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SAFEGUARDS MATERIAL CONTROL AT LICENSED PROCESSING FACILITIES

QUARTERLY REPORT

April through June 1977

R. B. Hollstien, A. Maimoni, and L. R. Spogen

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April through June 1977

R. B. HOLLSTIEN
A. MAIMONI
L. R. SPOGEN

Lawrence Livermore Laboratory
University of California
Livermore, California 94550

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OFFICE OF NUCLEAR REGULATORY RESEARCH
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PREFACE

This report was prepared as an account of work sponsored by the U.S. Nuclear Regulatory Commission, under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under contract number W-7405-ENG-48.

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ABSTRACT

This is the third quarterly report of progress at LLL on assessment methodologies and tools to assist the NRC in the development and enforcement of performance based regulations pertaining to special nuclear material safeguards at licensed facilities. The first quarterly report presented an overview of LLL's approach as of February, 1977. The second quarterly report describes the design of a hypothetical material control system referred to as the "test bed design" which is being used at LLL in the development of techniques for the assessment of material control system effectiveness. This report describes one of these techniques, a specialized computer simulation program for determination of material control system responses to particular adversary action sequences that constitute a material diversion attempt. The report contains an overview description of the Material Control System Simulator (MCSS) program and its role in the LLL assessment procedure. The complete MCSS User's Manual is available in LLL report UCID 17727. This and the previous quarterly are detailed topical reports and do not present progress made in other areas of this program. Future quarterly reports will resume broad coverage of all aspects of LLL's assistance to the NRC on Safeguards Material Control at Licensed Processing Facilities.

INTRODUCTION

The general objective of the NRC program at LLL is the development of the methodology and software which will be required by the NRC for the assessment of material control and accounting (MC&A) systems at fixed facilities. The methodology is oriented towards determining the capability of an MC&A system to detect and interrupt an adversary sequence. More specific objectives are to provide a consistent means of assessing applicant compliance to regulations at all stages, from the preliminary design phase through all the preliminary and final approvals, inspection during construction, initial and normal plant operations. Thus, we believe our assessment methodology will be useful to NRC licensing and inspection personnel and could be used by the NRC in the development of Performance Based Regulations. If provided to prospective licensees, it would also serve as a very effective design aid.

This report describes the current status of a Material Control System Simulator (MCSS) program for determination of material accounting uncertainty and MC&A system response to particular adversary action sequences that constitute plausible material diversion attempts. The program is intended for use in situations where randomness, uncertainty, or interaction of adversary actions and material control system components make it difficult to assess effectiveness against particular material diversion attempts. Although MCSS may be used independently in the design or analysis of material handling and processing systems, it has been tailored toward the determination of material accountability and the response of MC&A systems to adversary action sequences.

An outline of the LLL procedure for assessment of MC&A systems is presented in the next section of this report to clarify the role of the MCSS program.

Next an overview of MCSS is given which summarizes the philosophy and use of the program. Two example applications with details on modeling technique, data preparation, and program execution are described in the MCSS User's Manual (LLL report UCID 17727).

The simulation of complex systems is itself a complex problem, and the effort required to implement a computer simulation must be carefully weighed against the benefits expected from it. The details of general simulation technique can easily obscure important information and insight concerning the system under investigation. MCSS is based on a functional building block approach and may be modified or extended to meet specific requirements as they evolve in the NRC's development of assessment procedures. The specialized functions of MCSS are designed to simplify the computer simulation of MC&A systems when simulation is the only practical approach to a design or assessment problem.

At present the MCSS supervisory control programs and sixteen functional modeling elements are included in the program under development at LLL. We hope that potential users of the program will carefully examine the user's manual and will direct any comments or suggestions they may wish to make to LLL so that further work on MCSS will benefit from their experience and judgement.

ASSESSMENT OF MATERIAL CONTROL AND ACCOUNTING SYSTEMS

As shown in Figure 1, the LLL assessment procedure consists of the five basic steps: target selection, event set generation, sequence/stimuli generation, MC system response/outcome determination and MC system evaluation. In addition, we require models of adversary perception and of the various components of a MC&A system. The assessment tools (methodology and computer codes) are designed to be very general in their capabilities; they are made specific to a given plant by the use of appropriate unit models to describe the applicant's process and MC&A system.

The procedure systematically assesses the vulnerability of the applicant's proposed or existing facility to particular adversary action sequences, it progresses from sequences which are the easiest to assess to those which are more difficult. Thus, the procedure allows the rejection of a system without necessarily having to complete all the steps. The steps in the procedure are modular and can be used individually by an analyst or as a part of the integrated procedure.

A. INFORMATION REQUIREMENTS

Information required for assessment of MC&A systems is as follows:

NRC criteria as reflected by regulations and its perception of the adversary and of societal preferences. Specific criteria from NRC are identified for each step in the assessment.

Description of the applicant submittal or existing facility. Details are required of the physical plant and process, characteristics of the MC&A system and those plant operation procedures that have impact on safeguards. Most of the information needed is already presented in documents such as the FSAR, Accountability Measurements Plan, Security Plan, etc.

The automated tools (methodology and computer codes) supplied by LLL.

The NRC/LLL data base from which information such as unit models of the applicant's process and monitors are obtained to make the above automated assessment tools specific to the applicant's submittal or existing facility.

B. THE ASSESSMENT PROCEDURE

The steps of the procedure are described in more detail as follows:

1. Target identification

In our context a target is 1) a given type of SNM, 2) a location in the plant where this material may be obtained, and 3) the conditions necessary to cause the SNM to appear at this location. Identification of targets are made via the following steps:

- a. All locations in the plant containing SNM are identified and ranked according to material attractiveness to a potential adversary. The material attractiveness is, in part, a measure of the amount of effort required to prepare the SNM for malevolent use. For example, ^{239}Pu is much more attractive than uranium ore.
- b. The material flow (piping) and instrumentation systems are searched systematically to obtain all the normal and abnormal (adversary-induced) material access points. At this point, the NRC analyst can perform a preliminary analysis of the vulnerability of the plant design to diversion.

2. Event Set Generation

An event set is defined as the set of adversary acts and corresponding conditions in the MC&A system which would allow the adversary to successfully remove material from a given target. In this step we determine all the

events generated by an adversary that could lead to successful diversion of material. Once the entire set of adversary events is generated for a facility, we can perform an analysis of vulnerability to diversion and identify those events that, due to their complexity, require more detailed analysis.

For this step of the procedure we use directed graphs (digraphs) to model adversary movement, materials movement, signals and actions generated by the various components of the MC&A system, as well as the response of its decision logic. In the digraphs we can also show the effects of normal equipment failures and of direct actions by an adversary. For further analysis, we also will need data for probability of detection, of false alarm, susceptibility to tampering, etc.

Once the digraphs for a system are developed (one for each material access point), they are converted to fault trees and the fault trees are examined to obtain the event sets, i.e., the minimum set of adversary actions and MC system conditions that might lead to removal of material. For example, a sequence of actions by an adversary might be: Fill a container at a sampler glove box, clamp the glove, cut the glove to remove the container and exit with the material. The conditions that could permit such actions without detection are failure of a liquid level sensor and no detection by the observer. Since in this case the two conditions in the MC system that would allow for removal of material are independent of one another and do not show common cause failure (for example, a power failure), we can obtain a probability of removal of material for this particular event from the probabilities of failure of the level sensing system and of the observer.

We anticipate that the outcome of most of the event sets can be obtained from the probability of the independent conditions, as indicated above. Event sets requiring a more detailed analysis are the input to the next step.

3. Sequence/Stimuli Generation

The event sets generated by the previous step define the adversary acts and conditions required for material diversion. In some event sets it may be necessary to sequence or time order these events. In this step we develop detailed sequences by time ordering the adversary acts and required conditions. We characterize the sequences by the order, duration, and time separation of the adversary acts. We also characterize the stimuli (disturbances or signals that feed information to the MC system) generated by the adversary acts in terms of type classification, time delay, duration, and intensity. The sequenced event sets, stimuli, and detailed information are then used as input to a functional simulation of the diversion attempt against the facility and MC&A system.

4. MC&A Systems Response/Outcome Determination

In this step we estimate the probability of response of the MC&A system to specific adversary action sequences and, using information related to performance of physical security, obtain the probabilistic outcome for the diversion attempt. The Material Control System Simulator (MCSS) program developed for this purpose is the subject of this topical quarterly report. Using MCSS, the relevant parts of the material processing facility, safeguard system, and adversary event sets are represented in a model system which is tested by replicated simulation

runs during which statistical data are collected on the MC&A system response and outcome of the diversion attempt. The MCSS program may be used to analyze event sets obtained from the sequence/stimuli generation step of the assessment procedure or event sets obtained independently by the NRC analyst.

5. Aggregated MC&A System Evaluation

In this step we score the overall effectiveness of the MC&A system. The probabilities of outcomes of individual sequences obtained in previous steps are aggregated, using NRC criteria, into an overall measure (or measures) of MC&A system performance. An example of NRC criteria that might be required are measures of societal costs and probability of occurrence for different types of sequences. The theoretical structure for performing the aggregation is now being developed using decision analytic techniques.

6. Adversary Perception

Models of adversary characteristics, e.g., the number of individuals involved, their skills, information available to them, risks they may be willing to take, etc. are essential inputs to many aspects of the analysis. These models of the adversary are being developed in close cooperation with the NRC using a variety of modeling techniques.

7. Component Performance Generation

To be useful in our assessment, the characteristics of the process and the components of the MC system have to be expressed as simple functional representations (models). We require two different kinds of models.

First, for the event-set generation, we generate models in the form of directed graph (digraph) representations of the flow of information,

materials, failure modes and adversary acts for different items of process equipment and components of the MC&A system. Second, for the determination of the outcome of a given event, once the adversary acts and conditions are identified, we need to know how well the components of the MC system perform in the context of the environment in which they are located. We need to know the probabilities of detection and false alarm as well as pertinent time response information.

Typical components of an MC system are monitoring equipment, opportunity-reduction components such as barriers or locks, humans as operators or observers, material estimation and accounting, etc. Means for modeling the decision logic of MC&A systems and the reactions of physical security are also needed.

OVERVIEW OF MCSS

MCSS is a computer program for simulation of nuclear material control and accounting systems. It is intended for use by the NRC during the assessment of proposed or existing facilities and by license applicants during the design of safeguard systems. In the LLL assessment procedure, MCSS is used to determine the probabilities of material control system responses and the probabilities of interruption during the progress of adversary action sequence when randomness, uncertainty, or interaction of adversary actions and MC&A components preclude their determination by mathematical computation.

The MCSS program provides a set of predefined modeling functions that are generic simulations of material processing operations, safeguard components, the actions of adversaries, and the actions of physical security. To simulate a particular system, the user selects MCSS functions that represent the relevant components, assigns parameter values to define the performance characteristics and interconnection of all functions in the model, sets initial values of state variables, and operates the model system in the computer to observe either its detailed behavior during individual simulation runs or its statistical behavior over an ensemble of replicated runs. The assignment of parameter values to define particular performance characteristics requires only information pertaining to the simulated system; details of data structure, timing, scheduling of events, etc. are managed by the MCSS control programs and require no attention by the user. No computer programming or knowledge of simulation techniques are required to use MCSS.

Some of the functional elements of MCSS models are illustrated in Figure 2 which shows, on the left, receiving, transport, measurement, processing, storage, control, and shipping functions that are typically involved in the

simulation of the material processing functions of a safeguarded facility.

Data for the specification of these functions are supplied by the license submittal documentation.

In the center of Figure 2 are shown functions that represent the initiation of ordered sequences of adversary actions and the four types of action functions provided by MCSS. Independent actions occur without regard to events or conditions in other functions of the model system. Dependent actions may be specified to begin or end only if certain conditions are satisfied by other functions. Modification actions are capable of altering the parameters or variables of any function of the model system and, therefore, may be used to represent adversary actions such as the disruption of a material processing operation or control actions such as the activation of a system monitor. Material acquisition actions simulate the removal of material from the normal containment configuration of the process model.

During the performance of adversary actions, stimuli are generated which may or may not be detected by monitors in the material control system. Simulations of these stimuli are characterized by a type classification, their delay, duration, and intensity. The four types of adversary action described above may, therefore, be used to simulate a wide variety of physical actions that generate stimuli as different as the visible presence of an unauthorized person, an irregular pressure or flow reading on a measurement instrument, or an anomaly in the documentation of operational procedures.

Monitor functions generate signals that are operated upon by decision functions of the MC&A system to produce response variables as shown on the right of Figure 2. The specification of these components is also based on data supplied in the license submittal.

Two examples in Section 4 of the MCSS User's Manual describe in detail how functional models are constructed and run to obtain material balance uncertainty and system performance information that may be used in assessing accountability effectiveness and protection against particular adversary action sequences. The process simulated in these examples is shown schematically in Figure 3. In this hypothetical system, eight different types of materials in various containment configurations and quantities arrive periodically at three receiving stations. Upon arrival, the incoming material batches are measured and the observed quantities are recorded as entries in the material balance area defined by the three incoming measurement stations on the left and the single outgoing measurement station on the right of Figure 3. The batches are transported from input to output measurement stations and are then placed in storage. Materials arrive at the receiving stations at times that deviate randomly from periodic schedules. The item count and mass quantities of the different material types vary according to specified probability distributions and statistics. The measurements are characterized by systematic and random components of error and by randomly variable times required to perform the measurements. The transport times from incoming to outgoing measurement stations are also random; this simulates variable residence times in material processing operations within the material balance area. These processing operations might be simulated individually in a more detailed analysis.

In the first example the material balance uncertainty due to different measurement errors is determined for 4 week (28 day) operating periods. Then data are collected over 10 and 50 replications of the 4 week operating period to determine the means, variances, and observed probability distributions of material balance errors at specified times over the ensemble of runs.

Histograms that indicate the material balance uncertainty for the particular material type 4 at the end of each week of operation over the 50 replicate runs are shown in Figure 4 to illustrate the type of results that may be produced for analysis of material accountability. In this example, an average of 40.0 mass units of material 4 are received in daily deliveries that arrive randomly at any time between 8 a.m. and 5 p.m. The quantity of material 4 received in each delivery has a truncated normal distribution with a standard deviation of 20.0, a minimum of 0.0 and a maximum of 1000.0 mass units. Measurements of material 4 entering and leaving the material balance area have no systematic error (bias) and are normally distributed with a standard deviation of 2.0 mass units. An average time of 4.0 hours with a maximum uniform deviation of 0.5 hours is required to complete the incoming and outgoing measurements. Material batches containing material type 4 remain in the balance area an average of 48.0 hours, but the residence time varies uniformly with a maximum deviation of 24.0 hours. The results in Figure 4 show that the mean, standard deviation, maximum, and minimum value of the error in material 4 accountability at the ends of the four weeks of simulated operation are as follows:

<u>End of Week</u>	<u>Time, hours</u>	<u>Mean Error</u>	<u>Std. Deviation of Error</u>	<u>Maximum and Minimum Errors</u>	
1	168	.933	6.07	11.4	-13.5
2	336	.505	9.57	23.3	-30.8
3	504	2.26	13.0	31.6	-29.0
4	672	2.74	14.1	35.4	-37.4

where positive errors indicate observed (book) values greater than the actual quantity of material in the balance area. The histograms of Figure 4 show the observed distributions of accountability error at the end of each week of simulated operation.

In the second example, we analyze the possibility that certain coordinated actions of two adversaries might accomplish a diversion from batches in processing within the material balance area. Three actions, depicted as A1, A2, and A3 in Figure 3 are performed by adversary A and actions B1, B2, B3, and B4 are performed by adversary B. Adversary A gains access to the material processing area by action A1 and by actions A2 and A3 disrupts a processing operation so as to increase the mean time that batches containing material type 4 remain in the material balance area. Adversary B, after completion of actions B1 and B2 which are necessary to gain access to the delayed materials, acquires a specified amount from the process by action B3 and removes it from the boundaries of the material access area by action B4. Various stimuli are presumed generated by these adversary actions and specific characteristics of the stimuli are assigned. Monitors, control, actions, and decision functions of a hypothetical MC&A system are defined and parameter values are specified. The postulated adversary diversion action sequence and material processing system model is first run for a period of 137 hours while tracing (printing) in chronological order all events that occur. The simulation run is then replicated 50 times while data are gathered for output in the form of means, variances, and observed probability distributions of the material balance uncertainty and the MC response variables at specified times during the time interval of the simulated diversion attempt.

Adversary A begins action A1 between 8 and 10 a.m. on the first day of simulated operation. Between 2 and 4 hours are required to complete action A1, after which A must wait, in action A2, until material enters an incoming measurement station to perform action A3 which increases the mean processing time from 48 to 96 hours. Adversary B begins the first action of the sequence

B1, B2, B3, B4 at some time between 8 and 10 a.m. on the fifth day. Each of the actions performed by B are assumed to require between 1 and 2 hours. Actions B1 and B2 might represent steps required for B to enter and gain access to materials in the processing operation. During action B3, the adversary acquires material. And action B4 represents a step required in removing the material from the boundaries of the material control area. Completion of the diversion attempt is defined as the time at which B completes action B4.

We suppose that the analyst has determined, based on the configuration of the material control system under investigation, that two stimuli are generated by action A1, three by action A3, and one each by actions B1, B2, B3, and B4. MC&A system monitors are used to detect all of these stimuli, and four response signals are generated by a hypothetical decision logic which receives the monitor output signals.

The MC&A system response for this simulated diversion attempt is reported in terms of statistics and observed probability distributions at user specified times as shown in Figure 5. The four response signals assume only binary values 0 and 1, so there are only two cells in each of the report histograms. Report no. 3, for example, indicates that response (control) signal 2 has an observed 0-value probability of 0.38 and a 1-value probability of 0.62 at 5 p.m. of the first day (time 17.0). Reports on the probabilities of the other response signals are interpreted similarly.

The outcome of the diversion attempt is reported, as shown in Figure 6, in terms of the observed probability distribution of the times at which the actions of adversary B are completed and the distribution of the quantity of material acquired during the replicated simulation runs. The possibility of interrupting the diversion attempt may be inferred from the response probabilities

and the adversary action completion times. In 19 of the 50 replicated runs (or with an observed probability of 0.38) no material was acquired during the simulated diversion attempt. The distribution of the quantity of material acquired in the 31 runs in which material was acquired by adversary B is represented by the histogram at the bottom of Figure 6. A mean value of 10.0 and standard normal deviation of 2.0 mass units were specified as diversion objectives in the system model.

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Figure 1 MC&A System Assessment Procedure

Figure 2 MCSS Modeling Functions

Figure 3 System Simulated in the Examples of the Appended MCSS User's Manual

14 702 CMBA
 MATERIAL TYPE
 DATA
 VARIABLE
 SAMPLING
 REPLICATE SAMPLING TIME
 MEAN VALUE
 MAXIMUM VALUE
 MINIMUM VALUE

REPORT NO. 1
 4
 ERROR (OBSERVED - TRUE)
 MASS
 REPLICATE
 1.6800E+02
 -9.3288E-01
 1.1370E+01
 -1.3462E+01
 NUMBER OF OBSERVATIONS
 STANDARD DEVIATION
 TIME OF MAXIMUM VALUE
 TIME OF MINIMUM VALUE

50
 6.0653E+00
 1.6800E+02
 1.6800E+02

14 702 CMBA
 MATERIAL TYPE
 DATA
 VARIABLE
 SAMPLING
 REPLICATE SAMPLING TIME
 MEAN VALUE
 MAXIMUM VALUE
 MINIMUM VALUE

REPORT NO. 2
 4
 ERROR (OBSERVED - TRUE)
 MASS
 REPLICATE
 3.3600E+02
 5.0490E-01
 2.3257E+01
 -3.0805E+01
 NUMBER OF OBSERVATIONS
 STANDARD DEVIATION
 TIME OF MAXIMUM VALUE
 TIME OF MINIMUM VALUE

50
 9.5653E+00
 3.3600E+02
 3.3600E+02

Figure 4 Material Accountability Error Histograms

14 702 CMBA
MATERIAL TYPE
DATA
VARIABLE
SAMPLING
REPLICATE SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE

REPORT NO. 3
4
ERROR (OBSERVED - TRUE)
MASS
REPLICATE
5.0400E+02
2.2555E+00
3.1573E+01
-2.8997E+01

NUMBER OF OBSERVATIONS 50
STANDARD DEVIATION 1.2999E+01
TIME OF MAXIMUM VALUE 5.0400E+02
TIME OF MINIMUM VALUE 5.0400E+02

14 702 CMBA
MATERIAL TYPE
DATA
VARIABLE
SAMPLING
REPLICATE SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE

REPORT NO. 4
4
ERROR (OBSERVED - TRUE)
MASS
REPLICATE
6.7200E+02
2.7426E+00
3.5393E+01
-3.7426E+01

NUMBER OF OBSERVATIONS 50
STANDARD DEVIATION 1.4135E+01
TIME OF MAXIMUM VALUE 6.7200E+02
TIME OF MINIMUM VALUE 6.7200E+02

Figure 4 Continued

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 1
1
1.7000E+01
2.0000E-02
1.0000E+00
0.
50

STANDARD DEVIATION 1.4000E-01
TIME OF MAXIMUM VALUE 1.7000E+01
TIME OF MINIMUM VALUE 1.7000E+01

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 49 0.9800 BUTION
1.0000E+00 1 0.0200 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****
| %

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 2
1
4.1000E+01
0.
0.
0.
50

STANDARD DEVIATION 0.
TIME OF MAXIMUM VALUE 0.
TIME OF MINIMUM VALUE 4.1000E+01

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 50 1.0000 BUTION
1.0000E+00 0 0. 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****
|

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 3
2
1.7000E+01
6.2000E-01
1.0000E+00
0.
50

STANDARD DEVIATION 4.8539E-01
TIME OF MAXIMUM VALUE 1.7000E+01
TIME OF MINIMUM VALUE 1.7000E+01

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 19 0.3800 BUTION
1.0000E+00 31 0.6200 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****
| *****

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 4
2
4.1000E+01
6.2000E-01
1.0000E+00
0.
50

STANDARD DEVIATION 4.8539E-01
TIME OF MAXIMUM VALUE 4.1000E+01
TIME OF MINIMUM VALUE 4.1000E+01

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 19 0.3800 BUTION
1.0000E+00 31 0.6200 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****
| *****

Figure 5 MC&A Response Histograms

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 5
3
8.9000E+01
0.
0.
0.
50

STANDARD DEVIATION 0.
TIME OF MAXIMUM VALUE 0.
TIME OF MINIMUM VALUE 8.9000E+01

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 50 1.0000 BUTION
1.0000E+00 0. 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****+
|

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 6
3
1.1300E+02
6.2000E-01
1.0000E+00
0.
50

STANDARD DEVIATION 4.8539E-01
TIME OF MAXIMUM VALUE 1.1300E+02
TIME OF MINIMUM VALUE 1.1300E+02

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 19 0.3800 BUTION
1.0000E+00 31 0.6200 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****+
| *****

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 7
4
8.9000E+01
0.
0.
0.
50

STANDARD DEVIATION 0.
TIME OF MAXIMUM VALUE 0.
TIME OF MINIMUM VALUE 8.9000E+01

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 50 1.0000 BUTION
1.0000E+00 0. 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****+
|

61 801 DTBL
CONTROL SIGNAL
SAMPLING TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

REPORT NO. 8
4
1.1300E+02
3.8000E-01
1.0000E+00
0.
50

STANDARD DEVIATION 4.8530E-01
TIME OF MAXIMUM VALUE 1.1300E+02
TIME OF MINIMUM VALUE 1.1300E+02

LOWER LIMIT OF CELL COUNT DENSITY DISTRI-
0. 31 0.6200 BUTION
1.0000E+00 19 0.3800 1.0000

0.0 0.25 0.5 0.75 1.0
+ + + + +
| *****+
| *****

Figure 5 Continued

30 902 RMDS
SEQUENCE COMPLETION TIME
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

1.1193E+02
1.1459E+02
1.0967E+02
50

STANDARD DEVIATION

1.1515E+01

LOWER LIMIT OF CELL	COUNT	DENSITY	DISTRI- BUTION
1.0000E+02	0	0.	0.
1.0050E+02	0	0.	0.
1.0100E+02	0	0.	0.
1.0150E+02	0	0.	0.
1.0200E+02	0	0.	0.
1.0250E+02	0	0.	0.
1.0300E+02	0	0.	0.
1.0350E+02	0	0.	0.
1.0400E+02	0	0.	0.
1.0450E+02	0	0.	0.
1.0500E+02	0	0.	0.
1.0550E+02	0	0.	0.
1.0600E+02	0	0.	0.
1.0650E+02	0	0.	0.
1.0700E+02	0	0.	0.
1.0750E+02	0	0.	0.
1.0800E+02	0	0.	0.
1.0850E+02	0	0.	0.
1.0900E+02	0	0.	0.
1.0950E+02	0	0.0200	0.0200
1.1000E+02	6	0.1200	0.1400
1.1050E+02	5	0.1000	0.2400
1.1100E+02	5	0.1000	0.3400
1.1150E+02	11	0.2200	0.5600
1.1200E+02	3	0.0600	0.6200
1.1250E+02	9	0.1800	0.8000
1.1300E+02	6	0.1200	0.9200
1.1350E+02	2	0.0400	0.9600
1.1400E+02	1	0.0200	0.9800
1.1450E+02	1	0.0200	1.0000
1.1500E+02	0	0.	1.0000
1.1550E+02	0	0.	1.0000
1.1600E+02	0	0.	1.0000
1.1650E+02	0	0.	1.0000
1.1700E+02	0	0.	1.0000
1.1750E+02	0	0.	1.0000
1.1800E+02	0	0.	1.0000
1.1850E+02	0	0.	1.0000
1.1900E+02	0	0.	1.0000
1.1950E+02	0	0.	1.0000

30 902 RMDS
DIVERSED MATERIAL
MEAN VALUE
MAXIMUM VALUE
MINIMUM VALUE
NUMBER OF OBSERVATIONS

5.8943E+00
1.3295E+01
0.
50

STANDARD DEVIATION
TIME OF MAXIMUM VALUE
TIME OF MINIMUM VALUE

4.9537E+00
1.1059E+02
1.1176E+02

LOWER LIMIT OF CELL	COUNT	DENSITY	DISTRI- BUTION
0.	19	0.3800	0.3800
0.0000E-01	0	0.	0.3800
1.0000E+00	0	0.	0.3800
1.5000E+00	0	0.	0.3800
2.0000E+00	0	0.	0.3800
2.5000E+00	0	0.	0.3800
3.0000E+00	1	0.0200	0.4000
3.5000E+00	0	0.	0.4000
4.0000E+00	0	0.	0.4000
4.5000E+00	0	0.	0.4000
5.0000E+00	0	0.	0.4000
5.5000E+00	0	0.	0.4000
6.0000E+00	2	0.0400	0.4400
6.5000E+00	1	0.0200	0.4800
7.0000E+00	0	0.0400	0.5000
7.5000E+00	0	0.0400	0.5400
8.0000E+00	0	0.0600	0.6000
8.5000E+00	0	0.	0.6000
9.0000E+00	0	0.0600	0.6600
9.5000E+00	0	0.0600	0.7200
1.0000E+01	0	0.0600	0.7800
1.0500E+01	0	0.0200	0.8000
1.1000E+01	0	0.0600	0.8600
1.1500E+01	0	0.0400	0.9000
1.2000E+01	0	0.0600	0.9600
1.2500E+01	1	0.0200	0.9800
1.3000E+01	0	0.0200	1.0000
1.3500E+01	0	0.	1.0000
1.4000E+01	0	0.	1.0000
1.4500E+01	0	0.	1.0000
1.5000E+01	0	0.	1.0000
1.5500E+01	0	0.	1.0000
1.6000E+01	0	0.	1.0000
1.6500E+01	0	0.	1.0000
1.7000E+01	0	0.	1.0000
1.7500E+01	0	0.	1.0000
1.8000E+01	0	0.	1.0000
1.8500E+01	0	0.	1.0000
1.9000E+01	0	0.	1.0000
1.9500E+01	0	0.	1.0000

Figure 6 Adversary Action Sequence Completion Time and Acquired Material Histograms for a Simulated Material Diversion Attempt

Technical Information Department

LAWRENCE LIVERMORE LABORATORY

University of California | Livermore, California 94550