusion vulnerabilities. The next step was to incorporate into a new model only those features, common to both the Facility X and VNC MA systems, that were required by the current MA regulations.

The development of the logic diagram for a generic minimal MA system was completed. The generic MA system model delineated the various data sources, data types, data checks, and data access controls which characterize any MA system in compliance with the current regulations. The generic model contained no site-specific licensing elements. This system is generic in that it is representative of the material accounting systems of any current nuclear facilities licensed by the NRC; it is minimal in that it contains no safeguards or accounting elements in excess of those required by regulations. The logic diagram of the generic minimal system delineates the current MA capabilities required by the NRC.

The current NRC material accounting regulations are being evaluated by the assessment of the generic minimal MA system. The assessment of the system involves the derivation of a set of Boolean equations from a logic diagram model and the solution of these equations for the event sets. The event sets consist of the minimal sets of safeguards and accounting elements which must be tampered with in order to disguise a special nuclear material theft. Moreover, the event sets will indicate the vulnerabilities inherent in the current NRC material accounting regulations.

In addition to the above, an upper level functional decomposition for material accounting was completed this quarter. This decomposition organized material accounting into basic functions in a systematic logic tree. The functions were organized to separate the responsibilities of the NRC, the facility management, the control area custodians, and the unit process operators. This information has been provided as input to the ongoing LLNL/NRC task: Development of Guidance for Material Control and Accounting System Design.

4.0 AGGREGATED SYSTEMS MODEL (ASM) DEVELOPMENT

R. Al-Ayat

4.1 INTRODUCTION

In the previous quarterly we described our approach to value-impact (V-I) analysis using the ASM. Work this quarter was devoted to demonstrating the V-I methodology at an operating facility; namely, VNC. A draft report on the study for VNC was completed and delivered to the NRC on schedule.[5] In what follows we briefly describe the data-gathering effort and the analysis performed.

4.2 DATA GATHERING AT VNC

Our data-gathering effort at VNC consisted of several working sessions with a team of experts from the facility. The team represented a variety of occupations; e.g., personnel from physical security, material control and accounting, operations and management.

The data elicitation closely followed the ASM framework. Only information for the adversary model, S/G technology model, and the facility model were gathered. The following briefly describes the type of information gathered.

4.2.1 The Adversary Model

Here we identified generic types of adversaries and their strategies. The strategy description included SNM goal quantity, collusion, falsification of records, and/or substitutions of material.

4.2.2 S/G Technology Model

For this model a description of the facility's S/G components together with their performance was assessed. Components for this study were defined at a high level of aggregation. Cost incurred from implementing some specific design changes was also considered.

4.2.3 Facility Model

This is the more involved part of the elicitation. Here we evaluated the performance of the S/G system against the adversary types identified in 4.2.1. For each adversary attempt we identified:

- Types of timely detectors that the facility possesses, the probability that each detector will discover an abnormality, and the lag time before each alarm is tripped.
- For each type of alarm, the facility procedures for resolving these timely alarms was also identified.
- Information on the late detectors similar to those indicated above for the timely detectors. Information on late alarms is needed for those attempts where no timely alarms occur or for those where the timely alarms were not resolved. (Such as an inventory difference, or document discrepancy. Here the investigation process is more involved than those for timely alarms and may include outside agencies.)

4.3 DATA ANALYSIS

Many insights into the strengths and weaknesses of the safeguards system can be developed by analyzing the data collected. First, the adversary choice of stratgegy was analyzed. Using the concept of an adversary preference function described in Ref. 6, the relative preference for each attempt outcome was quantified. A key concept here is the adversary deterrence. If the adversary has no attractive diversion stratgegy, he or she will be deterred. This analysis aids in assessing the true system vulnerabilities.

A second key concept is the aggregation of the performance against individual adversaries into a single set of performance measures for the facility. This aggregated performance reflects the facility performance against only the adversaries who are not deterred. Sensitivity of the system performance and adversary choices to the data collected were also examined.

4.4 IDENTIFICATION AND EVALUATION OF S/G DESIGN CHANGES AND S/G RULES

The results of the safeguards system evaluation were used to analyze the benefits and costs of safeguards improvements. By examining the data and reviewing the probability assignments for adversaries who are not deterred, the weak areas of the system that enabled the success of the adversary attempts were identified. Design changes to block these attempts were considered.

Assessing the effect of improvements has two steps. First, each of the existing strategies is reevaluated. One anticipates that alarm and resolution probabilities will rise enough to deter some adversaries without making any other adversary strategies more successful. The second step is investigating the possibility that new adversaries or scenarios come about when the new safeguards are added. If so, system performance against these new threats must be assessed.

The results from Vallecitos were also used to demonstrate our value-impact analysis for an illustrative set of MC&A upgrade rules.

4.5 CONCLUSION

The analysis at Vallecitos provided an excellent means of testing and refining the value-impact methodology. We were able to evaluate the potential adversaries and identify the parts of the system vulnerable to each threat. Design improvements were then evaluated, identifying both the values and the impact of the improvements.

5.0 ADVERSARY MODELING

R. S. Schechter

5.1 INTRODUCTION

Our main effort over the past few months involved interviewing recognized experts in the field of industrial security and evaluating the results for perceptions into the insider threat to nuclear activities. Our sources included top-ranking security officers from government regulatory and investigatory agencies, research organizations, and commercial enterprises. The major findings of this work have recently been summarized in an internal memo soon to be published as a UCRL report.[7] Highlights are outlined below.

5.2 FUNDAMENTAL PROBLEMS OF INTERNAL SECURITY

The basic difficulties which tend to render a facility highly vulnerable to the insider threat were found to include: (1) employee alienation and frustration; (2) excessive loyalty to one's immediate supervisor; (3) failure to consistently enforce security procedures; (4) failure to separate and rotate duties; (5) failure to insure the janitorial staff's integrity.

5.3 TYPICAL BASES OF CONSPIRACY FORMATION

At present, conspiracies are felt to be a far more serious threat to nuclear security than the single adversary; this probability can be expected to increase even further as safeguards become more sophisticated. The following were reported as typical bases, or favorable conditions, for conspiracy formation: (1) insiders unwittingly compromised by fellow employees; (2) mutual animosity toward firm; (3) friendship; (4) mutual greed; (5) psychopathic instigation; (6) outsiders manipulating disgruntled insiders; and (7) outsiders intimidating insiders.

5.4 OPTIONS FOR THE NRC: POSSIBLE MEASURES FOR IMPROVING THE QUALITY OF NUCLEAR SAFEGUARDS

The following lists are derived from the recommendations of the interviewees; each measure was chosen on the basis of its possible applicability to nuclear security.

A. Personnel Policies

To increase employee awareness:

1. Have licensees require that all employees sign a list of rules which they can be fired for breaking.
2. Recommend that licensees solicit employee suggestions on the best ways to implement the regulations.

To reduce employee frustration and alienation:

3. Recommend that licensees provide grievance committees for the evaluation of worker complaints.
4. Offer workshops for licensees' supervisors on employee consultation.
5. Encourage licensees to adopt a "team approach" to operations.
6. Offer workshops for licensees' supervisors on employee consultation.
7. Recommend that licensees provide free psychological services to employees.
8. Require that all employees be treated the same with respect to personnel searches, access procedures, etc.
9. Recommend high wages and benefits for employees of nuclear facilities.

To improve employee screening:

10. Include a personal interview by security personnel as part of the preemployment screening process.

B. Control Measures

1. Rotation of duties on randomized basis, with assignments unknown until the last minute.

To prevent cover-up of material discrepancies:

2. A mandatory continuous two-week vacation for all employees.

To prevent lax enforcement of regulations by management:

3. Spontaneous unannounced audits of security system by independent agency, with tests of guard performance.
4. Direct NRC involvement in physical inventories.

To improve the reliability of access controls:

5. Use automated booths for personnel entry to sensitive areas.

To improve surveillance capability:

6. Install automated devices for routine monitoring of sensitive operations.

6.0 COMPONENTS PERFORMANCE

J. Candy, D. Gavel, R. Rozsa

During this reporting period the components task was confined to investigating the uranium reprocessing facility at Facility X. Initially a two-man team (chemical and signal processing engineers) was sent to the facility to gather process and measurement information. The investigation was confined to the concentrator-precipitator (liquid-to-solid conversion) of the facility.

An LLNL concentrator simulation was modified for the uranium cycle and run at Facility X operating conditions to provide reasonable estimates of uranium quantities processed and operating times. Sewage tanks models were also developed during this period to depict more reasonably the facility operation. From these runs and information gathered from the facility personnel, an analytical study was performed to estimate detection probability using existing process measurements and using proposed process measurements plus signal processing techniques.

A draft report on this work was delivered to the NRC in late September.[8] This report emphasizes simple signal processing techniques for enhancing the probability of detecting a material loss.

In the report, we evaluated material balance accounting (MBA), a scheme traditionally employed at nuclear processing facilities, and compared its performance to three proposed alternative methods. The proposed detectors covered two levels of process model complexity. The first two detectors were elaborations of the basic MBA method. The third detector employed a parameterized (algebraic) model of the dynamics of one of the chemical processing units.

Results indicate that employing simple models for chemical processing units in a signal processing scheme can significantly improve the probability of detecting SNM diversion over MBA techniques at Facility X.

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