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VALIDATION OF NUCLEAR MATERIAL CONTROL AND ACCOUNTABILITY (MC&A) SYSTEM EFFECTIVENESS TOOL (MSET) AT IDAHO NATIONAL LABORATORY (INL)

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ABSTRACT

A Nuclear Material Control and Accountability (MC&A) Functional Model has been developed to describe MC&A systems at facilities possessing Category I or II Special Nuclear Material (SNM). Emphasis is on achieving the objectives of 144 "Fundamental Elements" in key areas ranging from categorization of nuclear material to establishment of Material Balance Areas (MBAs), controlling access, performing quality measurements of inventories and transfers, timely reporting all activities, and detecting and investigating anomalies. An MC&A System Effectiveness Tool (MSET), including probabilistic risk assessment (PRA) technology for evaluating MC&A effectiveness and relative risk, has been developed to accompany the Functional Model. The functional model and MSET were introduced at the 48th annual Institute of Nuclear Material Management (INMM) meeting in July, 2007. A survey/questionnaire is used to accumulate comprehensive data regarding the MC&A elements at a facility. Data is converted from the questionnaire to numerical values using the DELPHI method and exercises are conducted to evaluate the overall effectiveness of an MC&A system. In 2007 a peer review was conducted and a questionnaire was completed for a hypothetical facility and exercises were conducted. In the first quarter of 2008, a questionnaire was completed at Idaho National Laboratory (INL) and MSET exercises were conducted. The experience gained from conducting the MSET exercises at INL helped evaluate the completeness and consistency of the MC&A Functional Model, descriptions of fundamental elements of the MC&A Functional Model, relationship between the MC&A Functional Model and the MC&A PRA tool and usefulness of the MSET questionnaire data collection process.

INTRODUCTION

The functional model and MSET were introduced at the 48th annual Institute of Nuclear Material Management (INMM) meeting in July, 2007[1,2]. A companion paper titled "BENCHMARKING MSET: A PROGRESSIVE REPORT ON THE MC&A SYSTEM EFFECTIVENESS TOOL[3]" will be presented prior to this paper at the 49th INMM Annual Meeting in Nashville, Tennessee. The companion paper describes MSET in greater detail. However, for completeness, this paper describes MSET at a high level, followed by a description of the INL benchmarking activities.

MSET is a self assessment tool used to determine the overall effectiveness of an MC&A system at a nuclear facility. MSET consists of three components:

1. MC&A functional model, which delineates necessary components of MC&A and their relationships and interdependencies.

2. MC&A survey, which is a data collection tool, in the form of a questionnaire, used to acquire information on how well MC&A components are being performed.

3. MC&A probabilistic risk assessment (PRA) technology, which is the data analysis tool used to convert survey results to numeric values using expert opinion and evaluate relative risks associated with material control and accountability processes in nuclear facilities. It has two components; a DELPHI data reduction process, and a fault tree logic structure. The PRA technology provides the logical structure to combine the effects of the input data for the functional components, in order to calculate the likelihood of failure of the total system. This gives a measure of relative system ineffectiveness.

MC&A FUNCTIONAL MODEL

The MC&A Functional Model consists of 144 fundamental elements in key MC&A areas ranging from categorization of nuclear material to establishment of Material Balance Areas (MBAs), controlling access, performing quality measurements of inventories and transfers, timely reporting all activities, and detecting and investigating anomalies. The model is based on detection of loss, theft, or diversion of Category I or II SNM. However, it can be utilized to assess Category III and IV Material Balance Areas as well. Fundamental elements in the model can be graded to place more emphasis on some elements over others. The graded approach helps prioritize the set of fundamental elements needed to effectively protect materials at different category levels.

MC&A SURVEY/QUESTIONNAIRE

A questionnaire is used to gather information about the nuclear facility being assessed. The questionnaire is designed such that responses cover all of the basic MC&A elements represented in the fault tree. The questionnaire is broken down into twenty sections and consists of approximately 230 questions. The first five sections of the questionnaire are designed to answer questions about the overall MC&A system for a given site. Sections six through twenty are Material Balance Area specific questions. The questionnaire is made up of the sections as shown in the following table.

Section Number	Title
1	Nuclear Material Control and Accountability System Foundation
2	Measurement and Measurement Control Programs
3	Establish, Implement, and Maintain TID Program
4	Surveillance Program
5	Survey and/or Audit Program
6	Protected Area Containment
7	Material Access and Material Balance Area Containment
8	Storage Area Detection
9	Automated SNM Detection at Portal
10	Manual SNM Detection at Portal
11	Reserved for Protection Element of MPC&A
12	Waste Stream Detection
13	Shipped Material Accountability
14	Received Material Accountability
15	Non-Transfer Inventory Changes within MBA
16	Stored Material Accountability
17	In-Process Material Accountability
18	Recoverable Material Accountability
19	Irrecoverable material Accountability
20	Maintain and Validate Material Balance

FAULT TREE

The basic MC&A elements represented in the fault tree are derived from the functional model. The MC&A model consists of a control branch and an accountability branch. Each branch has a sub-structure that represents the functions represented by that branch.

Functions represented in the control branch are:

- Protected Area Containment
- Material Access and Material Balance Area Containment
- Detection
    - Automated SNM Detection at Portal
    - Manual SNM Detection at Portal
    - Storage Area Detection
    - Protected Area and Material Access Area Response

Functions represented in the accountability branch are:

- Shipped Material Accountability
- Received Material Accountability
- Non-Transfer Inventory Changes within the Material Balance Area
- Stored Material Accountability

- In-Process Material Accountability
- Recoverable Material Accountability
- Irrecoverable Material Accountability
- Maintain and Validate Material Balance

DELPHI

A DELPHI process is used to convert adjectival data to numerical values. Quantification of the basic MC&A events of the fault tree by the DELPHI process is performed by a team of individuals with experience in nuclear safeguards and security, with proven credentials and experience in nuclear materials control and accountability and with knowledge of the probabilistic risk assessment methodology.

SAPHIRE

Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) software is used to perform calculations, from the numerical values derived from the DELPHI process, to determine failure of the overall MC&A system. Understanding the overall system effectiveness, or in this case – system ineffectiveness, of an MC&A system helps with management decisions on funding specific elements of an MC&A program at a facility to help mitigate insider threats.

PEER REVIEW AND BENCHMARKING

A three part process was used to validate MSET.

First, a peer review was conducted June 11 through June 22, 2007[1]. The peer review team evaluated completeness and consistency of the MC&A functional model, descriptions of fundamental elements of the functional model, PRA/DELPHI methodology, mathematical correctness of the PRA, relationship between the functional model and PRA tool, PRA components (correctness of the components and relationship between elements), questionnaire data collection and information gathered from exercises that had been conducted to validate the authenticity of MSET.

Second, utilizing the questionnaire, a survey was conducted using mock facility data. After the questionnaire was completed, the DELPHI process was used to convert adjectival questionnaire data into numerical values for the mock facility. Numerical values were processed through the SAPHIRE software to establish overall baseline system ineffectiveness. Sensitivity tests were conducted on the mock facility data to determine the effects of improving or degrading elements of the MC&A program.

Third, MSET was used at an operating U.S. facility. Idaho National Laboratory (INL) was chosen to complete benchmarking activities for MSET.

INL BENCHMARKING

In FY 2008, the INL was asked to participate in the validation process for MSET. A planning and educational meeting was held in Idaho in January 2008 to begin the process. Copies of the questionnaire were distributed to representatives of the INL MC&A organization, and sections of the questionnaire were assigned to personnel according to their expertise and current MC&A roles and responsibilities. The self assessment was conducted on two MBAs; one storage MBA and one processing MBA. The self assessment was conducted on a part time basis while personnel conducted their normal MC&A duties.

After the questionnaire was completed at the INL, representatives from the INL Nuclear Nonproliferation and Safeguards and Security divisions met with the MSET development team in Oak Ridge, Tennessee to refine the questionnaire and ensure that all questions were addressed and complete. The process of conducting the self assessment alone gave the INL insight into the strengths and weaknesses within specific sections of their MC&A program.

Through this process a number of changes were made to the questionnaire, enhancing the self assessment process and improving the correlation between the questionnaire and the fault tree. This will improve and streamline the DELPHI process in the future.

Once the questionnaire was completed, the MSET development team and a representative from INL commenced with the DELPHI process, converting adjectival data to numerical values. Values were assigned to each basic MC&A event in the fault tree. These are the events at the bottom levels of the fault tree.

The DELPHI team was made up of six MC&A experts and one monitor to administer the process. A numerical value was derived independently by each of the six team members for each basic MC&A event. Scores were derived for each basic MC&A event by calculating a numerical average of the six independent scores. If there were large discrepancies in numerical values among the technical experts, the monitor pursued clarification of the ratings from each individual. Discrepancies were discussed and resolved through the DELPHI process.

Numerical values used for basic MC&A events in the process are as follows:

Numerical Value	Adjectival Value
<0.001 to 0.005	very well done
>0.005 to 0.01	well done
>0.01 to 0.1	adequate
>0.1 to 0.99	needs improvement

Basic MC&A event values were processed on the SAPHIRE software to establish overall system effectiveness values from the SAPHIRE program. The results are shown in the following table:

Basic MC&A Events	Overall System Effectiveness
If all basic MC&A events are set to 0.001 in the SAPHIRE software, the overall MC&A system effectiveness value of very well done	**= 0.00000004011**
If all basic events are set to 0.005 in the SAPHIRE software, the overall MC&A system effectiveness value of well done	**= 0.000005072**
If all basic events are set to 0.01 in the SAPHIRE software, the overall MC&A system effectiveness value of adequate	**= 0.0000415**
If all basic events are set to 0.1 in the SAPHIRE software, the overall MC&A system effectiveness value of needs improvement	**= 0.05126**

The numerical values were processed through the SAPHIRE software to establish a baseline for each MBA. After the initial run, sensitivity testing was conducted to determine the effects of making changes to practices in the MC&A program.

Results of using MSET to analyze the INL program resulted in well to very well overall system effectiveness. INL recently underwent a DOE-HQ inspection, and the results of the MSET analysis were reflective of recent audit activities.

SENSITIVITY TESTING INL BENCHMARK DATA

The SAPHIRE software produces a prioritized listing of those basic MC&A events that have the most impact on risk reduction and the most impact on risk increase. The prioritized listings were used to sensitivity test effects of degrading or improving different basic MC&A events in the INL program. Sensitivity testing resulted in significant information about the importance of specific fundamental elements in the INL program.

A few of the basic MC&A events in the INL assessment were rated at the "adequate" level in the DELPHI process. Without completing the SAPHIRE process, it could be assumed that expending resources, time and labor, to address these "adequate" level basic MC&A events would improve the overall system effectiveness of the MC&A program. Sensitivity testing the basic MC&A events through the SAPHIRE process indicated that improving those specific events to the "well" level had no statistical significance on the overall system effectiveness for the MC&A program a the INL.

Further sensitivity testing indicated that degrading those same adequate basic MC&A events to the "needs improvement" level would negatively impact the overall system effectiveness of the MC&A program, dropping the overall system effectiveness to an "adequate" level. This indicated that the overall MC&A program was functioning well, but allowing certain elements of the program to degrade could impact the overall program.

Sensitivity testing was conducted on several aspects of the program to develop an understanding of the program and the effects throughout the fault tree. In the tests where basic MC&A events rated with the highest impact on Risk Increase were allowed to degrade, the overall system effectiveness was pushed near failure.

In the tests where basic MC&A events rated with the highest impact on Risk Reduction were improved to a higher level, the overall system effectiveness was pushed to a higher level. However, the impact was not statistically significant, because the INL MC&A program was already operating at a high enough level that the improvements did not produce significant results.

SAPHIRE also identifies basic MC&A events that, if degraded in combination with other basic MC&A events, can fail the entire system. Sensitivity testing was conducted on combinations of basic MC&A events to understand the impacts of failing to maintain specific elements of the INL program. As with any facility, it was determined that continuing to maintain good practices in monitoring waste streams at process MBAs and maintaining portal monitoring at Vault MBAs were vitally important to the overall programs at INL.

Not only does the MSET process produce an overall system effectiveness, or system ineffectiveness, it provides an avenue to view specific affected areas in the program at the basic MC&A event level within the fault tree. This is useful for understanding how the basic MC&A events contribute to overall system effectiveness, good or bad.

CONCLUSION

The results of the MSET validation were positive at INL. The overall system effectiveness was in the well to very well range. However, this benchmarking is not focused on the integrity of the MC&A program at the INL, but the effectiveness and value of MSET.

Personnel at INL have found MSET to be an excellent training tool for new, as well as seasoned, employees. It provides a comprehensive view of the fundamental elements required in a good MC&A system and the interdependencies between those fundamental elements.

Personnel at INL also found MSET to be an excellent assessment tool. They were able to identify specific areas in their program that lend the most to either risk reduction or risk increase. After the benchmarking was complete, INL MC&A management asked for the updated questionnaire to utilize in assessing additional MBAs.

MSET provides a systematic approach to ensuring an MC&A system is complete by providing all of the fundamental elements of a good MC&A system. If the overall MC&A system at a facility is whole, the probability of preventing insider activities is increased, which helps mitigate the insider threat.

Sensitivity testing through MSET provides an avenue for management decisions on budget and resource prioritization on existing as well as new projects.

The exercise of benchmarking MSET at INL also produced good information for the developers of MSET. The questionnaire has been modified based on the interaction with INL, which enhances the information gathering process and should streamline the DELPHI process.

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