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Safeguards Material Control and Accounting Program: Quarterly Report, October-December 1979

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FOREWORD

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ABBREVIATIONS

ASM	Aggregated Systems Model
LLNL	Lawrence Livermore National Laboratory
MA	material accounting
MC&A	Material Control and Accounting
NRC	Nuclear Regulatory Commission
NRC-RES	Nuclear Regulatory Commission, Office of Nuclear Regulatory Research
SAA	Structured Assessment Approach Program
SNM	special nuclear material
SVAP	Safeguards Vulnerability Analysis Program
V-I	Value-Impact
VNC	General Electric Vallecitos Nuclear Center

ABSTRACT

Activity for the quarter October-December 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 the automated safeguards assessment tool called the Structured Assessment Approach (SAA) Program, giving particular attention to enhanced collusion analysis. Work has continued on the development of the Aggregated Systems Model (ASM) in support of the NRC development of MC&A upgrade regulations, and we include Value-Impact analyses of alternative safeguard rules, a first-cut safeguards cost model, and a study of the impacts of MC&A reulations on licensees. The report concludes with a description of more work in support of the MC&A upgrade rule development, which is our evaluation and critique of the current NRC material accounting regulations, an attempt to identify inherent vulnerabilities.

1.0 INTRODUCTION

The LLNL Material Control Safeguards Evaluation Program for FY80, under the auspices of the NRC-RES, is directed into two main areas: (1) Application and further development of automated safeguards assessment tools, and (2) Assistance in the development of guidance for the forthcoming Material Control and Accounting (MC&A) upgrade rule.

Two automated safeguards assessment procedures were delivered to the NRC in late September, 1979. These were the Structured Assessment Approach (SAA) Program and the Safeguards Vulnerability Analysis Program (SVAP). As reported previously,[1,2,3] SVAP and SAA are complementary detailed assessment tools; their identical objectives are to uncover, in a rigorous fashion, the safeguards vulnerabilities for a facility. The primary differences lie in the detail of their modeling philosophies and in the structure of their codes. SVAP has been applied to the General Electric Vallecitos Nuclear Center (VNC); it uses a minicomputer to format input/output information and is therefore fairly well user-oriented. On the other hand, SAA considers an expanded threat spectrum with greater modeling detail and consequently will be able to do a more in-depth assessment than SVAP.

Our work for this quarter, with respect to automated safeguards assessment tool development, has focused almost entirely on the SAA and is described in Section 2. Particular emphasis has been given to an enhanced collusion analysis in order to identify tampering vulnerabilities for MC&A systems where there may be an abuse of authority. A more comprehensive collusion analysis naturally leads to a larger conditional logic graph, which must be solved for the underlying safeguards vulnerabilities (i.e., event sets). This problem is discussed further in Section 2, where we also conceptually describe a graph partitioning algorithm for handling large conditional graphs. Other issues surrounding the SAA development are also presented in Section 2.

In addition to our detailed assessment effort, a significant part of our FY80 program plan is devoted to technical support to the NRC in their development of MC&A upgrade regulations. Our Aggregated Systems Model (ASM) work has actually bridged both efforts, however. The ASM is a high-level assessment tool employing decision analysis techniques to assess facility safeguards performance (value) and safeguards impacts (cost).[4,] We are currently directing our ASM work to further model developments and to Value-Impact (V-I) analyses of alternative safeguard rules. In Section 3 we present extension to the ASM including a first-cut safeguards cost model. Last, we report an analysis, in support of the ASM effort, to study the impacts of MC&A regulations on licensees.

Section 4 concludes this quarterly report by presenting a synopsis of an evaluation and critique of the current NRC material accounting regulations.[5] This work is also in support of MC&A upgrade rule development and has attempted to identify the inherent vulnerabilities associated with a representative, minimal material accounting system, which was derived from an examination of current regulations.

2.0 ASSESSMENT METHODOLOGY DEVELOPMENT

A. A. Parziale, C. J. Patenaude, D. W. Freeman, I. J. Sacks*

2.1 INTRODUCTION

This section presents methodological and application developments for the Structured Assessment Approach (SAA).[2,6] Much of the development has been directed to improving aspects of the assessment package for its eventual use in future assessments of licensees' compliance to the NRC fixed site physical protection Part 73 upgrade regulations. The upgrade regulations have recently been issued and, ultimately, industry compliance to these regulations must be tested.

Specific areas of the technical development include the following:

- Comparison of assessment input data requirement,
- Development of enhanced collusion analysis,
- Development of a graph partitioning procedure,
- Improvement in the probability of detection adequacy analysis.

The following subsections provide a brief discussion of ongoing work in each of the above areas:

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2.2 COMPARISON OF ASSESSMENT INPUT DATA REQUIREMENT (TASK 1.1.1)

A. Parziale, I. Sacks*

Efforts have begun to compare the data input requirements for performing a detailed SAA assessment against data to be requested under the U.S. NRC Part 73 fixed site physical protection upgrade rule to be issued in the near future. This effort is important for identifying areas where information may be lacking to perform a comprehensive safeguards assessment, and important for making the detailed assessment tools more useful in their application.

2.3 DEVELOPMENT OF ENHANCED COLLUSION ANALYSIS (TASKS 1.2.4 AND 1.2.5)

C. J. Patenaude, A. Parziale, I. Sacks*

The LLNL assessment package is capable of performing adversary collusion analyses to identify combinations of facility personnel who can compromise or disable detection devices that protect a diversion path. However, determination of these collusion groups was originally based upon their direct authorized access to only those detection devices or monitors that protected diversion path elements, such as portals, areas, and process piping system elements. The authorized access of facility personnel to other safeguard components, such as tamper monitors, signal transmission lines, and supporting utility components, was not explicitly addressed.

The enhanced collusion analysis to be incorporated into Level 4 of the SAA will address basic tampering strategies that can be used by individuals and collusion groups who, starting from their authorized access to facility locations and safeguard system components, can gain access to and compromise monitors, signal lines, and utility components, ultimately resulting in the disablement of a collection of monitors protecting a diversion path. The adversary collusion group (or individual) will be allowed to increase its "influence" over the facility and safeguard system by effectively expanding its access from authorized to unauthorized areas and components through

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tampering For example, tampering acts may compromise monitors, allowing an adversary to enter other areas or compromise additional components that would have otherwise been protected. If a complex sequential progression of compromising or tampering/disabling acts were to result in an unprotected diversion path, then the individual(s) and/or collusion group(s) who can execute this sequence will be identified, and this identification will be an output of the enhanced collusion analysis.

The enhanced collusion analysis capability is being developed through the use of conditional logic graphs, which model safeguard system component interdependencies, facility location adjacency, facility personnel authorized access, as well as other aspects of the facility and its safeguard system. Additional detailed information concerning the conditional logic graph approach and recent developments in this area are addressed in Reference 2.

2.4 DEVELOPMENT OF A GRAPH PARTITIONING PROCEDURE (TASK 1.2.5)

D. Freeman, A. Parziale, I. Sacks*

Very large conditional logic graphs, which model safeguard system interdependencies, may result when addressing the sophisticated tampering adversary who may be in collusion. The solution of such graphs is essential to the identification of adversary collusion groups who can defeat a system by disabling a collection of monitors protecting a diversion path.

A procedure that automatically partitions large graphs, thus allowing the computational solution of the graph model in piecemeal fashion, has recently been developed. It is based upon the local solution of the graph about a termination node, which may represent the disablement of a collection of monitors protecting a diversion path, or which may represent the defeat of the system in a more general sense. This local portion of the graph can then be solved and reduced, allowing a greater portion of the remaining unsolved part of the graph to be included in the next iteration or solution step in the procedure. Progressive partitioning of the graph outward or backward from a termination node, in conjunction with stepwise solution at each partition

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step, would continue until the entire graph is consumed and solved. Hence, it appears that arbitrarily large conditional logic graphs can be solved by the implementation of this new procedure.

Current work in this area has been devoted to the development of a computer program that performs the partitioning procedure automatically. Computer tests show great promise for this approach. Documentation of the partitioning procedure and its viability with respect to safeguards assessment is forthcoming.

2.5 IMPROVEMENT IN THE PROBABILITY OF DETECTION ADEQUACY ANALYSIS (TASK 1.2.6)

C. J. Patenaude, I. Sacks*

The detailed assessment procedure performs a calculation to determine the probability of detecting a nontampering adversary along each diversion path in the facility. The inputs required to perform the calculation include identifying the collection of detection devices or monitors protecting each diversion path, as well as additional components that support the propagation of the detection signals from monitors to their destination.

An improvement in the calculation of the probability of detection along a diversion path was achieved by explicitly considering the situation in which detection devices are invoked (can detect a measured stimulus) more than once during a single diversion sequence. A typical example of this situation is a scenario in which an adversary traverses the same physical path in entering and in exiting from a target, a point where material can be acquired. In this case, each detector along the path will have two chances to detect the adversary. In this situation the detection probabilities for entry and exit cannot be simply combined, due to common or shared utility components supporting detection signal propagation, and due to multiple use of monitors during the diversion.

The correct probabilistic mathematics for explicitly addressing multiple use of monitors, as well as share components, has been incorporated into the detailed assessment adequacy analyses.

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3.0 AGGREGATED SYSTEMS MODEL

R. Al-Ayat, B. Judd*, J. Huntsman*

3.1 INTRODUCTION

Work on the Aggregated Systems Model (ASM) has been directed towards the development of a systematic methodology for performing Value-Impact (V-I) analysis for safeguards rules. The ASM capabilities for assessing the values and impacts of safeguards decisions was demonstrated at Vallecitos Nuclear Center (VNC). Below we briefly describe areas in which the VNC analysis and the model structure have been extended during this quarter. We also report on a "first-cut" safeguards cost model we developed to assess the cost impact of safeguards regulations on operators of nuclear facilities.

3.2 EXTENSION TO THE ASM

The VNC analysis was extended to lay the groundwork for building a database for a representative facility. Several things have been accomplished:

- The adversary list was extended to a more generic one to be used in an analysis for facilities with higher throughput than VNC.
- The fundamental nuclear plans for the NFS facility and for other hypothetical facilities were reviewed.
- The scope of the ASM structure has been expanded to analyze generic error conditions that can generate late alarm. New performance measures have been introduced to assess the ability of the system to correctly resolve alarms conditioned on the initializing event being a given error condition. The probabilities and expected times to receive late alarms and to correctly resolve them as error conditions are among these measures.

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3.3 SAFEGUARDS COST MODEL

A Safeguards Cost Model, summarized here and described in detail in Reference 7, has been developed that gives "first-cut" cost formulas consistent with engineering-economic evaluation procedures (often called life-cycle costing) used in the nuclear industry. The formulas are intended to give an "order of magnitude" estimate of the incremental costs born by the operator when additional safeguards are mandated. Actual cost calculations are very complex, and input parameters to that calculation are uncertain. Therefore, the simple model discussed here is an approximation to be used for comparing alternatives, rather than a precise accounting formula for estimating actual costs.

The Safeguards Cost Model evaluates the impact of a new regulation in terms of its annual cost to a facility operator. In the model annual costs are "levelized" by using a fixed (or capital) charge rate. There are other ways to measure operator impact besides annual levelized costs, such as reduced present value of profits, levelized cost-per-unit of production, and present value of all future costs. The annual cost measure, however, can be readily translated into these other measures.

Safeguards impacts can be divided into three cost catgories: capital cost, direct operating cost, and indirect operating costs. Included in the capital cost calculations are capital investments and long-duration periods of plant unavailability, such as construction delays or one-time process shutdowns. Direct operating costs include materials and labor salaries, wages, incentives, benefits, and training. Finally, the indirect costs from MC&A regulations arise from two general effects -- loss of productivity and delays in production. The cost impact from loss of productivity is an increased annual expense to operate a facility at the normal production level. The total annual safeguards cost impact is then calculated by summing capital, direct, and indirect impacts.

3.4 STUDY OF THE IMPACTS OF MC&A REGULATIONS ON LICENSEES

R. Al-Ayat and Woodward Clyde Associates*

The purpose of this work was to identify and evaluate the impacts of material control and accounting (MC&A) regulations on a facility's operations. The analysis was designed to capture both the positive and negative impacts from existing and proposed MC&A regulations. Results produced and insights gained from this task will be integrated into our Value-Impact analysis for assessing the impacts of specific regulatory decisions.

With the premise that individuals working in a facility have more knowledge and understanding of the problem, several working sessions with VNC personnel were held. The purpose of these sessions was to develop an objective function representing the values an operator would use to evaluate the regulations impact on the facility's operations. Such a utility function will allow proposed regulations to be ranked according to their overall acceptability to licensees. The first step in our analysis, therefore, was to systematically develop an objective hierarchy representative of the operator's thinking. This hierarchy is presented below.

3.4.1 Hierarchy of Objectives for MC&A Regulations Impact

Figure 1 shows the hierarchy developed both as a result of our meeting with the Vallecitos personnel and based upon our knowledge of the MC&A regulations. As seen from the figure, the hierarchy captures both the economic impact (i.e., cost of implementation) and the noneconomic impact, such as the regulations' impact on employee morale and health.

At the top level we have the overall objective to minimize the impact of MC&A regulations on a facility's operation. This top level objective is broken down at the next level into four components. Each component is, in turn, broken down whenever feasible to lower level objective. The next step is to develop a model for each of the four objectives: minimize cost of regulations implementation, minimize impacts to employee, minimize regulatory uncertainty, and minimize interagency jurisdictional conflicts. These four

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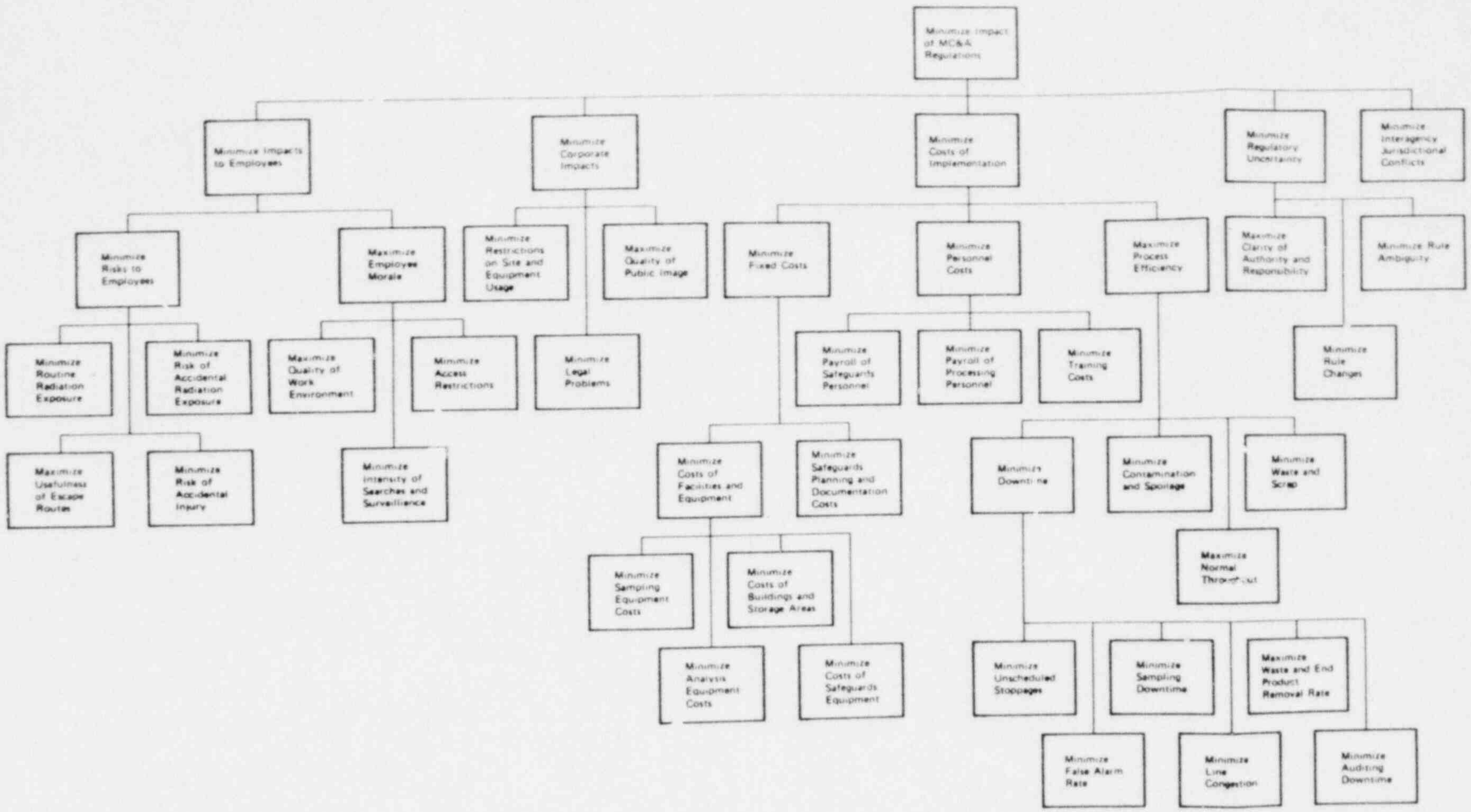

FIG. 1. Preliminary hierarchy of objectives for impact of MC&A regulations on licensees.

value models will be appropriately integrated to an overall model reflecting the operator's preferences among these four objectives.

As of now, the value model for the first objective, to minimize cost of regulations implementation, has been completed. Some of the categories under this objective were slightly modified and a two-attribute utility function has been developed. The two parameters of concern here are the annualized fixed cost and the annual operating cost. Work is continuing to generate the value model for each of the other three objectives.

So far the major results of this analysis have been insights -- about the major concerns of operators of facilities handling nuclear material, about alternatives to control such material that may otherwise be overlooked, and about the operational appropriateness of proposed rules.

4.0 UPGRADE RULE ANALYSIS

J. Huebel, J. Lim, P. Wahler

Some of our recent work in upgrade rule support has been to systematically evaluate and critique the current material accounting (MA) regulations.[5] To evaluate the MA regulations, a generic minimal material accounting system was developed to the extent defined by the requirements, both explicit and implicit, specified by the regulations and by accounting systems in general. This system was generic in that it was representative of most material accounting systems that comply with the current MA regulations; it was minimal in that it possessed no safeguards or accounting mechanisms in excess of those required by the current regulations. The generic minimal system delineated the material accounting capabilities possessed by current nuclear facilities licensed by the USNRC. To critique the MA regulations, the generic minimal system was assessed by an adaptation of the fixed-site safeguards assessment methodology. The assessment indicated the vulnerabilities inherent in the current MA regulations

The model of the generic minimal MA system was developed using a modified logic diagram. The generic MA system model delineated the various data sources, data types, data checks, and data access controls that characterize any MA system in compliance with the current regulations. The generic model contained no site-specific licensing elements and consisted of three SNM loss detection and identifiation procedures:

1) Inventory Procedure
2) Item Count Procedure
3) Item Quantity Procedure

Thus, the capabilities of material accounting systems in compliance with the current USNRC material accounting regulations were derived from the accounting elements in the above three procedures.

The vulnerabilities in the current USNRC material accounting regulations were determined by the assessment of the generic minimal MA system. The assessment involved the derivation of a set of Boolean equations from the logic diagram model and the solution of these equations for the event sets. The event sets were the minimal sets of accounting elements that must be tampered with in order to disguise a special nuclear material theft. Event sets were generated in both aggregated and detailed forms. The aggregated form would provide information that can be useful for establishing regulations and the detailed form would supply information useful in licensee implementation. The aggregated form consisted of the adversary access and tampering of elements in terms of six general material accounting categories: reports, records, documents, measurements, controls, and consistency tests. The detailed form consisted of the access and tampering of specific elements in the generic minimal system. Specific elements include such things as Facility Item Control Records, Shipper/Receiver Difference Reconciliations, Measured Discard Controls, etc.

Furthermore, protection path sets were generated for the vulnerabilities identified by the event sets. In general, a path set is the minimal set of system elements that must function in order to insure that the system funtions. In our context, a path set is the minimal set of system elements that must be protected so that the generic minimal system will become "tamperproof". The protection path sets were generated in the aggregated form and some examples were provided in the detailed form.

The reader is referred to Reference 5 for more detail.

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