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Material Control and Accounting in the Department of Energy's Nuclear Fuel Complex

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Material Control and Accounting in the Department of Energy's Nuclear Fuel Complex

A Report Prepared by the

Committee on Material Control and Accounting
Energy Engineering Board
Commission on Engineering and Technical Systems
National Research Council

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PREFACE

This study was commissioned by the Department of Energy (DOE) in November 1986 in order to:

- o Advise the DOE on the current management of the special nuclear material control and accounting (MC&A) systems; and
- o Advise the DOE on managerial and technological change appropriate to the needs to the end of the century, as they relate to MC&A.

Material control and accounting takes place within an envelope of activities related to safeguards and security, as well as to safety, health, and environment, all of which need to be managed to assure that the entire nuclear fuel complex can operate in a societally accepted manner. Within this envelope the committee was directed to carry out the following scope of work:

(1) Review the MC&A systems in use at selected DOE facilities that are processing special nuclear material (SNM) in various physical and chemical forms.
(2) Design and convene a workshop for senior representatives from each of DOE's facilities on the flows and inventories of nuclear materials.
(3) Plan and conduct a series of site visits to each of the facilities to observe first hand the processing operations and the related MC&A systems.
(4) Review the potential improvement in overall safeguard systems effectiveness, as measured by expected reduction in inventory difference control limits and inventory differences for materials balance accounts and facilities, or other criteria as appropriate. Indicate how this affects the relative degree of uncertainty in the system.
(5) Review the efficiency of operating the MC&A system with and without the upgrading options and assess whether upgrading will contribute further efficiencies in operation, which may reduce many of the current operations costs. Determine if the current system is cost-effective.

(6) Recommend the most promising technical approaches for further development by DOE and further study as warranted.

The committee held its initial meeting on January 13-15, 1987, at which time a DOE manager group headed by the assistant secretary for defense programs briefed the committee. The deputy assistant secretary for security affairs asked the committee to recommend ways to improve top-level management of MC&A at DOE's headquarters. Accordingly, the committee also reviewed the MC&A management processes at DOE headquarters, and interpreted Task 6 to include managerial and policy as well as technical approaches.

In carrying out its work, members of the committee visited selected facilities at the following sites for briefings on the MC&A systems in place, and first hand observation of how these systems are functioning:

- Y-12 Plant at Oak Ridge
- Savannah River Plant
- Rocky Flats Plant
- Pantex Facility
- Idaho National Engineering Laboratory (INEL)
- Argonne National Laboratory
- Hanford Reservation
- Portsmouth Gas Diffusion Plant
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory

At these sites, committee members viewed process lines, material balance areas, material control operations, instrumentation, supporting laboratories, record keeping, personnel-computer interfaces on and off the process lines, material storage and vault facilities, data-base management systems, procedures for material control (seals, alarms, and so on), accounting methodologies, and physical protection systems. In addition, inventory, audit, and inspection procedures were described, and briefings were provided on local experience with inventory differences and shipper-receiver differences. Where applicable, the integration of MC&A operations with production, safety, criticality, health, and environmental controls was also indicated.

At each site, managers were asked to comment on their experience with all aspects of DOE oversight of their MC&A operations, and to make suggestions for improving this oversight.

In addition, the committee was briefed on the following:

- MC&A management issues, as presented by DOE managers in Washington D.C., as well as MC&A managers in DOE area and field offices
- The master safeguards and security agreement (MSSA) process at the Idaho National Engineering Laboratory and at Hanford Reservation
- Research and development programs for MC&A at Los Alamos and Sandia National Laboratories
- The Safeguards Technology Training Program--MC&A for nuclear safeguards at Los Alamos National Laboratory

- The Tactical Vulnerability Assessment Training Program, as presented by personnel of Lawrence Livermore at the Central Training Academy in Albuquerque
- The nuclear material management and safeguard system (NMMSS), formerly the nuclear material information system (NMIS), operated by Martin Marietta at Oak Ridge
- Systems analysis for material control and accounting technology (SAMCAT) under development at the Argonne National Laboratory
- The dynamic material control and accounting system (DYMCAS) at Portsmouth
- The dynamic material accounting system (DYMACS) and the material accounting and safeguards system (MASS) at Los Alamos National Laboratory
- The dynamic material accounting system at Oak Ridge National Laboratory

Finally, the committee organized a workshop in November 1987 at Germantown, Maryland that included a series of presentations and panel discussions as follows:

- Panel 1: Threat Assessment and Risk Management
- Panel 2: Material Control
- Panel 3: Material Accounting
- Panel 4: Resource Allocation
- Panel 5: Performance Evaluation
- Panel 6: Management Tools

The detailed workshop agenda and list of participants is provided in the Appendices B and C, respectively. Proceedings of the workshop have been compiled and are available for reference.

The initial written statement of work was reinterpreted and modified in the course of sessions of the committee. Some of these changes took place in discussion with Michael Seaton, who had been director of DOE's Office of Safeguards and Security at the start of the committee's activity, and who later became deputy assistant secretary for security affairs with safeguards still within his area of responsibility. Furthermore, the committee came to see that MC&A had to be reviewed as embedded in the overall safeguards system. It will be seen in the report that much of the discussion is on the more general topic of safeguards, but the topics in mind are MC&A-related. All recommendations made affect MC&A or its part in the balance of activities in safeguards.

Finally, tasks (4), (5), and (6) were interpreted by the committee as follows:

- Task (4): The Committee discovered that inventory difference control limits and inventory differences are not necessarily the most important measures of overall safeguards effectiveness. Two subsections of Chapter 3 are devoted to this issue: Evaluating System Performance; and, Management of Inventory Differences. Thus, the emphasis in the task has been on " . . . other criteria as appropriate."

o Task (5): The language of the task would seem to suggest that some measure of efficiency and cost-effectiveness be applied to various options for upgrading safeguards. Developing and applying quantitative measures for efficiency and cost-effectiveness would require program resources far beyond those available to this committee. Accordingly, the committee focused on providing general policy and managerial guidance that it believes will contribute to a more efficient and cost-effective safeguards system. In particular, the following sections of Chapter 3 directly relate to cost-effectiveness: Resource Allocation; Strategic Planning; Planning of New and Upgraded Facilities; and Risk Analysis.

o Task (6): As indicated earlier, the committee interpreted the task to include managerial and policy as well as technical approaches for further development by DOE. The recommendations of Chapter 3 emphasize policy and managerial measures as being prerequisite to efficiently applying technical approaches.

The committee wishes to thank all persons from the Department of Energy, the national laboratories, and the contractor organizations for their assistance and input to the committee's work. The work of the committee is almost entirely based the information and viewpoints provided by these dedicated personnel who took time from their demanding jobs to assist the committee in its understanding of the problems and opportunities that confront the Department of Energy in managing the complex. In particular, William Hagis, chief of the validation branch in the office of safeguards and security worked closely with the committee on the planning of all of the above events. His personal attention and special efforts assured in all cases that the committee would be well received and have access to all relevant facilities and information. He was available to interpret, where necessary, and to provide additional information when requested.

The committee expresses its appreciation to Rosena Ricks for preparing the manuscript of this report and for seeing it through the several draft stages, and for her commitment in organizing the committee workshop where she managed all of the logistical arrangements.

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The Facilities

The Department of Energy (DOE) is responsible for producing nuclear materials and components for the nation's nuclear weapons program as well as nuclear fuel for propulsion of nuclear-powered naval ships and for research reactors. To fulfill this mission, the DOE maintains a complex of industrial facilities in various locations across the United States covering every aspect of the nuclear fuel cycle. This includes the ability to extract uranium from uranium concentrate, to chemically purify it, to enrich it in U-235, to produce Pu-239 in reactors, to fabricate these materials into components of nuclear explosive devices, to operate test and research reactors utilizing plutonium and enriched uranium, to store such materials, and to recycle scrap containing plutonium and enriched uranium. In addition, there is the capability to recycle the materials in retired warheads and chemically process spent nuclear fuel assemblies.

Fissile materials must be protected from unauthorized diversion and sabotage. The systems for protecting such materials are referred to as "safeguards" systems. DOE is responsible for developing and operating the safeguards systems and for oversight of the performance and effectiveness of these systems in the nuclear materials production complex described above.

Other domestic and foreign facilities are engaged in operations requiring safeguards on fissile materials. Commercial and other facilities (not related to weapons production) requiring safeguards programs are regulated by the Nuclear Regulatory Commission in the United States. Comparable civilian programs in other countries are subject to national safeguards in the countries involved, and most of them are subject to verification activities of the International Atomic Energy Agency.

While the committee has drawn on the expertise and experience of persons familiar with these systems, the focus of this report is the DOE's safeguards program, with emphasis on the role of material control and material accounting systems, two of four principle components of DOE's safeguards system.

The Materials

The nuclear materials of special interest to the safeguards program contain U-235, U-233, and Pu-239, the isotopes of uranium and plutonium used to produce nuclear explosive devices.

Although U-233 is in principle usable in this way, its possibility in practice, raises little interest. U-233 is more difficult and more expensive to produce than the other two fissile isotopes. There are also highly undesirable accompanying radiation levels, which would make the material extremely difficult to handle. In the past, some U-233 was used in DOE's reactor research program, but interest in continuing these studies has almost disappeared. Nevertheless, U-233 is a safeguarded special nuclear material (SNM) subject to safeguards standards equivalent to those for plutonium.

Materials containing significant percentages of U-235 and plutonium are stored in vaults, are shipped between facilities, and are subject to various physical and chemical operations. These materials occur in gaseous, liquid, and solid form; as elemental metals and in compounds and mixtures with other substances on the process lines; and in waste streams. The management of nuclear materials includes production, quality control, criticality control, safety, health, environmental controls, and safeguards.

The Source of the Concern

It is national policy to require that special nuclear materials be safeguarded against potential theft or sabotage. The principal threats are considered to be the possibility of diversion, theft, sabotage, or malevolent radiological release. The principal potential adversaries are considered to be foreign or subnational groups that might seek, through illegal and clandestine means, to obtain or to produce nuclear explosive devices, or to spread plutonium contamination. Potential threats in these categories are generically classified as "outsider" and "insider." Outsider threats are defined as possible armed attacks by forces outside the facilities, efforts to procure the material overtly and by force, or efforts to sabotage or destroy facilities operated by or for the DOE, especially those needed for national defense. Insider threats are defined as covert theft or as collaboration by employees of a facility with outsiders mounting such an attack. Such collaboration could include the provision of information, cooperating in the attack, and/or using their insider positions and knowledge to surreptitiously divert material to outside agents. Insiders could be motivated by bribery, threats to their persons and families, and/or loyalty to the cause of the outsider. Drug dependency and mental illness could also be factors in insider threats.

Safeguards Programs

Safeguards programs consist of activities designed to protect special nuclear materials and the facilities against threats of the kinds indicated above. Protection "in-depth" is achieved by methods that would be effective in five different ways: deterrence of the threat, detection of a hostile action, response to an action upon detection, recovery of any materials involved, and assurance that SNM has not been diverted or stolen. Four principal components of the safeguards system have been developed to provide this defense-in-depth:

- Physical protection
- Material control
- Material accounting
- Human reliability

Each of these functions involves the application of design and management skills, and the use of increasingly sophisticated technology. The threat is changing, requiring reevaluation of the ability of the safeguards program to respond. Moreover, the state of the art in each area continues to evolve, and research and development (R&D) programs are important to take advantage of new technological possibilities and to respond to changes in DOE's program.

While the focus of this report is on the material control and accounting (MC&A) systems, it is not possible to fully understand these systems, nor to plan and manage them effectively, without taking into account the physical protection and human reliability components. All are needed for meeting a range of hypothetical threats in a redundant manner. In addition, the integration of MC&A operations with production, health, safety, criticality, and environmental protection adds significant controls to protect against potential theft and diversion.

The Role of DOE Headquarters

The secretary of energy has assigned to the assistant secretary for defense programs the responsibility for the safeguards and security program. Responsibility for the management of all activities of the DOE's nuclear weapons complex also resides with the assistant secretary for defense programs. Responsibility for establishing safeguards policy and for providing resources for safeguards is vested with the Office of Safeguards and Security (OSS), and responsibility for assessing the effectiveness of the programs is assigned to the Office of Security Evaluation (OSE).

OSS prepares a series of documents called "orders" that define the features required of safeguards programs at DOE facilities, to be implemented by the DOE field offices and the contractors who operate the various nuclear production and utilization facilities of DOE.

In addition, the DOE field offices, in cooperation with the facility managers, prepare documents known as individual master safeguard and security agreements (MSSAs) that designate the level of protection, and provide the basis for facility planning of safeguards upgrades. Facility managers also prepare detailed procedural manuals and control plans, separate and apart from the MSSAs; these are the documents by which the DOE operations offices audit the performance of the safeguards systems in DOE facilities.

Among the important responsibilities of the cognizant assistant secretaries at DOE headquarters is to allocate budgetary resources to safeguards upgrades across the facilities and across the four safeguards functions.

THE NATURE OF THE PROBLEM

This study was commissioned because the Department of Energy recognized a number of persistent and difficult problem areas in the management of the safeguards programs. These include:

- The estimated annual expenditures for safeguards and security programs is now about $800 million. The DOE would like to find ways to measure and improve the cost-effectiveness of safeguards to provide for a more balanced system, and to reduce costs without compromising the quality of protection.
- Planning for the future of safeguards, selection of safeguards upgrades, and allocation of the budgetary resources are complex. They involve an understanding of the nuclear material production processes, of the operations at existing and planned facilities, and of the evolving technological options for strengthening the components of the safeguards programs. The DOE would like guidance from outside experts on how to plan more effectively for the future of safeguards as a supplement to its own internal analysis.
- The DOE is responsible for the quality and effectiveness of the safeguards programs. The ordinary measures of safeguards effectiveness are not absolute, but are expressed in terms that require an understanding of probability theory for their interpretation. Providing assurance as to the integrity of the program requires that complex technical and probabilistic considerations be explained to the policy community, and to the public, in a manner intelligible to educated persons who nevertheless may lack pertinent technical background. Given the importance and the sensitivity of the safeguards mission, DOE seeks ways to improve communications and to maintain high credibility.

During the course of the study, the committee found that the models for quantitative treatment of the safeguards system would not permit, within the resources available to the committee, the cost-effectiveness analyses asked for in the statement of work (see page vii and viii of the Preface). Thus, the Committee focused on providing general policy and managerial guidance that it believes will contribute to a more efficient and cost-effective safeguards system.

PRINCIPAL OBSERVATIONS AND RECOMMENDATIONS

Studies, audits, and inspections have uncovered shortcomings and deficiencies in various parts of the safeguards system at specific sites. The committee believes that observations of this kind are only to be expected in an undertaking as complex as this one. Although such deficiencies should be eliminated where they are found, the problems they cause are generally compensated for by the defense in-depth aspect of safeguards. The measures used reinforce each other and reduce the vulnerability of the system as a whole to local and specific failures. This feature is, in some quarters, termed robustness. Thus, having visited a number of sites to view the actual operation of safeguards systems, and having reviewed the management and planning for safeguards at DOE headquarters, the committee believes that DOE management and its contractor community operate an essentially sound overall safeguards system in a generally effective manner. Nowhere in its site visits did the committee encounter what it considered to be practices or circumstances that produced an unacceptable level of protection for special nuclear materials. To be sure, the committee did not function as an inspection team. Nevertheless, this is the view of the committee based on longstanding familiarity of the committee with DOE's safeguards and on observations and briefings during the course of the study. Moreover, management at DOE is committed to upgrade and update safeguards in a systematic manner through the master safeguards and security agreements, that document safeguards upgrades, and through a recently revised series of orders which have shifted the assessment of safeguards adequacy from a compliance-based to a performance-based philosophy.

Yet these observations cannot be considered cause for complacency. Given the inherent complexity of the system, the role of measurement uncertainties and errors in defining inventory differences (IDs), the changing perceptions of threat, and the evolution of technology over time, the safeguards system will continue to be a source of technological and managerial challenge. As old problems are solved, new problems will emerge, some as the result of operation of new facilities, some responding to changing threats, and some as reaction to opportunities from new technology.

Adoption of some of the measures advocated by the committee will require institutional changes to well-established ways of operation. Some will require exploratory research, including the development of new concepts and measures. Most likely, the results will be incremental improvements over the next several years, which in the long-run will increase the effectiveness of the safeguards system and its economic efficiency.

The committee has considered how to ensure the effectiveness of DOE headquarters as it manages the program. Chapter 3 of this report provides the committee's detailed views and recommendations covering management and planning issues. A selection of the more important observations and recommendations in summary form follows.

Addressing Instability from Personnel Turnover

Observations

Over many years the Offices of Safeguards and Security and of Security Evaluation at DOE headquarters have undergone an exceptionally high rate of personnel turnover. This has impaired continuity of policy and planning, and has contributed to uncertainty in direction of the programs. It is unlikely that the situation will change soon. To continue to improve the system for protection of special nuclear materials, there must be an in-depth understanding of MC&A at all levels, its integration with all components of the safeguards system, and the interactions with the operational components of the nuclear materials complex. Management must be familiar with threat guidance, and the systems that must respond to these threats, so as to seek measures of effectiveness and select the most promising areas for improvement. DOE will require a system that provides stability of direction in safeguards in the face of expected change in its top management. A step toward stabilizing program direction is being addressed through development of the master safeguards and security agreements. The MSSAs designate the level of protection appropriate to each facility and provide the bases for safeguards implementation, and for budget submittals for the purpose of achieving desired levels of safeguards. The MSSAs are treated as if they were a contract between the DOE headquarters and the field offices with the implicit concurrence of the contractors. Such agreements on basic decisions related to safeguards implementation assure continuity of the safeguards program in the field beyond the term of the headquarters office directors. (See "Master Safeguards and Security Agreements" in Chapter 3.)

Recommendations

The committee strongly recommends stability be improved in the tenure of the directors of the Offices of Safeguards and Security and of Safeguards Evaluation, respectively. In order to buttress stability of the safeguards management process at headquarters, the following measures are recommended:

(1) The functions and responsibilities of the offices in DOE headquarters should be assigned and structured to be stable in the face of frequent personnel turnover in the higher-level positions. This could be achieved in part by clear and complete assignments of responsibility between and within these offices, by adoption of long-range plans with clear milestones and schedules, and by greater reliance on staff levels with more permanence.

(2) The MSSAs, once completed, will be extremely useful for planning, executing, and evaluating the safeguards system, as well as for laying the bases, however imperfect, for the budget submittal. Therefore the MSSAs should be kept reasonably stable to allow safeguards goals to be met.

Allocation of Resources

Observations

The Office of Safeguards and Security prepares each year a cross-cut budget that shows how the different offices of the DOE are providing resources for solving of their respective problems in safeguards. However, each program responsible for managing of nuclear materials in the DOE is funded from its own sources, and the individual program offices balance their safeguards requirements against those for programmatic purposes. There is no department-wide process that evaluates the urgency of safeguards needs in one area against those in others. Furthermore, there is no systematic balancing of the needs for MC&A against those of other components of the safeguards system.

Recommendations

o The Department of Energy should move toward establishing a department-wide method of resource allocation for safeguard functions. The current cross-cut budget process identifies expenditures in all programs that help to accomplish safeguards objectives, but the cross-cut budget is an information tool and it is not used in resource allocation for safeguards. Thus, this process does not in itself ensure a proper balance of the safeguard resources. (See "Balance in Safeguards Functions" in Chapter 3.)

o The process of resource allocation should incorporate explicit and as realistic as possible assessments of the relative risk exposures (to diversion, theft, or sabotage) of different facilities and processes on a given site, and also as between sites.

o The roles and functions of process control, material control, and accountability relative to physical security should be reevaluated periodically, and the applicable changes made in planning, budgeting, and resource allocation.

Integration of Safeguards in the Field

Observations

MC&A is viewed by most DOE field office managers as a system to itself, not integrated with the management of the other safeguards functions of physical protection and human reliability. In addition safeguards are not viewed as integrated with the management and planning of the entire process of nuclear material production and control. This has led to a process whereby orders are written, guidance is provided, funds are allocated, and responsibilities for oversight and management are defined for MC&A independently of similar actions for the other components of safeguards. Lack of integration impedes responsiveness to anomalous events and the cost-effectiveness of the safeguards program. Achieving a better degree of integration is inherently difficult, and the committee does not expect a quick solution to this problem.

Recommendations

Managers of MC&A in the field should work more closely with the managers of the physical protection and human reliability components so as to achieve a more balanced safeguards program.

DOE should state that its policy is to work toward integration of safeguards with other nuclear material production and management functions. Managers of the separate functions should be directed to coordinate with each other and to develop a conceptual framework to facilitate greater integration of their functions.

Management Information Systems

Observations

The data management systems at DOE facilities have been developed to meet essential local needs for nuclear materials production. There has not been an attempt to coordinate systems at different interacting facilities, nor has full advantage been taken of available commercial data management systems. This makes coordination of data among sites difficult, and it causes duplication of effort in constructing similar data systems. In some cases different data bases are used for different functions at the same site. This can lead to keeping several sets of books that may be irreconcilable. Such a practice undercuts the credibility of accounting records.

Recommendations

- Consideration should be given to the development of integrated data bases for use in MC&A, physical security, process operations, safety, and material quality at each site, and to restructuring and consolidating the leadership and funding for data-base management. Participation in the planning and development should include all parties at interest and should be cross-functional.
- The integrated data base should be viewed as truly cross-functional, and not solely the domain of special interests (i.e., only MC&A).

Reporting of Program Effectiveness

Observations

The DOE publishes a semiannual report summarizing inventory differences of special nuclear materials as compiled at the various facilities. This report is a means of informing Congress and the public about the effectiveness of the safeguards program.

Although the report contains an explanatory section telling of the limitations of the ID as a measure of effectiveness, it does not offer alternative measures of effectiveness. It fails to relate how all four safeguard components (accounting, control, physical protection, and reliability) work together to provide assurance. ID is reported outside the context of the safeguards system as a whole, and without a corresponding analysis showing the conclusion of investigations into the specific causes of any larger than allowable ID quantities. Results reported this way are misleading.

Recommendations

o The current semiannual ID report should be revised to provide specific understanding of the reasons for any abnormally large IDs that are listed, and to add information on the level of safeguards assurance provided by all of the components of the system.

Such information should include:

(1) an assessment of the statistical significance of the ID reported;
(2) the extent of redundant protection from other safeguards components, (e.g., from the physical protection systems);
(3) a summary of the results of any investigation into the causes of the ID reported; and
(4) a description of DOE's disposition of the ID report.

This supplementary information should permit the reader to understand the significance of the ID reported and to assess the appropriateness of DOE's disposition.

Risk Analysis

Observations

A formal and credible methodology is necessary for the evaluation of the performance of the safeguards activities in operation, and for proposing and analyzing improved safeguards measures now and in the future. Risk analysis can contribute to the development of more cost-effective safeguards system by providing a more rational basis for resource allocation.

Recently, the DOE has supported the refinement of systematic, computer-assisted assessment methodologies developed at the Lawrence Livermore Laboratory and Sandia National Laboratories to identify weaknesses in material accounting and internal controls (called ET), and in physical protection (called SAVI), and to compare and combine their conclusions (called MI$ER). These analytical procedures have been explained to DOE contractor and field office personnel, with the result that a more-or-less consistent methodology has been used throughout DOE to identify weaknesses in the physical protection, material control, and accounting systems employed at the DOE facilities with different processes and safeguards needs.

These risk analysis tools represent a very important, recent development. However, there are important shortcomings in these methodologies and in how they have been used.

Recommendations

o DOE should continue to emphasize the development of more useful and effective risk analysis methodologies.

o Given the inherent problems of using risk analysis tools as a basis for planning of safeguards, the limits of the capability to succeed in this objective should be explored prior to extensive expenditure of funds.

Significance of Inventory Differences

Observations

In the semiannual report issued by DOE stating the values of IDs at the different facilities for the preceding period, some values of ID are meaningless or misleading as indicators of effectiveness of safeguards. In these cases the ID is small compared to the variability expected of it on the basis of measurement accuracy and precision, and the statistical basis is inadequate for demonstrating that the ID is in fact larger than zero; simple reporting of ID in the absence of supplemental information about the safeguards system is thus misleading. Such partial reporting fails to provide assurance, and may raise inappropriate concerns. In these cases information from other activities such as physical protection and surveillance are vital to ensure absence of theft or diversion to a very high degree of confidence.

Recommendations

o For reporting systems involving inventory differences, and in particular those directed to public information, statistically nonsignificant differences should be reported and labeled as such. In such cases, supplementary information should be provided to assist in evaluating the meaning of the reported ID. However, measured values of ID should be retained in DOE's analytical systems, and DOE should study the long-term implications of ID using statistical tools and analysis of trends.

Evaluating System Performance

Observations

The practice up to now in performance evaluation has been to judge overall effectiveness of the safeguards systems in terms of a single measure: the comparison of inventory difference with its statistically expected variability, known as limit of error in ID (LEID). However, this comparison is not very useful where measurement error uncertainties accumulate to large values because of high throughput. Furthermore, safeguards are most important in areas where highly enriched uranium or plutonium are processed, but measurement accuracy is in general no better in these areas than in less important ones.

Because of these inherent technical problems, the ID-LEID comparison of itself may not be a useful index of diversion or of assurance. In all cases, information from all of the components of the safeguards system taken together should be used to provide a basis for a more comprehensive evaluation of effectiveness. For example, "anomalies" such as alarms resulting from incidents at barriers, portals, and within material control boundaries, as well as excessive ID-LEID levels, require investigation, reporting, and closure. An overall safeguards evaluation system would integrate information from all of these sources, together with the associated incident case histories, resolutions, and closeouts into a consolidated "state of safeguards" report. Such a system would include a running record of system performance and a summary of incident resolutions.

Superimposed on the system should be a method for audit of the overall effectiveness, both on a facility basis and for the system as a whole.

Recommendations

o There should be a systematic development and exploitation of a range of performance indicators and measures of effectiveness in addition to the ID-LEID comparison.

o A system for reporting unusual incidents in safeguards into a central data bank of should be implemented within the DOE complex, with identifiable dockets and investigations leading to conclusions as to the cause, and closure of the docket when the issue is resolved.

o Self-audit systems should be enlarged, such as safeguards committees to identify, investigate, and report anomalous occurrences or events, on an on-going basis, and to assess safeguards effectiveness by whatever means available.

o A blue-ribbon committee should be convened at periodic intervals (e.g. two to four years) to assess the continued effectiveness of safeguards on SNM across the DOE complex.

Research and Development

Observations

A well-planned and coordinated R&D program to meet new and changing problems is essential for the further evolution of effective safeguards. Project Cerberus, a DOE internal investigation (see Chapter 1, "Historical and Present Contexts for Safeguards"), developed recommendations to ensure strength and relevance of the safeguards R&D program. These recommendations were not being followed fully at the time of the committee's study. Project Cerberus called for a position of R&D manager in DOE headquarters (only recently filled). Cerberus also recommended an R&D council to analyze requests for R&D from the field, develop priorities, and recommend activities in response. While the council has been formed the committee found no evidence that it was active.

Recommendations

o The R&D Council supporting the headquarters R&D manager should meet at least once each quarter.

Additional Considerations

In addition, the committee has made other more-detailed observations and recommendations. These have been arranged in a systematic manner in Chapter 3.

While the committee did not attempt to estimate either the incremental costs or the improvements in cost-effectiveness of implementing its recommendations, it believes they will not, on balance, increase costs and they will materially increase safeguards effectiveness.

MINORITY REPORT ON COST-EFFECTIVENESS ANALYSIS

Dr. Jerome Bracken, independent consultant, adjunct professor, the Yale University, and visiting research scholar at the George Washington University maintains that DOE should have a formal cost-effectiveness analysis for safeguards that determine the societally optimal level and mix of safeguards expenditures. DOE has not provided quantitative measures of effectiveness, nor does it have a conceptual framework for thinking about the cost-effectiveness of the system. He also states that the total resources made available by the United States for safeguards may be excessive, because the vulnerability of fissile material is probably greater in other parts of the world. These views are articulated further in Appendix A written by Dr. Bracken.

1

INTRODUCTION

PURPOSE OF THE REPORT

This report provides the results of the committee's review of the system and practice of material control and accounting (MC&A) that is applied to special nuclear materials (SNM)* by the Department of Energy (DOE). These materials are used to make the fissionable parts of nuclear weapons and to fuel nuclear reactors. The gravest consequences could result should significant quantities of such materials fall in malevolent hands. DOE's safeguards system, of which materials control and accounting are parts, is designed to protect such materials.

The purpose of this report is to provide insights and recommend changes that can improve the effectiveness and efficiency of the Department of Energy's programs of MC&A at three levels:

- o Policies and planning guidance
- o Management of the safeguards program
- o Monitoring and evaluation

STRUCTURE OF THE REPORT

This chapter introduces the concepts and problems, and provides the background and history concerning the system of safeguards at DOE facilities. Discussion of the whole system, two components of which are material control and material accounting, is essential to understanding how all of its components contribute to the overall objective.

Chapter 2 is directed to a more detailed understanding of the system of material control and accounting (MC&A) in the DOE complex.

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*Special nuclear materials (SNM) means (a) plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other material which, pursuant to the provisions of Section 51 of the Atomic Energy Act of 1954, as amended, has been determined to be special nuclear material, but does not include source material; or (b) any material artificially enriched by any of the foregoing, but does not include source material.

Chapter 3 draws on the understanding of the system provided by Chapters 1 and 2, and focuses on the Committee's views of how the various components of MC&A can be improved, within the framework of the larger safeguards systems, and provides a number of specific recommendations to the Department of Energy.

OBJECTIVES OF THE SAFEGUARDS SYSTEM

Material control and accounting are activities conducted by the Department of Energy and its contractors, which are parts of a larger system to protect special nuclear material under the control of DOE. This larger system, the safeguards system, is directed toward ensuring that special nuclear materials not be diverted from authorized locations and uses. This is the first and the principal step in avoiding malevolent and antisocial use of this material, which could entail unauthorized incorporation in a nuclear explosive device. Some special nuclear material could also be the source of a severe environmental health hazard if it were dispersed so as to result in human exposure.

The safeguards program is not only designed to prevent such an undesirable course of events; it seeks to establish an impartial and credible basis for ongoing assurance to management, and the public, that such events have not occurred.

The system of safeguards that DOE presently requires in its facilities has four components:

- o Material control
- o Material accounting
- o Physical protection
- o Human reliability

Although the committee's task has been directed to the first two, it is not possible to address them in isolation from the other components. Together, the four components embody measures that constitute a complete system that serves the following functional objectives:

o <u>Deterrence</u> of the threat by providing a high degree of assurance that a perpetrator would be caught.

o <u>Detection</u> of any possible attempts to divert or steal material, or to penetrate the perimeter and enter the facility.

o <u>Response</u> to signals that could indicate potential diversion or loss of material, and potential penetration of the facilities.

o <u>Recovery</u> of materials if any should have been diverted or stolen.

o <u>Assurance</u> that material is in its proper place, and has not been diverted or stolen.

THE MOVING TARGET

These objectives would be inherently difficult to achieve in an environment that is institutionally and technically static. The actual environment within which DOE operates, however, is characteristically dynamic. To be effective, management must remain aware of a number of moving targets including:

- Changes in national defense policy itself that determines the rate of production of nuclear materials and the role of the various facilities.
- Changes in national budgetary policies that affect the ability to make multiyear commitments and may seriously constrain priorities.
- Changing perceptions of threat, and the codification of threat into guidance suitable for planning and specifying MC&A systems.
- Changes in the political environment that may influence the degree of congressional and public attention to facility safeguards, and to the role of MC&A.
- Changes in the facilities as they are upgraded to take advantage of technological improvements in production, and embodying design features specifically to facilitate the integration of MC&A functions with routine production operations.
- Change in the technology of MC&A itself, as instrumentation, computers, and alarm and control devices enable one to specify virtual real-time MC&A systems that integrate with physical and other security functions, and as innovations developed in research and development (R&D) programs are transferred to the facilities.
- Changes affecting the relationship and balance between MC&A, physical security, and human reliability programs.
- Changes in personnel with responsibility for management and oversight.

To cope with these and other moving targets, DOE in recent years has instituted a series of internal evaluations to assess its own effectiveness in managing safeguards and security, including a focus on the management of MC&A. This report is a contribution to this larger effort.

OVERVIEW OF FACILITIES AND PROCESSES

The activities of the Department of Energy involving special nuclear materials can be divided into several categories:

(1) the production of special nuclear materials (i.e., uranium enriched in gaseous diffusion plants, and chemically extracted from process flows and recycle streams; plutonium produced in reactors and chemically extracted from spent nuclear fuels);
(2) the use of special nuclear materials in the production of nuclear explosive devices;

(3) the use of special nuclear materials in support of research in basic and applied fields, primarily through operation of nuclear reactors of several kinds; and

(4) the production of fuel elements for nuclear reactors. (Little activity is, except for fabrication, under way at the Savannah River Plant of fuel used in the production reactors at that site. Essentially all fuel fabrication for other purposes is carried out in the commercial sector. This study does not cover commercial nuclear fuels.)

The facilities of particular interest to the committee for safeguards in general and MC&A in particular were those that produced or processed significant amounts of highly enriched uranium (U-235 >20 percent) and plutonium. Research and production reactors were not investigated because all SNM at these facilities is in countable and identifiable items, and so MC&A is not a significant problem there. Furthermore, the committee did not extend its attention to other DOE facilities that contain classified materials other than SNM. No review was made of the commercial facilities that fabricate naval reactor fuels or fuel for the St. Vrain gas-cooled reactor (containing high-enriched uranium) because the Nuclear Regulatory Commission, not the DOE, is responsible for safeguards at such facilities.

Figure 1-1 is a chart of DOE's operations involving the flow of special nuclear materials between the major facilities. Other material flows, such as the tritium stream, and other DOE facilities that produce non-nuclear weapon components were outside the scope of this committee's work.

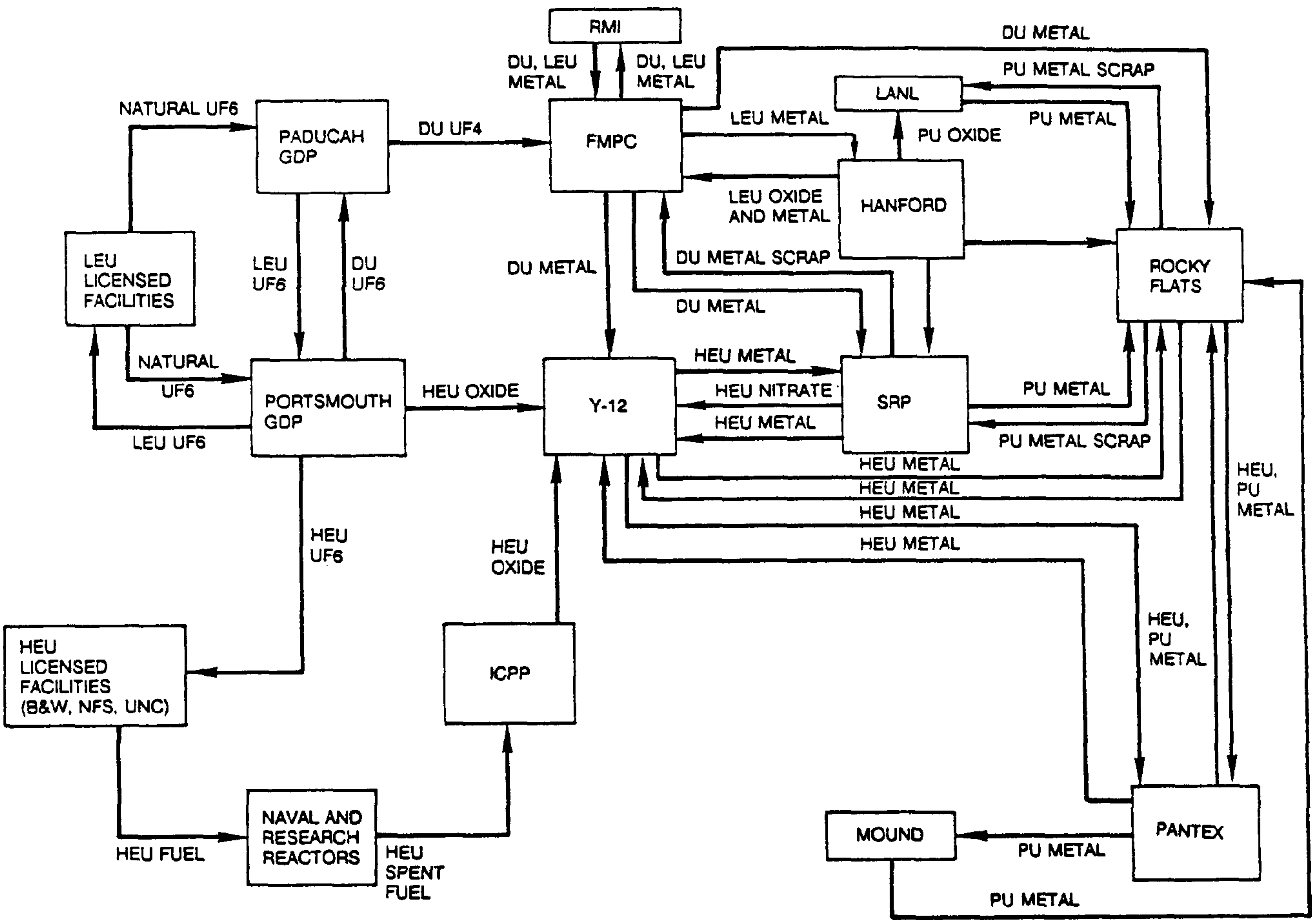
Table 1-1 lists the principal DOE offices with responsibility for nuclear materials management, the multiprogram and program-dedicated laboratories, and the major facilities, some of which are shown in Figure 1-1.

The Flow of Uranium

Enrichment

Starting at the upper left of Figure 1-1, natural uranium (U-235, 0.7 percent by weight) is fed to the gas diffusion enrichment plant at Paducah, and enriched to about 1.0 percent U-235. The uranium hexafluoride product (UF_6) is shipped to Portsmouth to be further enriched to about 3 percent for use in nuclear power reactors, to about 20 percent for some research reactors, and to 90 percent or higher for a few research reactors, naval reactors, and the Savannah River Plant and for defense purposes.

Low-enriched uranium (LEU) is used mainly by the commercial nuclear power industry in this country and abroad; DOE provides a low enrichment service for uranium whose ownership remains with the customer. Depleted uranium "tails" from Portsmouth and Paducah have a very low content of U-235, and most are put into permanent storage.



LEGEND

LOCATIONS

SRP - Savannah River Plant
LANL - Los Alamos National Laboratory
RMI - Reactive Materials
FMPC - Feed Materials Production Center, Fernald, Ohio
ICPP - Idaho Chemical Processing Plant

OTHER ABBREVIATIONS

PU - Plutonium
HEU - High Enriched Uranium
LEU - Low Enriched Uranium
DU - Depleted Uranium

FIGURE 1-1 DOE operations flow chart.

TABLE 1-1. Principal Department of Energy Office and Nuclear Facilities*

FIELD OFFICES		
Office	Number of Area Offices	Staffing
Albuquerque Operations Office Albuquerque, New Mexico	10	1300
Chicago Operations Office Argonne, Illinois	8	600
Idaho Operations Office Idaho Falls, Idaho	4	400
Nevada Operations Office Las Vegas, Nevada	1	300
Oak Ridge Operations Office Oak Ridge, Tennessee	1	700
Richland Operations Office Richland, Washington	1	300
San Francisco Operations Office Oakland, California	5	300
Savannah River Operations Office Aiken, South Carolina	1	300
Naval Reactors Office		
Pittsburgh, Pennsylvania	1	<100
Schenectady, New York	3	<100

TABLE 1-1. Principal Department of Energy Office and Nuclear Facilities (Continued)

MULTIPROGRAM LABORATORIES

Facility	Current Operating Contractor	Date Established	Staffing
Argonne National Laboratory, Argonne, Illinois, and Idaho Falls, Idaho	University of Chicago	1946	3900
Brookhaven National Laboratory Upton, New York	Associated Universities Incorporated	1947	3200
Idaho National Engineering Laboratory Idaho Falls, Idaho	EG&G Idaho, Inc., Westinghouse Idaho Nuclear Company, Inc. Exxon Nuclear Idaho Company, Inc.	1949	5700
Lawrence Berkeley Laboratory, Berkeley, California	University of California	1931	2500
Lawrence Livermore National Laboratory Livermore, California	University of California	1952	8000
Los Alamos National Laboratory Los Alamos, New Mexico	University of California	1943	8000
Oak Ridge National Laboratory Oak Ridge, Tennessee	Martin Marietta Energy	1943	5000
Pacific Northwest Laboratory, Richland Washington	Battelle Memorial Institute	1965	2600
Sandia National Laboratories, Albuquerque, New Mexico; Livermore, California; Tonopah, Nevada	AT&T Technologies, Incorporated	1949	8300

TABLE 1-1. Principal Department of Energy Office and Nuclear Facilities (Continued).

PROGRAM DEDICATED LABORATORIES			
Facility	Current Operating Contractor	Date Established	Staffing
Hanford Engineering Development Laboratory Richland, Washington (development of liquid metal reactors)	Westinghouse Hanford Corporation	1970	1800
Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania (includes naval reactor facility in Idaho Falls, Idaho-prototype reactors, and fuel examination operations)	Westinghouse Electric Corporation	1949	3600
Knolls Atomic Power Laboratory, Schenectady, New York (includes naval reactor prototype operations in West Milton, New York and Windsor, Connecticut)	General Electric Company	1957	3200
Savannah River Laboratory, Aiken, South Carolina, (support to defense programs materials production)	E.I. duPont de Nemours & Co., Inc.	1950	1000
New Brunswick Laboratory Argonne, Illinois (safeguards facility/ nuclear materials measurement and standards laboratory)	Federally operated	1949	50

TABLE 1-1. Principal Department of Energy Office and Nuclear Facilities (Continued).

WEAPON TESTING AND FABRICATION COMPLEX			
Facility	Current Operating Contractor	Date Established	Staffing
Kansas City Plant Kansas City, Missouri (nonnuclear weapons components production)	Allied Corporation	1949	7800
Mound Facility, Miamisburg, Ohio (integrated production and laboratory facility)	EG&G, Mound Applied Technologies	1949	2500
Pantex Plant Amarillo, Texas (weapon assembly plant)	Mason & Hanger-Silas Mason Company	1951	2800
Pinellas Plant, Largo, Florida (weapon components/ neutron generator production)	General Electric Corporation	1956	2000
Rocky Flats Plant Golden, Colorado (weapon component production)	Rockwell International, Atomics International Division	1953	6000
Savannah River Weapons Facility, Aiken, South Carolina (tritium production)	E.I. duPont de Nemours & Co.	1953	400
Y-12 Plant, Oak Ridge, Tennessee (weapon component production	Martin Marietta Energy Systems, Inc.	1943	7300
Nevada Test Site, Nye County, Nevada (nuclear weapon testing)	Reynolds Electrical and Engineering Co., Edgerton, Germeshausin, and Grier, Inc., Holmes and Narver, Inc.,	1951	8400
Tonopah Test Range Nye County, Nevada (nuclear weapon systems testing)	AT&T Technologies, Incorporated (Sandia Corporation)	1957	**

TABLE 1-1. Principal Department of Energy Office and Nuclear Facilities (Continued).

NUCLEAR MATERIALS PRODUCTION FACILITIES

Facility	Current Operating Contractor	Date Established	Staffing
Extrusion Plant Ashtabula, Ohio (uranium extrusions)	RMI Company	1961	100
Feed Materials Production Center, Fernald, Ohio (uranium metal melting, casting and machining)	Westinghouse Materials Company of Ohio	1951	1000
Hanford Production Operations, Richland Washington	Westinghouse Hanford Company		
- Reprocessing and waste management		1943	3500
- Fuel and reactor operations		1943	2200
Savannah River Plant Aiken, South Carolina (reactor operations, reprocessing, fabrication and waste management for defense programs)	E.I. duPont de Nemours & Co.	1950	6200

TABLE 1-1. Principal Department of Energy Office and Nuclear Facilities (Continued).

URANIUM ENRICHMENT FACILITIES

Facility	Current Operating Contractor	Date Established	Staffing
Oak Ridge Gaseous Diffusion, Plant (K-25); Oak Ridge, Tennessee (standby mode)	Martin Marietta Energy Systems, Inc.	1943	2800
Paducah Gaseous Diffusion Plant, Paducah, Kentucky (low enrichments)	Martin Marietta Energy Systems, Inc.	1950	1300
Portsmouth Gaseous Diffusion Plant, Portsmouth, Ohio (high enrichments)	Martin Marietta Energy Systems, Inc.	1952	2200

*SOURCE: Department of Energy, July 1988.

**Included in Sandia National Laboratories staffing.

Processing of Highly Enriched Uranium

Highly enriched uranium, in the form of uranium hexafluoride in sealed containers, is sent to a variety of places. Some goes to commercial nuclear fuel fabrication facilities. A portion of this is incorporated in fuel elements for naval nuclear reactors used for research and development. Most of the remainder is used in the manufacture of fuel elements for naval nuclear propulsion reactors. Part of the remaining UF_6 from Portsmouth is sent to Y-12, for conversion to uranium metal, a portion of which is used at Y-12 in the manufacture of components of nuclear explosive devices, with most of the remainder being sent to the Savannah River Plant (SRP) for fabrication into fuel elements for the nuclear reactors at that site. Most of the spent (i.e., used up) naval and research reactor fuels are sent to the Idaho Chemical Reprocessing Plant.

HEU recovered from spent naval and research reactor fuels at the Idaho facility is converted to a solid uranium oxide (UO_3) powder and shipped to Y-12. HEU recovered from the "driver" elements and other sources at SRP is converted to a uranium nitrate solution and shipped in tank trucks to Y-12. These highly enriched uranium compounds contain from about 60 to 90 percent U-235 with significant fractions of U-236 as well as U-234 and U-238. Y-12 is also the recipient of enriched uranium from other sources, such as scrap from fabrication processes, and returns of enriched uranium from obsolete nuclear explosive devices. Y-12 extracts uranium from all these sources, to produce of uranium metal destined for various other facilities. Ultimately, finished components containing HEU are shipped from Y-12 and Rocky Flats to the Pantex facility, for incorporation into nuclear explosive devices.

Only the highly enriched products are of special safeguards concern. However, accounting must be based on measuring all of the inputs and the withdrawals, regardless of their levels of enrichment, and measuring the in-process inventory while the many stages of the separations process are operating.

The Flow of Plutonium

The plutonium flow begins at the Savannah River Plant production reactors that produce plutonium through capture of neutrons in U-238. Plutonium and uranium are chemically extracted as separate products from spent nuclear fuel. The plutonium is converted to metallic form and sent to the Rocky Flats Plant for making weapon parts. Rocky Flats also receives plutonium scrap from Pantex. Facilities at Los Alamos and Lawrence Livermore national laboratories have plutonium processing facilities for R&D on nuclear explosives and other applications.

The Hanford facility is the site of the N-reactor previously used to produce plutonium, but now maintained as a standby facility the future of which is uncertain. A chemical reprocessing plant called the Purex Facility continues to operate at Hanford, extracting plutonium from spent fuel elements that were removed from the N-Reactor over the past two decades and stored on site. The extracted plutonium is stored in vaults. Recycling of plutonium scrap occurs at Savannah River and Rocky Flats. Facilities for plutonium fabrication and plutonium recycle also exist at the Los Alamos National Laboratory.

Weapons Assembly and Disassembly

The nuclear components fabricated at Y-12 and Rocky Flats and the nonnuclear weapons components, produced elsewhere, are assembled into weapons at the Pantex facility. Obsolete nuclear weapons or those needing rework are also received and dismantled at the Pantex facility. The uranium components are shipped to Y-12; the plutonium components to Rocky Flats.

Inherent Problems of Material Accounting Within and Between Facilities

Given the above understanding of the complexity of the nuclear materials system, the inherent material accounting problems within and between facilities can now be readily appreciated as introduced below, and further discussed in Chapters 2 and 3 in detail.

Accounting Within Facilities

From a MC&A perspective it is noted that some facilities contain a large part of their special nuclear material in the form of identifiable items, such as fuel assemblies or fuel components for reactors, identifiable parts of nuclear explosive devices, or sealed containers of previously measured material. Some facilities contain substantial amounts of special nuclear material in a distributed or bulk form, whose content can only be established quantitatively through measurements. Since all measurements are imperfect to some degree, accounting for such materials takes on a degree of uncertainty as to true amounts of the material present. This problem becomes more severe when the material is not in a form permitting good sampling or measurement. This occurs when material is in-process, unmeasurable because of inability to gain access, or when processes are unavoidably accompanied by inadequate material recovery, as when material is held up in pipes and vessels (i.e., "holdup"). Consequently, several facilities encounter inherent difficulties in material control and accounting. The result is apparent process "losses" in the accounting system. Inventory procedures are designed to account for these losses by closing the process line and actually cleaning out the "lost" material. But cleanout may not be complete, and establishing the uranium and plutonium content of such material is particularly difficult because the material may be highly nonuniform.

Accounting Between Facilities

Shipments of containerized special nuclear materials between facilities must be certified as to weight and material content by both shipper and receiver. This helps to provide assurance that no material was diverted in transit. However, the measuring instruments and sampling procedures in general differ among the facilities, giving rise to small discrepancies in the measurements.

Achieving reduced material discrepancy levels within and between facilities, and reporting discrepancies in the context of the complete safeguards systems, are important objectives as described in more detail in Chapters 2 and 3.

HISTORICAL AND PRESENT CONTEXTS FOR SAFEGUARDS

General Trends in Safeguards

In the period immediately following the World War II, and for several years thereafter, fissionable material was considered by the Atomic Energy Commission (AEC) to be classified, in the "secret" category. It was protected accordingly, as was the information concerning its location and quantity. Any apparent loss of fissionable material was investigated by federal authorities as a matter potentially affecting national security.

In 1954, Congress amended the Atomic Energy Act in a manner that opened the possibility of commercial exploitation of nuclear energy for civilian production of electricity. Since this would lead to possession of fissionable material by private electrical utilities, it would no longer be possible to treat such material as classified. This realization was strengthened when Congress removed the requirement that title to fissionable material must reside with the federal government; private ownership of fissionable material was legalized subject to licensing by the AEC.

At this point, with classification having been ended, fissionable material simply became another valuable article of commerce, but subject to regulations relating to safety and safeguards, as appropriate to materials that could be used in nuclear explosives. However, it was generally assumed by the AEC that the normal security practices motivated by the commercial value of the material would be so intensive and effective that government could do little more to add effective controls with the objective of protecting against malevolent misuse. These controls were essentially limited to accounting practices directed at after-the-fact assurance that no material had been lost in unexplained ways. The topic of safeguards was identified with nuclear material management, which in turn consisted of measurement and accounting. Since the protection of commercially used fissionable material per se was no longer considered a national security issue, reported losses of such material would be evaluated by federal law enforcement agencies only in terms of the monetary value of the losses and not in the potential consequences to national security.

The only exceptions were for fissionable material in forms having intrinsic security value as parts of systems and items with military importance.

There were several other aspects of the system prevailing at that time. The bulk of information on inventories and throughputs of fissionable material in the possession of the AEC remained classified, because it was associated with defense-related operations. But requirements for physical protection of this fissionable material were only retained for items with classified significance, such as nuclear weapons components and fuel elements for the naval propulsion reactors. The system used for fissionable material per se was not called "safeguards," the current terminology, but was called "nuclear materials management."

In about 1968, a trend began toward greater recognition of the need to prevent malevolent misuse of fissionable material. The AEC established one office under the general manager to oversee safeguards at the DOE-owned, contractor-operated facilities and another in the regulatory branch to define and enforce safeguards for the privately owned AEC licensed facilities. In recent years, stress has been placed on strengthening the physical protection of DOE's facilities, and the Nuclear Regulatory Commission has developed more demanding physical protection requirements for facilities it regulates. As a result, the safeguards programs of the DOE and the Nuclear Regulatory Commission are more rigorous than they have been at any other time since nuclear materials were declassified.

In addition, since 1970 there has been an international program of nuclear materials safeguards conducted by the International Atomic Energy Agency (IAEA), in which the United States plays a leading role.

Thus, nuclear materials today are increasingly subjects of systems of physical protection, control, and accounting. In the United States, annual expenditures of approximately $800 million in the nuclear material production program contribute either directly or indirectly to safeguards. Moreover, the level of technology employed in the U.S. safeguards program is increasingly sophisticated. From the viewpoint of physical protection, the committee believes that the Department of Energy's nuclear materials production complex is one of the most secure in the world from threats such as theft and sabotage.

Recent Initiatives by the Department of Energy

In its early days the weapons complex was considered primarily threatened by espionage from communist nations, and the protective features focused on this. While potential espionage remains a concern, its primacy as a concern has been replaced by other threats that were not contemplated 20 or 30 years ago.

The onslaught of international terrorism in the early 1970s established this as a credible threat to the DOE's high-profile nuclear activities. As the complexion of terrorism changed, so too did the department's perception of the potential threat and its concomitant defenses. Emphasis was placed on physical protection measures to defend against terrorist attacks, and as terrorists demonstrated greater resources and military capabilities, DOE continued to upgrade its physical security posture. Indeed, throughout the early 1980s the department spent a substantial amount of financial resources on a host of physical security-oriented defenses, ranging from fences and razor ribbon to high-technology, perimeter intrusion detection and assessment systems.

In 1984, the secretary of DOE created a Special Project Team (SPT) to review all aspects of safeguards and security throughout the nuclear weapons production complex. The SPT concluded that the physical security "crash program" had significantly reduced the vulnerability of the weapons complex to overt assault; however, this approach had led to expensive, nonstandardized security systems. As a consequence of the physical security program, the SPT stated that "other means of penetration may become more attractive to an adversary"--primary among those was the insider threat.

The SPT made 94 specific recommendations, many of which addressed the insider threat through diverse means ranging across all four safeguards components (physical security, human reliability, material control, and material accounting). Five of the recommendations were specific to the MC&A program:

- Improve MC&A by standardizing nondestructive assay equipment, upgrading process measurement, reducing maintenance backlogs on measuring equipment, regularizing insider vulnerability assessments, upgrading monitoring equipment, and better defining the interfaces between physical security and MC&A.
- Include in DOE orders the requirement for rapid detection of diverted, stolen, or misplaced special nuclear material, weapons, or critical components of weapons.
- Develop a plan to implement "propagation of error" analysis techniques for control limits at DOE facilities.
- Develop a program to reduce shipper and receiver material balance problems.
- Develop a comprehensive, top-down, anti-insider program action plan.

In summary, the SPT counseled "aggressive management oversight" in the MC&A area, and indicated that the primary initiative should be to advance this program to be comparable with physical security upgrades.

To implement the SPT recommendations, Operation Cerberus, an intraagency program, was formed. Operation Cerberus brought together safeguards and security experts from throughout the Department of Energy's nuclear fuel complex, including laboratories and contractor organizations. A special committee was formed to further develop and implement those Cerberus recommendations pertaining to MC&A. One of its interests was to ensure that adequate planning was done in advance of MC&A development and implementation so as to prevent the unsystematic approach that was associated with past implementation of physical security upgrades.

The special committee's efforts resulted in the drafting of recent revisions to the MC&A orders. In current DOE Order 5633.3, Control and Accountability of Nuclear Material, there are three major changes prompted by the SPT recommendations: (1) a new approach to graded safeguards in which five levels of attractiveness have been added, (2) system performance requirements to provide assurance that DOE facilities are performing to a specified level; and (3) a requirement to provide "defense-in-depth" (i.e., redundant safeguards protection from various components).

Changes in the technology development program within DOE's Office of Safeguards and Security were also implemented through Operation Cerberus (DOE, 1986). Older facilities were not taking advantage of technological advances and much of the existing MC&A equipment was no longer state of the art. The technology development program was reoriented towards meeting user needs, and emphasis was placed on those areas where research and development could assist multiple users.

Current Status of DOE Safeguards

The committee believes that DOE management and its contractor community operate an essentially sound overall safeguards system in a generally effective manner. Nowhere in its site visits did the committee encounter what it considered to be practices or circumstances that produced an unacceptable level of protection for special nuclear materials. To be sure, the committee did not function as an inspection team. Nevertheless, this is the view of the committee based on longstanding familiarity of the committee with DOE's safeguards and on observations and briefings during the course of the study.

The committee also found that DOE essentially has in place the essential internal mechanisms to identify problems and to move toward solutions on a continuing basis. During the course of its work, the committee has seen evidence of improved practices in the following areas:

- o Introduction and improvement of a graded basis for designing safeguards as a function of SNM attractiveness and vulnerability.
- o Improvement of the way in which "threat" is defined and guidance given on how to respond to threat.
- o Introduction of formal risk and vulnerability analysis using computer methods of analysis (i.e., ET, MI$ER, and SAVI).*
- o Advances in the design of safeguards systems and in the application of high technology.
- o Maintenance of research and development programs at Los Alamos, Sandia, and elsewhere to further improve the technology base of safeguards.

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*See Chapter 3, "Risk Analysis in the Management of Threat and Vulnerability."

o Progress toward "near real-time" MC&A systems.

o Increasing capability and sophistication of measurement and detection technologies.

o Recognition of the need to facilitate integration of MC&A with production management and physical security.

o Introduction of the Master Safeguards and Security Agreement mechanism as a way of assuring that DOE and facility managers better coordinate on planning safeguards upgrades.

o Steps taken away from a "compliance" approach to safeguards management, to a "performance" approach.

o Introduction of training programs for managers to help implement improved approaches to safeguards at the facilities.

o Continuing efforts to improve the set of DOE orders that define the management methods used in the safeguards programs in considerable detail.

A WIDER PERSPECTIVE

Ideally, safeguards planning and resource allocation should minimize some defined adverse level of consequences or, conversely, maximize benefit to society from a given level of expenditure. The allocation, based on a cost-benefit analysis, can be envisioned in a number of contexts. The broadest global context relates to a concern for inadequate international protection of weapons grade material and for the proliferation of such material in civilian reactor programs, particularly in Third World countries. One could evaluate the present level of nuclear safeguards expenditure in the United States in the context of the availability of special nuclear material from commercial electric power production in other countries and global safeguards expenditures. An analytical treatment of this problem was sketched out by William Niskanenat the committee's workshop . An order of magnitude analysis would suggest that the world as a whole invests insufficiently in safeguards, while the United States over-invests.

It is important to keep the global implications of diversion in mind when allocating resources for safeguards applied by the International Atomic Energy Agency. In addition, such analysis would be useful to U.S. policymakers in assessing the U.S. contribution to international safeguards in multilateral as well as bilateral programs. Even partial understanding of the equation defining international risks from diversion can be helpful here. But the scope of the committee's work did not extend this far.

The DOE safeguards program appears to define a higher level of threat than do other countries with strategic materials, as a matter of policy, because of the high domestic concern attached to the possibility of malevolent use of fissionable material, and the conviction that the United States must set a standard in safeguards for other nations to follow. Program planning and resource allocation in DOE's safeguards programs are concerned with optimization within these constraints. Even within this limited context, the ability to formally evaluate the terms of the risk equation that would define an analytical benefit-cost optimization is limited.

For example, the risk associated with the theft of special nuclear material can be stated as a function of four factors: (1) the probability that a theft will be attempted; (2) the probability of a successful theft; (3) the capabilities of the adversary to produce weapons using SNM; and (4) the consequences of the use. These elements of the risk analysis are not sufficiently well defined at this point to allow a complete and practical analytical solution to the allocation problem, within the limited context of the DOE facilities. The greatest uncertainty is in factor (1), the probability that a theft will be attempted. This is completely unknown. A later recommendation proposes parametric investigation of the risk based on varying the value assigned to this parameter. In the meantime, assignment of a value of unity to the probability of an attempt is a conservative course, which the safeguards systems follow at this time.

OVERVIEW OF PRINCIPAL PROBLEM AREAS

In the course of its review, the committee encountered a number of problem areas, which are addressed at greater length in the body of this report. Some of these are briefly indicated below.

Field Problem Areas

Inherent Errors

Accounting consists of a set of operations on a data base derived from measurements of weight, volume, and other properties of special nuclear material. All measurements, other than counting of discrete items, have inherent error margins. These inherent errors in the accounting data, along with fluctuations in unmeasured inventories, and a number of other factors involved in forming a material balance, combine to produce an overall uncertainty in the material balance. This uncertainty increases the detection threshold of the data, thus reducing its sensitivity. These errors will sometimes propagate from one time period to the next in the accounting system.

Complexity of Operations

The operations at DOE facilities are highly diverse in character, and they cover a variety of forms of special nuclear material in solid, liquid, and gaseous forms, as well as in diverse compounds and mixtures, under a wide range of pressures and temperatures. This raises substantial barriers to formulating a single set of detailed procedures of material control and accounting, applicable to all facilities and materials.

Balance Among Safeguard Functions

Material control and accounting constitute a portion of a much more comprehensive system of safeguards on special nuclear materials, with physical protection being a substantial part. Optimization of the entire system calls for balance among its elements. The efficacy and adequacy of material control and accounting cannot be arrived at without attention to the physical protection aspects, and to the role of human reliability programs.

Headquarters Problem Areas

Complexity of Management Structure

The management structure of the Department of Energy's nuclear material program is complex. An effective review of the system of material and control and accounting requires an understanding of the relations between DOE headquarters, the operations offices, and the contractors who operate the DOE's facilities; as well as the interactions at headquarters among the Office of Safeguards and Security, the Office of Security Evaluations, and the program divisions under the various assistant secretaries.

Management Turnover

An exceptionally high rate of turnover has been characteristic of the upper levels of the offices responsible for safeguards and security. This leads to a need for a system that can remain effective in the face of frequent replacement of the chief officers of OSS, as well as for efforts to stabilize the offices.

Information Systems

The computerized information systems used at the different DOE facilities have evolved independently of each other. These local systems are custom-designed and frequently do not make optimal use of commercially available data-base management systems. This situation poses a special challenge to headquarters management, which needs improved ways to abstract and synthesize information from the field for its own purposes, such as allocating resources across facilities and safeguards functions and improving long-range planning and policy formulation.

2

MATERIAL CONTROL AND ACCOUNTING WITHIN THE SAFEGUARDS SYSTEM

This chapter sets the stage for the committee's critique of the material control and accounting (MC&A) functions within the safeguards program. This critique is presented in Chapter 3.

The first section of this chapter provides a discussion of the basis for safeguards in terms of its actions against perceived threats. The second section introduces material control and accounting as two of four principal components of the safeguards system along with physical protection, and human reliability. This emphasizes the systems aspects of MC&A. The third section describes material control and accountability aspects in somewhat more detail.

THE NATURE OF THE THREAT

The principal threat concerning material containing the isotopes U-235 and Pu-239 is considered to be the possibility that national or subnational groups lacking legitimate access to such materials might attain them illegally from the Department of Energy complex for use in nuclear explosive devices. Such weapons could be intended for military purposes by other countries, for aggression or for terrorism.
Even if the group seeking illegal possession were to lack the capability to produce a nuclear explosive device, it could conceivably use the material to spread radioactive contamination.

Two kinds of attempt at illegal procurement can be visualized: (1) outsider threats in which commando type units assault a facility by force of arms, procuring targeted material, and then escape; and (2) insider threats in which employees of the facility may be motivated to steal or otherwise divert materials to outside agents, because of threats of harm by the agents, bribery, or loyalty to their cause.

A number of secondary threats are also considered by safeguards planners: extreme measures taken against nuclear weapons held in the national defense arsenal or against commercial use of nuclear energy; revenge by disgruntled employees; and irrational acts based on psychiatric disturbances. Theft may not be involved: sabotage and even propaganda may be the motivating purpose behind penetration and overcoming the safeguards system. These threats, which do not lead to producing a weapon, are clearly of a lower order, but cannot be ignored.

There is a large body of literature on the motives and capabilities of national and subnational groups that might be tempted to illegitimately procure nuclear materials and to produce weapons. (See list of references.)

Ultimately, perceptions of threat must be reduced to guidance for those who plan, design, and operate the DOE safeguard systems. In this context, threat is defined principally by an assumed range of adversary actions regardless of motive. A key distinction is made between "insider" and "outsider" threats, and appropriate scenarios are postulated, enabling the analyst to specify countermeasures and to evaluate their potential effectiveness. This provides a rational basis for comparing safeguards options and for seeking cost-effective configurations.

The committee reviewed how the DOE actually plans, designs, and operates the safeguard systems at its various facilities in a general way, and then focused on MC&A, as further described in this chapter.

COMPONENTS OF THE SAFEGUARDS SYSTEM

The four principle components of the safeguards system were identified in Chapter 1 as: physical protection, material control, material accounting, and trustworthiness of personnel whose job functions require them to have access to special nuclear material, to areas containing the material, or to certain information about the material.

The safeguards system is graded, being more intensive for materials with greater attractiveness for use in nuclear explosive devices. Grading is intended to help achieve economic efficiencies in the allocation of resources to safeguards. In general, attractiveness increases as the number of chemical and physical processes required to produce a nuclear explosive device decreases.

Categories are determined by the quantities of special nuclear materials (SNMs) at a site, with Category I defined by the the largest quantities. Table 2.1 shows the attractiveness levels and categories, as defined by Order 5633.3, for various forms SNM can take. Thus, for example, aside from assembled weapons, "pure products" in quantities greater than 2 kg of plutonium (Pu) and 5 kg of highly enriched uranium (U) would warrant the greatest safeguards intensity.

DOE orders reflect that the implementation of MC&A at facilities must start with appreciation of the role of MC&A in safeguards relative to physical protection. These roles are not interchangeable means of responding to the same threat. They are fundamentally different techniques that are to be integrated in a program capable of averting or countering all perceived types of threats of unauthorized possession

TABLE 2-1 Nuclear material safeguards categories

	ATTRACTIVENESS LEVEL	PU/U-233 CATEGORY (QUANTITIES IN KGS) I	II	III	IV[1]	CONTAINED U-235 (>20%) CATEGORY (QUANTITIES IN KGS) I	II	III	IV[1]	CATEGORY IV
WEAPONS ASSEMBLED WEAPONS AND TEST DEVICES	A	ALL QUANTITIES	N/A	N/A	N/A	ALL QUANTITIES	N/A	N/A		
PURE PRODUCTS PITS, MAJOR COMPONENTS, BUTTONS, INGOTS, RECASTABLE METAL, DIRECTLY CONVERTIBLE MATERIALS	B	>2	>0.4<2	>0.2<0.4	<0.2	>5	>1<5	>0.4<1	<0.4	
HIGH-GRADE MATERIAL CARBIDES, OXIDES, SOLUTIONS (>25G/1) NITRATES, ETC., FUEL, ELEMENTS AND ASSEMBLIES, ALLOYS AND MIXTURES, UF_4 OR UF_6(>60% E)	C	>6	>2<6	>0.4<2	<0.4	>20	>6<20	>2<6	<2	
LOW-GRADE MATERIAL SOLUTIONS (1-25G/1), RECYCLABLE PROCESS RESIDUES, MODERATELY IRRADIATED MATERIAL, PU^{236} (EXCEPT WASTE), UF_4 OR UF_6 (>20% <50% E)	D		>16	>3<16	<3		>50	>8<50	<8	
ALL OTHER MATERIALS HIGHLY IRRADIATED FORMS, SOLUTIONS (<1G/1), URANIUM CONTAINING LESS THAN 20% U-236 (ANY FORM OR QUANTITY)										REPORTABLE QUANTITIES

[1]THE LOWER LIMIT FOR CATEGORY IV IS EQUAL TO REPORTABLE QUANTITIES SPECIFIED IN THIS ORDER

SOURCE: DOE Order 5633.3 Control & Accountability of Nuclear Materials.

of nuclear material. A complete safeguards program must include a spectrum of capabilities, ranging all the way from the reduction of the threat through deterrence, to the recovery of material, as part of the comprehensive objectives of deterrence, detection, response, recovery, and assurance. The role of MC&A has been defined in DOE order 5633.3 as "that part of safeguards that detects or deters theft or diversion and provides assurance that all nuclear materials are present." MC&A activities are primarily designed to deter and detect unauthorized acts by insiders through sensors, surveillance, computer analysis, and alarms. In contrast, physical protection measures are primarily designed to deter and detect unauthorized acts by outsiders, by monitoring, barriers, and force. Physical protection includes the ability of guard forces to respond to attacks, defeat the attacker, and recover special nuclear materials if they are captured by the attackers. MC&A includes inventory actions to evaluate situations, locate material, and assist in recovery. MC&A and physical protection provide continuing assurance that material is in its proper place, and that no threatening activities have occurred.

Physical Protection

Physical protection requirements for special nuclear material at DOE facilities and in transit between DOE facilities are defined by DOE Order 5632.2A; Protection of Special Nuclear Material and Vital Equipment, issued February 9, 1988. The physical protection systems are the most visible and pervasive components of the safeguards system. Sensitive sites and facilities within sites are surrounded by multiple barriers, including razor ribbon and innovative devices to impede a potential penetrator. Access to personnel and material is confined to specially designed portals, where guard forces and remote-sensing devices perform the functions of identification, verification, and authorization of all entry and exit movements. This includes control of materials as they enter or exit portal points, involving procedures such as the checking of tamper-indicating devices, and use of sensory equipment to verify contents. The physical protection system is designed to detect any unauthorized penetration of barriers and portals, and to respond with immediate investigation and use of force as necessary. The technology of physical protection has become increasingly sophisticated in recent years, and while it has provided a major increase in security, it has also resulted in exponentially increasing costs to the safeguards program. While the committee's site visits focused on MC&A practices, the physical protection systems were also observed, and the interrelationships between the systems were indicated.

In particular, each component part of the safeguards system may be activated in response to alarms and other detection signals by the other. For example, anomalies in the accounting of materials may require investigation and special actions by the security forces. These forces also need training in response to specific plant contingencies, such as an emergency evacuation that may render the material and the MC&A system temporarily vulnerable to covert insider activity. Reciprocally, the physical security system may detect a suspected theft of material through various means, and MC&A must be used in generating positive assurance that material has or has not been diverted.

Physical security forces may also monitor technical personnel who carry out certain MC&A functions, by controlling internal portals giving access to very sensitive areas, and by enforcement of a two-man-access rule.

The committee did not study the physical protection systems in depth. It did consider the question, "How much is enough?," as applied to the safeguards program as a whole, and also the question of balance in the allocation of fiscal resources across all safeguards functions, as discussed in Chapter 3.

Human Reliability

The effectiveness of the safeguards and security system depends on the reliability of the people employed at all levels in the nuclear materials production complex. DOE facilities where substantial amounts of special nuclear material can be found now have or are developing human reliability programs (HRPs). These may have a range of activities, including the universally required conventional government security screening, indoctrination, training, and some personnel records functions, although there is no completely uniform policy that applies throughout the nuclear fuel complex.

No system of physical protection and MC&A can provide 100 percent protection against all conceivable contingencies of threat. Therefore, it is of vital importance that human reliability factors in safeguards and security contribute to the deterrence function, by reducing the likelihood or range of insider threats. There is an obvious tension between the traditional means of screening, selection, indoctrination, and motivation and the increasing recent emphasis on behavior monitoring, drug testing, and security review. Difficult questions relating to civil liberties and privacy are raised when one contemplates these measures.

Considering these problems and the complexity of DOE's operations involving special nuclear material, it is not surprising that the questions involving the effects of human factors have lagged behind those that can be addressed by engineering methods. Nevertheless, it is increasingly recognized that human behavior can have a pronounced effect on the adequacy of the safeguards system.

The Atomic Energy Commission, the Energy Research and Development Administration, and now the Department of Energy have historically had human reliability programs largely characterized by a system of security clearances based on background investigations. Initially, disloyalty to the United States was the prime concern in this process, and the security clearance generally did not address such matters as vulnerability to bribery and drug dependency.

These practices have now changed. Several recent cases of insider espionage against the United States, such as the events involving the Walker family, have shown that security clearance alone is not dependable as a barrier to espionage and, by extension as a barrier to theft or sabotage of SNM. Practices for screening individuals with access to SNM have undergone important changes in response to this realization. In particular, evidence of use of mind-altering and addictive drugs is now accepted as grounds for denial of access to SNM, or any position of responsibility relative to SNM.

The committee believes that more attention to human factors in safeguards would be of real benefit. Components should include an expanded concept of motives, education and indoctrination, on-the-job alertness to anomalous events and behavior, and employee morale. In addition, certain behavior patterns should serve to signal a need for immediate observation, surveillance, and in-depth investigation.

A critical aspect of MC&A and physical protection is the security of information about system vulnerabilities. Partial protection is provided by allowing personnel to have information only as required by their particular job function.

MATERIAL CONTROL AND ACCOUNTING

Material accounting is a technique for detecting losses of material during processing or providing assurance that no loss has taken place. Material control procedures emphasize activities such as control of access to nuclear materials, and the control of movements of material. Requirements on material control and material accounting are defined in DOE order 5633.3, Control and Accountability of Nuclear Materials. This order and those pertaining to other aspects of the safeguards system have been revised recently. They reflect a progressive refinement of the requirements taking into account past experience, new analysis, and the availability of improved technology.

A major change reflected in the new orders has been to define the requirements in terms of performance objectives, that is, the desired levels of protection and assurance to be achieved, rather than solely as detailed instructions for compliance. At this time, guides are being drafted by the DOE Office of Safeguards and Security (OSS) to assist personnel in the field operations offices and facilities in adapting to the new, performance-oriented methods and requirements.

The general requirements of the order are:

- A graded material control and accountability program.
- A management structure facilitating the implementation of the order.
- Provisions for appropriate documentation of authorities and responsibilities.
- Requirements for training and qualification of personnel.
- Establishment, development, and management of a MC&A plan for each facility.
- Integration of the material control and material accountability functions with physical protection activities.

o Development of emergency plans consistent with other DOE orders to respond to and resolve conditions, such as those that may indicate loss of control of special nuclear material.

o Provision of defense-in-depth such that the failure of any one component of the safeguards system does not degrade the overall capabilities necessary to meet defined performance requirements.

Material Control

The purpose of material control is to prevent unauthorized movement of special nuclear materials and to detect promptly the theft or diversion of the material should it occur. This capability also serves to deter theft or diversion. Material control may also provide for the ability to identify the individual or individuals responsible for the undesirable act, and may help to identify the means for prompt recovery of the material. The follow-up identification and recovery actions may themselves fall outside the scope of the material controls, extending into the domain of physical protection.

Material control measures can assume a variety of forms:

o Barriers to access or to unauthorized movement, such as secure vaults, access controls, and enclosures.

o Channeling material through authorized flow paths and storage locations.

o Clear observation of process lines to permit visual surveillance by persons not engaged in the process, and remote instrumental surveillance.

o Secure containers and storage provision for material not immediately in process.

o Seals and identification codes making items amenable to rapid verification of their location and condition.

Process control information ensures that material does not drop out of sight between successive process steps. Many of these controls have associated "alarms" in the form of instrument-based or computer-based signals that an "abnormality" has occurred.

Material controls are subdivided into four key functional performance areas:

o Access controls of personnel to nuclear materials; nuclear material accountability, inventory, and measurement data; and to data-generating equipment and other items of equipment where misuse or tampering could lead to compromise of the safeguards system.

o Material surveillance programs that monitor nuclear materials for the purpose of detecting unauthorized activities or anomalous conditions. Surveillance procedures are to include a description of the methodologies and operational/control points on which the material control program is based and are to provide for investigation, notification, and reporting of anomalies.

o Material containment programs that provide controls for nuclear materials operations relative to material access areas, storage repositories, in-process areas, and the use of tamper-indicating devices (seals) on containers.

o Detection and assessment capabilities that provide assurance that there has been no unauthorized removal of nuclear materials, consistent with the graded safeguards concept. The system is to be interfaced with the facility's physical protection and organizational systems, as appropriate, in order to provide a high probability of the detection of the removal of SNM from its authorized location and to provide effective response when such events are detected. Detection/assessment procedures and devices in the order include such material control detection assessment functions as:

-- Daily administrative checks of material balances areas processing a Category I quantity of SNM.

-- Program for control of tamper-indicating devices (TIDs) that assure that TIDs are used as appropriate to detect violations of container integrity, without their having been compromised.

-- Portal monitors that facilitate a physical or electronic search of vehicles, personnel, packages, and all other containers at all routine exit points from a material access area and/or protected area, to protect against the unauthorized removal of SNM by vehicle or personnel.

-- Waste monitors that determine the SNM content in all liquid, solid, and gaseous waste streams leaving a material access area to assure that discharge levels remain within process limits.

-- Other detection and assessment mechanisms based on item identification, number of items, verification of intact tamper-indicating devices, confirmation that no unauthorized access has occurred, process monitoring, near-real-time accountability, control procedures for use and movement of material, or any other approved technique for identifying anomalies that may be associated with attempts at theft or diversion.

Material Accounting

The purpose of material accounting is to ensure that all material of interest is accounted for, or to measure the loss of any, and to provide information for follow-up investigation, within error limits imposed by the process and by instruments.

Accounting Practices

Accounting practices provide the data for formation and verification of material balances, and also include a number of features that could properly be classed as material controls.

Some of the principal features of the accounting system are:

- o Each facility possessing SNM is divided into one or more material balance areas (MBAs). This permits the localization of losses to the MBAs.
- o Accounts are maintained by MBA, including transfers in and out and physical inventories when made. A material balance is formed at the appropriate times for each MBA.
- o Material balances are based on measured values for amounts of SNM transferred or in inventory. Systems of control of measurement programs are required.
- o Transfers of SNM between MBAs are documented and the documentation is signed by authorized custodians or their alternates.
- o A single individual is held responsible by management for each MBA, for ensuring that approved control and accounting practices are implemented in that area.
- o Documented internal reviews are made periodically of practices at facilities with Category I or II quantities of SNM, by qualified individuals independent of the process activities.
- o A system of alarms and investigation of alarms is defined, for following up on MC&A abnormalities.

Measurements

At the center of the technique is measurement of the mass (or volume) and of the composition of representative samples of material. The techniques called for depend on the chemical and physical form of the materials being measured and on their accessibility within a process line. In some cases, simpler methods based on item identification are used. These are discussed separately below.

Systematic records are kept covering all transactions involving the movement of an identifiable unit of material into or out of a well-defined physical area or unit process. Such units may be a batch in the process line, a unit defined by flow in a given time across given boundaries, containers as a unit, or individual countable items. Each such record includes information on the amounts of material being monitored. In the course of a process, chemical and physical alterations take place, which transform composition or which divide or combine units to form new ones. Measurements are made of the composition and mass of the transformed units, and these are used to determine the quantities in the units of the specific components covered by the accounting system.

Some of these measurements are made as part of process control, but they are incorporated into the safeguards system. Others are made solely to serve the safeguards accounting system.

Inventories

The quantity of all accountable material in a given area or process is determined at discrete time intervals. The total quantity of an accountable material across an area or process is called the "inventory" for a given accounting period. The normal practice in material accounting is to maintain a "book inventory," defined as the initial measured inventory at the start of an accounting period, as augmented by receipts and reduced by removals from the area or the process. At specified time intervals, the accounts must be balanced by actually performing a "physical inventory" based on material actually found to be present. An itemized list of all units of material found to be present in a physical inventory is called an "inventory listing." The physical inventory is formed through measurements of amounts of materials in the units of the listing. Measurements made during process steps may be used if there is reasonable assurance that they are still reliable at the time of the physical inventory.

The book inventory and the physical inventory of accountable material will usually be found to differ. One almost universal reason is the existence of limits to accuracy and precision of measurements resulting in so-called "measurement errors." These limits cause measured values of physical attributes, such as mass or composition, to differ from exact values to a fundamentally unavoidable extent. This "error" is inherent to the measurement process, and not to be confused with mistakes such as transcription errors and transposed digits, or the actual overlooking of material during a physical inventory. The inherent errors fall within statistically predictable ranges called "error limits," and in a system of accounting they combine statistically or arithmetically, depending on their nature, so that the total effect of many small errors can lead to a substantial departure of both the measured physical inventory and the adjusted book value from the actual amount of material present.

A second common reason for differences between book and inventory values is that many processes lead to generation of hard-to-measure forms of material. Examples are in-process holdup (i.e., deposits in pipes and tanks) and metal scrap. Where holdup occurs, very imprecise measurements must be used, or indirect methods of estimating mass and composition must be relied on.

Almost all processes that change the chemical or physical form of the material can generate some losses to the environment or to waste streams. Because nuclear material processing is designed to eliminate the discharge of radioactive wastes to the environment, these losses are generally very small. Such releases should be measured wherever possible, however.

The resulting difference between the book and physical inventories is called the "inventory difference" (ID). Detection of a theft or a diversion of material by measurement of the ID requires that the ID stand out against this background of measurement uncertainties.

Accounting Period

Any material balance report is associated with a specific accounting period. It is formed using the data from physical inventories at the start and end of the period, and the measured inputs and outputs of material over the period. Thus, thefts or diversion occurring between ID measures will not be detected until completion of the accounting period. In some processes there is an endeavor to maintain an up-to-date, or near-real-time, estimate of the physical inventory, based on ongoing process measurements and other measurements specifically for material accounting. Where this can be done, a near-real-time material balance can be formed. That is, a time-dependent ID can be determined based on a starting physical inventory at any designated reference time with very small time increments between measures. This capability is a major advance helping to integrate material accounting more actively in the safeguard operations.

Limit of Error

The limits on measurement accuracy and precision, additional uncertainties resulting from estimation of inaccessible materials in-process, estimation of contents of loss-streams, and assignment of content of scrap and process residues, are combined by statistical methods into an overall variance (sigma squared) of error on inventory difference. Limit of error of inventory difference (LEID) is defined as two standard deviations (two sigma); thus, in principle, any measurement of ID, where the difference is in fact zero, should fall within the LEID 95 percent of the time. A value of ID substantially exceeding LEID would be a reason for investigation to determine the cause.

Item Accounting

In many cases, materials are in the form of recognizable discrete items, including sealed containers, whose mass and composition remain subsequently unchanged. Simpler and more accurate accounting methods are based on item identification and counting. Item accounting is clearly preferable whenever the process allows materials to be managed in discrete units.

Examples of material suited to item accounting are fuel rods, fuel plates, and fuel elements of nuclear reactors, manufactured components of nuclear explosive devices, and containerized liquids, gases, or solids. Tamper-indicating devices are used to seal containers, and nondestructive measurement and analysis (NDA) techniques, such as neutron or gamma measurements, are used to verify nonimpairment of containers.

Elements of Material Accounting

Included in DOE Order 5633.3 are specific requirements relative to the accounting and control of the SNM. Accounting systems are designed to provide a data base for tracking nuclear material inventories, documenting nuclear material transactions, and issuing periodic reports, and for verifying, detecting, and evaluating loss detection elements in a timely manner. Key elements of material accounting are defined as:

o Accounting system procedures that describe the structure and operation of the nuclear accounting system.

o Periodic physical inventories that determine the quantities of nuclear materials on hand, including process holdup where practical.

o Measurements and measurement control programs that ensure quality of the measurement data base and establish nuclear material values for all items in the material balance.

o Material transfer programs to account for inter- and intrafacility transfers of nuclear materials. The programs include documented procedures that specify the requirements for authorization, documentation, tracking, verification, and response to abnormal situations.

o Material control indicators that through analysis and investigation can provide assurance that losses and unauthorized removals of nuclear materials did not occur. Each facility is to document plans specifying responsibilities and providing procedures for evaluating control indicators. The indicators specifically identified in the order are:

-- shipper/receiver differences;
-- inventory differences; and
-- inventory adjustments.

The Roles of Material Measurement and Accounting

It is particularly important to recognize two distinct roles of measurement in the accounting process. The first is to establish the mass or content of a newly created unit of special nuclear material. Uncertainties in measurements at such a stage as noted above become inherent and unavoidable contributions to the uncertainty in the material accounting process. The other type of measurement is one designed to confirm that a previously established value of mass or content has not changed. Such confirmation is one possible (and possibly redundant) technique for detecting whether there has been an unknown or unauthorized change in a previous value, or it can certify that no such change has taken place. In this case, measurement uncertainty determines the sensitivity of the control, but does not contribute to any uncertainty in the material balance, because this is governed by the original measurement, which is only being verified. In particular, shipper-receiver comparisons are a control of this type, since they are, by definition, measurements on the same item of material unless an unknown or unidentified change took place. They verify the validity of an item accounting process that does not inherently involve measurement error.

Finally, it is noted that neither the inputs to the accounting system nor the outputs it provides are necessarily unique to the safeguards function, but are inherent to management of the production process and to quality control of the materials themselves.

ORGANIZATION OF MC&A WITHIN DOE

Figure 2-1 shows how DOE headquarters is organized to manage the safeguards responsibilities of the department.

The policies and requirements for safeguards on SNM within the Department of Energy, including those for MC&A, are formulated by the Office of Safeguards and Security, under the deputy assistant secretary for security affairs of the Office of the Assistant Secretary for Defense Programs. OSS is also responsible for research and development on safeguards, and for activities pertinent to DOE's interest in international safeguards. Implementation of the policies and guidance is a responsibility of the Operations Offices, which reports to the under secretary of energy.

The effectiveness of implementation of these programs by the Operations Offices is determined through inspections by the Office of Security Evaluation (OSE), which reports directly to the assistant secretary for defense programs. These relations are seen in Figure 2.1. In addition to the indicated chain of responsibility involving the assistant secretary for defense programs, there are other responsibilities in safeguards assigned to other assistant secretaries and secretarial officers who administer programs involving SNM. These are primarily responsibilities with respect to planning and funding for safeguards.

Since most of the DOE's SNM is used in programs under the assistant secretary for defense programs, that office is the most affected by the assignment of responsibility to secretarial officers. The principal inspections and audits in safeguards including MC&A are carried out by OSE. DOE order 5634.1A requires that the cognizant field organization (i.e., Operations Offices) conduct and report nuclear materials surveys. This includes oversight tests. DOE order 5633.3 requires that the operating contractor conduct internal reviews and assessments of safeguards if he possesses Category I or II amounts of SNM. Ad hoc studies of effectiveness have been made from time to time over the years. All of these assessments are valuable, and those required formally are necessary features of the discharge of responsibility in the administrative chain within DOE.

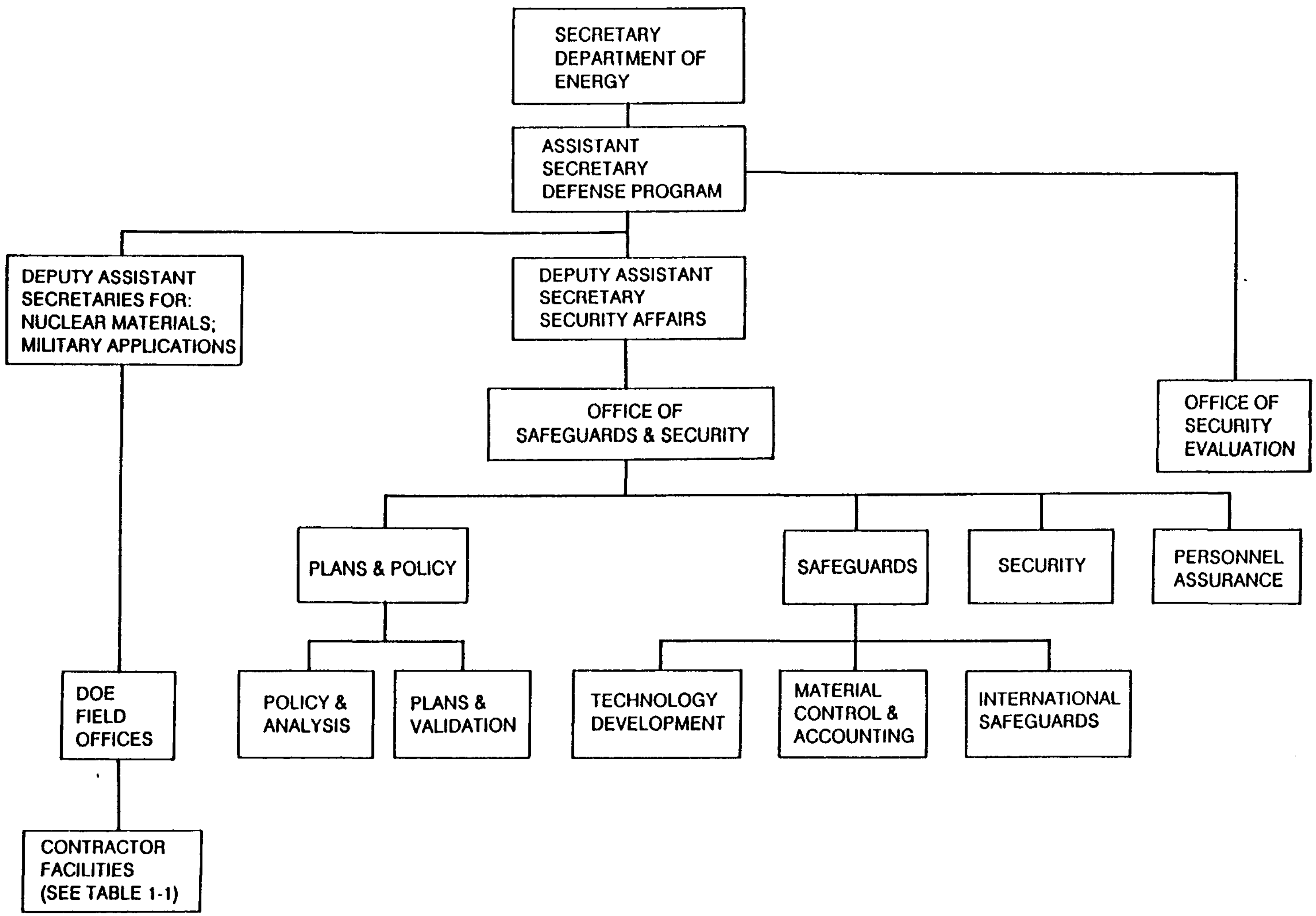

FIGURE 2-1 DOE organizational structure for safeguards policy and evaluation.

3

TOWARD IMPROVED MANAGEMENT AND PLANNING FOR MC&A

CONTEXT FOR THE COMMITTEE'S CRITIQUE

The general background for this critique was provided in Chapter 1. It includes a description of the inherent difficulties of planning and managing the complex from headquarters (The Moving Target), a description of Department of Energy (DOE) actions aimed at dealing more effectively with the complex (The Department of Energy's Initiatives), and citation of evidence that DOE continues to improve the planning and management of safeguards (Current Status of DOE Safeguards). Chapter 1 also includes an overview of certain problem areas requiring additional attention by DOE. Additional specific background has been provided in Chapter 2, which contains a description of the DOE's safeguards program and the role of material control and accounting (MC&A) within that program.

In this chapter the committee provides its views on what areas of planning and management for the various MC&A functions need further improvement, beyond the significant progress already made by DOE. It is important to state that concurrent to the work of this committee, the under secretary of energy formed a task force to update the current DOE orders, as recommended by the Special Project Team. Drafts of these orders were made available to the committee, and some were finalized prior to completion of this report. Many of the concerns expressed by the committee at the workshop and at briefing sessions have been addressed in the updated orders. Given the rapid pace of implementing changes to the Orders, and other changes by headquarters management, the critique that follows may include some recommendations for action already adopted by DOE.

The following sections group the comments of the committee as follows:

- Establishment of policies and planning guidance
- Management of the safeguards program
- Monitoring and evaluation of safeguards

Within each section a discussion is followed by specific recommendations.

ESTABLISHMENT OF POLICIES AND PLANNING GUIDANCE

The committee faces a quandary as it reviews policies and planning for MC&A. These are topics inextricably bound in questions of management. But management issues arise in connection with safeguards as a whole subject, because MC&A is only a component in a total system. Therefore the comments that follow have a character broadly addressing the whole safeguards system.

This section addresses issues relating to the manner in which DOE headquarters sets management policies relating to safeguards, and provides guidance to DOE field offices and to contractors. The following topics are presented:

- Responsibilities and Authorities
- Orders and Guidance/Standards and Criteria
- Master Safeguards and Security Agreement
- Resource Allocation
- Strategic Planning

The first topic deals with the way DOE is organized at headquarters for the management of safeguards. The second topic deals with the fundamental management documents promulgated by headquarters to the field offices and the contractors, implementing the intent of the safeguards program. The third topic focuses on a recent management innovation to improve the level of planning for safeguards upgrades by the contractors and the field offices. The fourth topic deals with the problem of resource allocation; that is, the problem of allocating funds for safeguards upgrades across the various sites and facilities of the complex. The last topic discusses strategic planning for the long term, as a guide to policymaking and to planning.

These topics are generic to the management of safeguards, of which MC&A is a part. Nevertheless, if MC&A planning and management is to be improved, the place to start is at the level of safeguards as a whole. The comments and suggestions that the committee has provided would not make much sense if they were restricted to the MC&A component of the system.

Responsibilities and Authorities

In principle, the current organizational structure as shown in Figure 2-1, is adequate for an effective safeguards system. However, to have an effective management team in safeguards, there must be clear, consistent, and comprehensive assignments of responsibilities and authorities within the organizational structure that recognize the probable continuation of the past high turnover of personnel in key headquarters positions. The responsibilities and authorities of the various organizational units within DOE are defined through various DOE orders and other documents, some of which are still in draft form. The committee reviewed the newly issued DOE orders, the statements of functions under the Office of Safeguards and Security (OSS), and other similar documents containing this information. It was clear that in their totality these reflected a much improved system of safeguards and in many ways a better assignment of responsibilities and authorities than previously.

However, the Committee found that the flow of responsibility and authority through the documents is not always consistent, nor are responsibilities and authorities completely assigned for each organizational unit. In some instances, different orders state lists of authorities and responsibilities for the same office that are different and not readily reconcilable. In other instances responsibilities or authorities that were not delegated to an office are delegated by it to a subordinate office. In some instances a responsibility is defined without commensurate authority, and vice-versa. On occasion, authorities or responsibilities that are implicitly to be attached to an office are not explicitly assigned to it. These managerial oversights are certain to have an impact on the effectiveness of the safeguards program.

Further, the time required to implement changes needed to maintain safeguards policies and guidance up-to-date is long. The committee recognizes that some of this delay has been the result of the frequent turnover of key personnel. Continued improvement to the safeguards program will require heightened attention to staffing, clarification of responsibilities and authorities, and more rapid updating of policy and program changes.

The problems resulting from the high rate of turnover of personnel in higher policy positions in safeguards are no doubt going to continue. The management of safeguards is politically and socially a sensitive activity. Because of the way the safeguards function is funded and discharged, individuals in policy-setting positions in DOE headquarters are frequently held accountable for aspects of the program over which they have little or no funding control or immediate authority, and which they cannot quickly modify. This inevitably leads to a sense of frustration and a readiness to move on to a different job with a greater promise of feeling of accomplishment.

Furthermore, the sensitiveness of the safeguards activity keeps it in view of those at the highest levels of DOE. As changes take place in higher levels in DOE, downstream changes tend to follow in headquarters safeguards management, with the appointment of persons in which the new top management has confidence. This practice tends to downgrade the value given to the experience and capabilities of DOE career personnel, who have a detailed knowledge of the weapons complex and of safeguards.

The system is very responsive to these changes, and needs to achieve a stability in the face of them.

Recommendations on Responsibilities and Authorities

o The assignment and delegation of safeguards responsibilities and authorities to the various levels of DOE management should be made complete and consistent. There should be a more traceable flow of authority and responsibility from the top to the units below.

o The functions and responsibilities of the offices in DOE headquarters should be assigned and structured to be stable in the face of frequent personnel turnover in the higher level positions. This could be achieved in part by clear and complete assignments of responsibility between and within these offices, by adoption of long-range plans with clear milestones and schedules, and by greater reliance on staff levels with more permanence. Consideration should be given to providing incentives for a career commitment to the safeguards system.

Orders and Guidance/Standards and Criteria

As noted elsewhere in this report, the revised DOE orders are a significant improvement in the definition of responsibilities for the elements of the safeguards system. Similarly, the change in emphasis from a compliance to a performance evaluation process was a beneficial step toward improving the system of safeguarding of special nuclear materials (SNM). The necessary tools for evaluating performance of organizations, in response to the new structure of the DOE orders, and with the performance standards and criteria have not yet been developed. These changes to improve safeguards will not achieve their purpose if a companion set of tools is not devised to be used to evaluate performance on a consistent basis under new orders and standards and criteria.

One of the strengths of a performance-based system of safeguards is that it permits innovations to be introduced into the system by the organizations handling SNM. The evaluation methods should be sufficiently broad to permit the results of innovations to be assessed, and management should be evaluated on the innovations introduced within its operations to improve the safeguarding of SNM.

Recommendations on Orders and Guidance/Standards and Criteria

o The DOE should follow the issuance of new orders and of standards and criteria with a corresponding endeavor to develop the necessary tools for use in evaluating the performance of organizations handling SNM.

The Master Safeguards and Security Agreement (MSSA)

DOE order 5630.13, Master Safeguards and Security Agreements, in February 1988, established the Department of Energy's policy, requirements, responsibilities, and authorities for the development of Master Safeguards and Security Agreements (MSSAs). The MSSA is intended to:

- o Designate the level of protection of DOE safeguards and security interests that field offices, program offices, and safeguards and security policymakers acknowledge is adequate.
- o Identify levels of protection appropriate to the particular safeguards and security interest in accordance with the potential risks to national security and the health and safety of the public.
- o Provide the basis for facility planning, executing, and evaluating the protection program.
- o Provide the basis for budget submittals consistent with the commitment made in the MSSA.

In the realization of the objectives of the MSSA, it is implicit that there be:

- o A consistent analysis of risks across the DOE complex.
- o A consistent protection for like assets at differing sites.
- o A "buyoff" by all those responsible for implementation and funding.
- o Funding necessary to implement the upgrades plan.

The format, content, and specific guidance for the development of MSSAs is given in the MSSA Preparation Guide of October 1986. A new draft guide is being prepared, consistent with the new DOE Orders. The guide requires that the MSSA include an overall statement of the facility's safeguards and security performance level based on the status of several complementary performance indicators, such as the results of vulnerability analyses, system performance tests, surveys, inspections, evaluations, and training levels, as well as the field manager's judgments of the effectiveness of the protection system. It also requires that they contain summary-level information adequate to describe the basis supporting the agreement, assumptions, exceptions, and conclusions. The MSSAs are to be supported by back-up documentation. This may include system studies, vulnerability analysis, cost-benefit analyses, implementation procedures, and risk analyses.

The committee finds that the MSSAs are an excellent management tool that can be strengthened. Some observations about MSSAs are:

- o The MSSAs are a recent management innovation that have the potential for producing a valuable management tool for characterizing and understanding the safeguards program at DOE sites, and to ensure safeguards programs are consistent even though not identical from site to site. MSSAs are now the basic document for planning and justifying upgrades to safeguards on a site-by-site basis.

- o The MSSA signature and sign-off requirement does not currently include the contractor responsible for the operation.

o Long periods of time have been needed for formulation, review, and finalization of MSSAs.

o The procedures being used to estimate risk for the MSSA are based on a "worst-case" combination of adversary intent, knowledge, capability, and protection system response. Specifically, they neglect deterrence activities and probabilities prior to attempts, and also neglect recovery activities and probabilities after an attempted or actual threat. These assumptions yield an extremely conservative estimate of protection system performance. Thus, the risks reported in the MSSAs are not true risk probabilities, but scenario extremes that may easily be misinterpreted to be measures of actual risk.

o The risk evaluation required by the MSSAs, and the guidelines provided by DOE headquarters, do not answer the question: "How much (protection) is enough?" Additional methodological development and guidance is needed.

o The principal thrust of the MSSA risk analysis is with regard to physical protection. Little, if any, credit is taken for MC&A systems or human reliability programs for reducing overall system risk.

o Consequence evaluations are restricted to those materials and quantities of strategic significance only. Other consequences meriting consideration include facility sabotage, toxicological sabotage, economic loss, and adverse public and political perceptions.

o There are inherent limitations in the capabilities of personal computer (PC) based evaluation and planning codes, such as ET, SAVI, and MI$ER, to adequately quantify "risks" associated with complex facilities, protection systems, and threat scenarios. (These codes are discussed in a subsequent section.)

Recommendations on MSSAs

o The MSSA should be signed by the:

-- assistant secretary for defense programs;
-- program director responsible for funding;
-- the applicable operations office; and
-- contractor for the operation.

o Headquarter's Office of Safeguards and Security should have review and concurrence responsibility for consistency and uniform level of commitment across the whole DOE complex.

o The MSSAs should be completed expeditiously. Once completed, they will be extremely useful for planning, executing, and evaluating the protection system, as well as for laying the basis, however imperfect, for the budget submittal. Therefore:

(1) promised modification of existing planning and reporting requirements to eliminate duplication of functions by different organizations should be accomplished; and

(2) the agreement should be kept reasonably stable, to allow safeguards goals to be met.

o The word "risk" in the MSSA guidance document and subsequent MSSAs should be changed to "figure of merit."

o To the extent possible, the subjectivity of input parameters to the risk evaluation should be reduced through improved data bases, so that the results can be used in formulating guidance for comparisons and for allocation of resources between facilities.

o Models and data should be developed for consistent evaluation of safeguards subsystems. Additional modeling is required to include human reliability for MC&A as well as for physical protection, to facilitate resource allocation.

o Consideration should be given to including as consequences, toxicological sabotage, economic loss, political impact, and adverse public perception.

o In order to achieve consistency of application of risk assessment across the DOE complex, improved headquarters guidance should be provided with respect to threat levels, importance of consequences, acceptable risks, risk evaluation, cost/benefit methods, prototype vulnerability assessments, and MSSA preparation. Also additional guidance is needed in cost modeling, including the combination of capital costs, operating costs, and effect of changes on production.

Resource Allocation

There is no current risk-based method of allocation of resources among different facilities in the DOE complex. Resource allocation in the DOE weapons production complex can be viewed as having passed through three recognizable phases: (1) an initial phase by the Atomic Energy Commission marked by pioneering and rapid growth; (2) a mature, nearly steady state phase of improvement, refinement selective growth, and diversification of weapons systems; and (3) a period of selective modernization of older facilities.

The first phase of nuclear materials production was driven by performance and schedule requirements, with essentially unlimited access to resources. The first two decades of the second phase were also largely driven by requirements, with resources a secondary consideration. The last decade of the second phase and the beginning years of the third have been marked by an environment of increasingly severe constraints on the timing and levels of resources, both as congressional authorizations and appropriations. This is leading to enhanced pressure on the safeguards budgets for activities in the nuclear weapons production complex, since these budgets are not broken out and protected from overall production budgets and requirements. The two doublings of safeguards costs in less than a decade resulting in an annual expenditure level of about $800 million culminate an expansion phase that has now ended. A major contingency in future planning and management is the much greater likelihood of severe budgetary constraints. This puts an even greater pressure on the process of resource allocation to provide more transparently objective and defensible rationales for resource allocation, both in total for the DOE complex and in the distribution between different elements of the complex.

Because the total resources for DOE are also likely to be more subject to constraints, it is important that all overhead types of functions, including safeguards, be more critically examined and justified than previously. Otherwise, the pressure of reduced total resources and increasing overhead costs will reduce the productivity and output of the system. A kind of inadvertent disarmament (reduction in capability) could result that foreign subversion or domestic opposition could hardly hope to accomplish.

It is also very important to keep in mind that misallocation of safeguards resources to secondary risks (typically resulting from political overreaction) limits the resources applied to primary risks. The misallocation is not simply a waste of resources. It actually results in an increase in the level of risk exposure incurred for the given level of resources. (This is an aspect of the Pareto Principle.) Stated in more familiar terms, it should be a moral, ethical, and professional principle for all risk managers to strive for the "most bang for the buck" from risk management resources, since misallocations inevitably increase the total risk exposure of the system.

Recommendations on Resource Allocation

o The Department of Energy should move toward establishing a department-wide method of resource allocation for safeguard functions. The current cross-cut budget for safeguards does not ensure a proper balance of the safeguard resources. (Also see section on "Balance in Safeguards Functions".)

o The process of resource allocation should incorporate explicit and as realistic as possible assessments of the relative risk exposures (to diversion, theft, or sabotage) of different facilities and processes on a given site, and also between sites.

o The judgments of relative exposures should take note of the results of insights from use of formal risk assessment models (e.g., extensions of ET, SAVI, and MI$ER, or their successors). Improved models on these lines should explicitly include estimates of the probability of detection and thwarting or deterrence of attempts as a function of the size and resources of a presumed adversarial group. The improved models should also take explicit account of the communications and resources available for reaction, response, and recovery, given that an attempt to penetrate has led to access to SNM.

o The roles and functions of process control, materials control, and accountability relative to physical security should be reevaluated periodically, and the applicable changes made in planning, budgeting, and resource allocation.

Strategic Planning

Certain units of the Department of Energy and the Department of Defense are engaged in a major strategic review of the production capabilities and goals for nuclear weapons for the coming decade. The most immediate concern is over the progressive loss of capability to produce tritium and plutonium, and the lengthy lead times for designing, authorizing, and building replacement capacity.

At the same time, there has been a growing recognition that some of the DOE production facilities are obsolescent. This has led to plans for the major modernization of essential production facilities and their supporting infrastructure. The process of modernization is already well under way at some sites, with replacement facilities in various stages of design, authorization, and construction.

The modernized facilities provide a vital opportunity to remove constraints on the MC&A systems imposed by longstanding designs and layouts, to introduce new MC&A technology, and also to improve inherent physical security.

The impact of recent tight federal budgets on the funding of the needed replacement facilities is being felt, however, and some desirable refinements in MC&A and other functions may be limited or delayed.

As discussed elsewhere, the likelihood of continued high rates of change in requirements, and probably in funding, will be a continuing and increasing challenge to both current management and to strategic planning.

The usual budget planning cycles require at least 3 years for relatively modest changes, and 5 to 12 years to implement major items such as a new facility.

Recommendations on Strategic Planning

- A continuing strategic planning process for safeguards should be institutionalized, to produce and maintain rolling 3-, 4-, and 10-year strategic plans to be used in current guidance. (A strategic plan is one with built-in options for actions in the future, as a function of different possible outcomes or events.)
- Areas or topics in the broad strategic plans that have substantial potential for significant changes in requirements for weapons systems or their features, and that would require changes to MC&A, should also be the impetus for associated reevaluations and changes in facilities, personnel, and programs devoted to safeguards.
- The strategic planning process should be carried out in parallel with the monitoring of trends in scientific and engineering developments that may mature into usable technology in a 10 to 20-year time frame. The insights generated will assist in the review of design goals, and in the specification of safeguards for new processes and facilities. In addition, this insight will be useful for maintaining contingency plans as circumstances such as policies, change, or as various research and development (R&D) projects generate revised technological outlooks.

MANAGEMENT OF THE SAFEGUARDS PROGRAM

The topics that follow relate to a series of very difficult problems inherent to the safeguards program. Here the focus is much more on MC&A than in the previous section. There are no ultimate solutions, but there is continuous progress toward better practice and results.

The topics are:

- Integration of Safeguards in the Field
- Planning of New and Upgraded Facilities
- Management of Research and Development for Safeguards
- Risk Analysis
- Data-Base Systems for MC&A
- Balance in Safeguards Functions
- Evaluating System Performance
- Management of Inventory Differences
- Management of Shipper/Receiver Differences

The topics proceed from the more general to the more specific. The planning of new and upgraded facilities relates to DOE's efforts to plan upgrades and allocate funds to projects across the complex in an efficient manner.

The research and development programs are the key to providing a base of technologies and analytical methodologies that management can use in the future. Risk analysis is a helpful tool for making planning and resource allocation decisions in the DOE's safeguards environment at each site (as in the MSSA process) and across the various sites. Data-base systems are essential for several management purposes including the previous topics, and for achieving balance in safeguards functions and in evaluating system performance which follow. Finally, the committee presents its views on two specific aspects of performance evaluation that have been a continuing concern to headquarters management: inventory differences and shipper/receiver differences.

Each topic is extremely complex, and this presentation does not provide the depth of analysis that each deserves. In what follows, the committee attempts to provide insight and suggestions. Some of the recommendations, such as those presented with the final two topics, are provocative. The intent here is not to prescribe solutions and approaches, but to stimulate a more effective problem-solving process in all areas on the part of DOE.

Integration of Safeguards in the Field

The safeguards system is well integrated in the headquarters offices of the Department of Energy, as can be seen in the organizational structure discussed earlier in this report. The same is not completely true at all Operations Offices, where responsibility for different parts of the safeguards activity is lodged in different parts of the organization.

There are instances where physical protection and materials accounting are managed by sections of Operations Offices far apart in the organizational structure. This separation of components of the system acts counter to the need for a complete system with balanced components, providing by its overlapping features a defense-in-depth that mitigates the effects of failures in the system. This affects the way orders are written, guidance is provided, funds are allocated, responsibilities are assigned, and effectiveness is estimated.

There are local problems in some places that underlie such a separation of components of the safeguards system. The committee believes that only highly compelling reasons could justifiably support such a structure of fragmented responsibilities.

Recommendations on Integration of Safeguards Management

Managers of MC&A in the field should work more closely with the activities of the balanced safeguards program. DOE should state that its policy is to work toward integration of safeguards in the field. Managers of the separate components should be directed to coordinate with each other and to develop a framework for coordinating integration.

Planning of New and Upgraded Facilities

Important experience in the development of more advanced safeguards systems has been accumulated within DOE, in the course of planning for and designing recently constructed facilities. This experience can be valuable in improving safeguards methods used at other facilities.

The design of new facilities or major modifications of existing facilities has required each organization so affected to satisfy the requirements of safety, environmental protection, and safeguards, while still achieving the desired level of production performance. The resulting experience base covers a variety of processes and safeguards concepts that integrate production controls, material controls, safety controls, and physical security for a redundant safeguards system.

A review of recent designs could be beneficial in planning the research and development program, to further improve safeguards over the longer term. For example, reduction in process holdup for more accurate material balances, and more remote detection methods to reduce potential possibilities for theft and diversion of SNM, are concepts that need to be considered in planning for future facilities.

Some of the recently upgraded and constructed facilities noted by the committee are the Navy Fuel Processing Plant at Savannah River, the upgrade of the reprocessing plant at Idaho, the fuel element examination facility at Richland, and the scrap recovery facility at Y-12.

Recommendations on Planning of New and Upgraded Facilities

o DOE should initiate a special study of the designs of recently constructed SNM production facilities, with the purpose of developing design guidance for upgrading existing facilities and to provide design guidance for future SNM processing facilities.

Management of Research and Development for Safeguards

The program of research and development in safeguards is an important activity under OSS. It has many facets.

Moving Targets

Research and development needs for MC&A are being defined by the following factors, each of which is a moving target:

- o Opportunities exist to design features more suited to automated and more effective MC&A operations into the new facilities that will be built to replace aged and outdated ones.
- o Disarmament negotiations may lead to reductions in numbers of nuclear warheads, resulting in an increase in special nuclear material that is to be stored as stockpile. The reprocessing and recovery of special nuclear material from old warheads naturally leads to generation of scrap and waste. Innovative methods can be sought to keep the scrap and waste at low levels, and to provide for secure processing. Opportunities are available for decisions on physical forms for storage, and a secure control methodology for stockpile material.
- o The most evident change in processing technology on the horizon is in methods to be used for separating isotopes of uranium and plutonium. New technology in this area will require changes in the methods of accounting and control, and a different balance in safeguards techniques.
- o It is likely that continued improvements in reliable sensor and computer technology will lead to better and more automatic methods of material measurement and control, as well as to more timely and versatile methods of data management for use in material accounting.

These and other moving targets of policy and technology render the task of planning for safeguards R&D particularly challenging.

Structure for Long Range R&D Planning

The R&D Committee under Operation Cerberus set up a structure for long-range planning of research and development in safeguards and security. In its report, the R&D Committee proposed a central research and development manager to be based in the Office of Safeguards and

Security, and an R&D Council to oversee the formulation of plans. The R&D Council was described as being formed of members from "each major outlay program office and those with related responsibilities in threat assessment, safety, environment, inspections, and evaluation." In addition, Centers of Excellence were to be set up to provide leadership roles in certain areas. The Centers of Excellence were defined as DOE laboratories (contractor-operated and government-owned) that possess demonstrated and recognized expertise in specified areas requisite to the safeguards and security needs of DOE. It was mandated that the centers would maintain technical preeminence and leadership in their designated areas. The centers were also mandated to provide and maintain technical coordination and collaboration with other laboratories whose capabilities and programs supplement or complement those of the center. These recommendations were put into effect. The centers and their principal charges are:

- o Sandia--Develop physical protection components and systems including hardware, software, and systems analysis.
- o Los Alamos--Develop material control and accountability components and systems, including hardware, software, and systems analysis. Develop protection systems for classified and sensitive information and computer security technology, including hardware, software, and systems analysis.
- o Brookhaven- Develop technical criteria for long-range policy and planning and the development of integrated protection programs and systems, including systems analysis and systems evaluation.

In addition to the Centers of Excellence, with their charters, several specialty Operational Support Centers have been set up as follows:

- o Oak Ridge Diffusion Plant--Maintain a national nuclear material data base and information system (NMMSS), including related hardware, software, and systems analysis.
- o New Brunswick Laboratory--Maintain a nuclear measurement reference base to define and evaluate safeguard practices.
- o Oak Ridge Associated Universities--Implement a human reliability program.
- o Central Training Academy at DOE Albuquerque--Maintain a uniform training curriculum in the DOE complex for security, response forces, and effective evaluation.

A review of the activities of the R&D manager at DOE headquarters and of the R&D Council indicated that the planning process started with great energy. However, the post of R&D manager fell vacant as a full-time responsibility, and the R&D council has effectively minimized its activities after the first year and has functioned mainly on an "as necessary" basis.

It appears that in the absence of central leadership, the planning responsibility has been assumed by the Centers of Excellence, with their strong technology leadership. This introduces a potential conflict of interest in that the centers acting alone may tend to define R&D programs in terms of their own specialties and interests, with inadequate integration and reference to user and to system-wide needs, and with inadequate account of the R&D capabilities at facility locations other than the designated centers.

DOE established at the start a management process to receive user requests for R&D, for setting priorities, and for selection of projects within the limited budget. The R&D projects dealt with on this level are generic, with site-specific R&D projects remaining the responsibility of each site. This process was effective, but it can continue to be so only if the strong central leadership intended in DOE headquarters is actually provided.

The Usefulness of R&D

The MC&A research program has had a number of successes in technological innovation. Yet the committee's tours of the various DOE user facilities revealed a decidedly mixed application of material and safeguards technology, ranging in the same facility from the lowest to very high technology levels. The committee found that groups at some sites are doing research on their own and not relying on the results of other DOE-sponsored R&D programs, providing well-investigated techniques already implemented by industry. The committee has a concern that the current lack of a strong central organizational influence to plan, define, coordinate, evaluate, and allocate resources has weakened the R&D community's ability to implement technological innovations for safeguards. Competent research personnel, when lacking guidance, will normally provide their own. The result may be good research, but not necessarily research in the best interests or needs of DOE. There is further concern that groups at sites and field offices may have also responded to a vacuum in headquarters leadership, assuming responsibilities and acquiring "not invented here" attitudes by rejecting developments outside their small local spheres.

Many of the R&D planning ideas that were developed under the Cerberus program are excellent. The R&D shows evidence of tactical R&D plans, but without the framework of an all-encompassing strategy for its guidance. This omission can mean that the tactical R&D plan is technically correct, but may not be appropriate to meet long-term needs.

Candidate R&D Technologies

Base technologies meriting support are those that could affect instruments, processes, and methods of MC&A, to increase effectiveness and/or to reduce costs. The committee has not made a systematic attempt to identify appropriate new technologies for the R&D effort; however, a few examples of promising areas are: laser technologies (e.g., visual, infrared, and ultrasonic,); computer technology; optical recognition; and fiber optics transmission. New technologies, such as in sensors, robotics, and computer control, can be applied in different ways to the different nuclear material process methods. R&D in the MC&A area can ensure that adequate safeguards measurements using the most advanced technology are incorporated directly in the material process streams. In a narrower focus, there is an obvious need for continued R&D in areas such as tamper-indicating devices, error propagation for measurements, nondestructive analysis (NDA) by calorimetry, near-real-time computer reporting, and other methods. R&D groups should maintain awareness of new, developing technologies that may be useful for incorporation into MC&A instrumentation and methodology, thereby assuming responsibility for keeping MC&A at a state-of-the-art level.

The development of new instrumentation for measurement seems to be satisfactory. Apparently, the interchange that has taken place between R&D groups and user facilities is adequate in this area. However, it was pointed out at the committee's workshop that such "hardware" solutions may not be addressing those safeguards problems that require modification of management or process procedures. The review of basic R&D programs by potential users who, in turn, would pay for their implementation should bring R&D closer to the real needs of the user community.

Recommendations on the Management of R&D for Safeguards

- The DOE should fill the existing R&D management vacancy in the Office of Safeguards and Security with a qualified individual as soon as possible.
- The R&D manager should be supported by a deputy who can step into the position when needed. The R&D manager should be actively involved in setting directions and goals, reviewing priorities, and making decisions. A considerable fraction of his time should be spent in the field to coordinate user needs with the capabilities of the R&D facilities.
- The R&D Council supporting the central R&D manager should meet at least once each quarter. It should have specific financial support for the time and travel expenses associated with its tasks, so there will be no real conflict as to time, attendance, or travel support.
- Each site preparing a MSSA should identify and highlight areas in which improvements in performance are not available with the existing methods, but are desirable. These can then be the items discussed with the R&D manager and the R&D Council, as stimulus for user-oriented research.
- A strategic plan should be developed that addresses the long-term R&D needs of MC&A. This plan should take into account the moving targets that DOE is likely to encounter, and in particular the changes in technology that seem to be developing. It should include support of base technology important to the strategic development of MC&A. Although the plan should be coordinated centrally by DOE-OSS, and OSS should be responsible for ensuring its fulfillment, its concepts, needs, and priorities should be identified by the user community. The major R&D laboratories should be partners in the planning process,

providing analysis and evaluation. This should help to ensure the necessary commitment to the R&D strategic plan by all participating groups in OSS, the Operations Offices, DOE operating contractors, and the national laboratories.

o The OSS should identify the generic R&D program needs and incorporate them into the research program. It should review these along with the site-specific R&D programs to ensure fulfillment of the strategic plan.

o R&D planning should include increased emphasis on human factors engineering, including individual and group performance, reliability factors, and refinements in ergonomics, procedures, and training methods.

o Increased attention should be given to acquiring technology in timely ways from fields, such as lasers, optical recognition and robotics in which rapid developments are occurring outside DOE.

o Continued emphasis should be placed on coordination and timely communication of R&D results and programs. While innovative initiatives at different sites should be encouraged, these should be monitored to minimize unnecessary diversity in means of accomplishing similar functions (e.g., computer programming, certain kinds of instrumentation, training methods, and analytical methods including risk analysis and assessment).

o Sustaining programs and appropriate funding should be devoted to providing a nucleus of skilled and experienced personnel, whose primary function will be R&D, but who will also be deployed as needed to help solve urgent technical problems as they develop.

Risk Analysis

The DOE complex has started to use systematic risk analysis methods to identify and prioritize required safeguards functions. The methods in use (employing the computer-based models MI$ER and ET, developed by the Tactical Vulnerability Assessment Program at Lawrence Livermore, and SAVI developed at Sandia)* are an important advance, that provide for systematic analysis of perceived paths for diversion or theft. They also provide for a reasonably objective assessment of the proposed system improvements to protect against defined threats, as well as a basis for cost/benefit analysis of effectiveness. Moreover, they can be used as a training tool and for reviews of effectiveness. (The latter is important to limit a wide range of individual and regional interpretations of what scenarios are plausible, and in the evaluations of safeguards plans and systems.)

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*MI$ER--Program to integrate SAVI and ET with economic decision criteria for safeguards upgrades; SAVI--Systematic Analysis of Vulnerability to Intrusion; and ET--Insider Evaluation Technique.

The present models are limited, however, in that they do not take account of the "front-end" or "back-end" of realistic scenarios for diversion and theft. Therefore, these methods do not provide estimates of true risk. Different scenarios have different probabilities of front-end attempt, detection, and deterrence, and also different characteristics in back-end response and recovery. The inability to estimate risk also limits the use of these methods in assessing the relative importance of decision in resource allocation to different functions. The omission of these elements from the explicit scenarios and evaluations raises the question of whether the planning, implementation, and integration of these activities is effective or adequate. More complete models would help to make threat guidance and definition more realistic and more specific to the difference in facilities, processes, and materials types and conditions.

Recommendations on Risk Analysis in the Management of Threat and Vulnerability

- More complete risk assessment models should be worked on. Extensions should include cautious exploration of the implications of estimates of the probabilities of detection and deterrence, as a function of the range of resources and skills required to make penetration, diversion, or theft plausible, as well as of the amount stolen or diverted, and the timeliness of detection. The models should also be extended to include exploration of estimates of the probabilities of response and recovery for various assumed scenarios; explicitly including and modeling the effects of various levels of readiness and detection capabilities of the response and recovery forces.
- Before extensive work begins on improving models to generate risk estimates, the limits on capability to succeed in the objective should be explored, to ensure that funds are not expended on efforts not related to the objective.
- Please refer to additional recommendations relating to risk management in the context of the master safeguards and security agreements.

Data-Base Systems for MC&A

Integration and Uses of Data at Individual Sites and Facilities

Using All Available Data At most sites, significant attention has been devoted to the development of automated information systems. However, the results do not usually make best use of data derived from plant operations and from safety, security, and MC&A activities. Throughout the course of the committee's work, the concept of integrated data bases has required definition. For the purposes of this report the functions served by an integrated safeguards data base include:

- Operation of the process
- Quality control on material production
- Safety measures
- Physical security
- Material control
- Material accounting

This concept of data-base management embraces the generation, sharing, and use of all the information associated with the operation of a given facility or site. Managing data bases and the tools used to develop these bases may mean many things to different readers. The committee defines the interrelated elements associated with the generation, maintenance, and use of integrated data bases as follows:

- Collection of data: the use of sensors, measurements, reports, and other means to define or acquire a piece of data.
- Validation: error checking at the source. Logic and forms checks. Authorization. Validation includes reporting of discontinuities to appropriate business functions and protection of the data base. This is all a part of the data collection function.
- Data-base structure: the collection of information (data elements) defined by specification. This often consists of a commercially available set of software units, specially integrated and adapted to the local situation.
- Data-base management: the ongoing collection, protection, control, and update of the data base. Also considers ongoing specifications.
- Applications software: system-based routines for data-base users, which selectively retrieve data sets, perform analysis, and produce results useful in decision making.

Much information must be generated, sorted, controlled, and reported in support of safeguarding nuclear material. Such information can be handled manually or in an automated manner. It can be collected in the form of numbers pertinent to single-process functions, or it may represent an organized composite of operations-related information from several processes. The information must be effective in purpose, nonobtrusive to operations, and cost-effective.

During its tours of sites the committee saw instances where persons engaged in one or more of the key facility operations functions were developing data bases and information management schemes. Many different philosophies of data management and data sharing were expressed. In a number of cases, limited systems were functioning quite well given the restrictions built into them.

<u>Process Engineering in Data-Base Design</u> The constructing of process models, process flow balances, and process control routines characteristically requires engineering analysis. Data bases and their management schemes logically follow process flow; yet with the exception of the most recently constructed facilities, it was not evident that a process engineering approach had been taken in data base

construction and use. Moreover, there did not appear to be evidence of integration across the needs of different functions in the design of the data bases.

While different functional groups have undertaken the responsibility for designing the data systems at various sites, in every case some single special interest (i.e., safeguards component) has been dominant. This has been independent of whether a single data-base management system was used at the site.

The committee pursued the questions as to why data management systems could not be integrated, the need for independence between functions, and the quality of data used in the data system. It appeared that a single data management system to serve all objectives of a site may be cumbersome, but there seems to be no reason why all systems at a site should not use a common data base. Some attention was also focused on data-base security.

The committee believes that common data bases are important in MC&A and that in the near term there would be a distinct gain if data bases were integrated across operations on a site-by-site basis.

The committee also believes that integration of data is an engineering function and that it must be accomplished by multifunctional representation where all interest groups are properly represented and properly served. Some uses of the data are likely to be shared among different groups. Generally, the manager of each function will want to know what material is where at what time.

There may be certain added performance requisites. At some point the needs diverge. Some functions may call for added information on such items as status of data, material forms, measurement quality, and so on. The important points are that the data needs should be defined jointly and that agreement should be reached on how the data are collected and who is responsible for each data element.

The committee believes that all information and data generated under known and controlled conditions are valuable in determining that movement of material has occurred, and in testing process actions as to reasonableness, within-quantity limits, quality, timing, and type of material moves. Using process monitoring information can significantly reduce the time between measurements, and near-real-time accounting can be accomplished. Good information management in a near-real-time accounting system operates as a strong deterrent to the insider, by providing an enhanced detection capability and a complex overlay of "third party" assurance. Such an information management system does not require 100 percent accuracy and even with relatively low effectiveness can provide a high deterrence factor.

<u>Barriers to Integration of Safeguards Data</u> For the purpose of safeguarding and evaluating the effectiveness of material safeguards, MC&A organizations have generally wanted to use only data they generate, and more specifically only data used in the construction of IDs and LEIDs.

MC&A professionals often believe that only highly accurate and precise measurement-based information is effective in meeting the safeguards challenge. There is also a widespread feeling that separation of functions and independence of assurance mandate that special people (MC&A custodians) generate the MC&A data.

The committee finds that even in those cases with the greatest independence of material accounting, much of the data that are used in MC&A are generated as part of the processes of production, material quality control, and process quality assurance. There seems to be no advantage to ignoring the existence of such data in forming a material balance.

The application of process engineering to monitoring techniques varies widely from site to site and facility to facility. Few sites have attempted automated data validation techniques. In some cases process measurements are not at all integrated into the SNM safeguards functions. Complexity of operations and strategic considerations mitigate for the use of all relevant data from whatever source.

Recommendations on Integration and Uses of Data at Individual Sites and Facilities

o Consideration should be given to the development of integrated data bases for use in MC&A, physical security, process operations, safety, and material quality at each site, and to restructuring and consolidating the leadership and funding for data-base management. Leadership of this development and participation should be organizationally neutral. In addition, participation in it should be cross-functional.

o The committee recognizes that a new policy calling on sites to implement an integrated data base can prove to be time consuming and expensive to accomplish. It may also run counter to established practices and the corporate culture at each site. Therefore, implementation of these recommendations should be based on a careful site-by-site study of the full benefits, implications, and costs of data-base integration. Such studies should clearly recommend whether or not to proceed, and provide practical guidelines upon a decision to proceed.

o In the event of a decision to integrate an on-site data base, the following additional recommendations are provided:

-- The functions of MC&A, operations, security, safety, and quality should be serviced by the same central data base with specialization provided to the various users as required.

-- The originator of each data element should be responsible for its input, accuracy, and control in accordance with measures acceptable across functions. Systems of process data monitoring, checking, and surveillance should be used that validate the data at the time of their generation, thus providing error checking at the source.

-- The integrated data base should be viewed as truly cross-functional, and not solely the domain of special interests (i.e., only MC&A).

-- An intersite working group should be formed to share and transfer information between sites with regard to data-base and safeguards information system capability, with a view to sharing benefits and developing compatibility of data and systems where different sites interact.

-- In the application to MC&A, all relevant data generated should be used, and not just that needed for ID and LEID.

-- Monitoring of process data should be especially strong in those processes involving material of high strategic significance.

-- In-plant programs should be instituted to ensure the integrity of the data generation system.

-- Systems and procedures should be developed for entering data promptly into the data system, so that timely and appropriate actions can be taken if data are suspect, in error, or if someone is trying to manipulate the system.

Older Versus Newer Facilities

There are significant differences between facilities (mainly as a function of age and technology available when built) that have a direct bearing on both the safeguards and operational productivity to be gained by integration of data bases and the automation of information processing.

Facilities visited were built from the 1950s to the 1980s. Some of the new facilities had not even begun operation. These facilities cannot be treated uniformly with respect to MC&A information needs. In some of the older facilities, it may be difficult or impossible to change processes and layouts in order to enhance the safeguards function.

Recommendations Regarding Age of Facilities

- For all new facilities and when significant modifications are made to upgrade older facilities, a high priority should be placed on integrated data collection and use.
- Where at older facilities it is difficult to support a high degree of process monitoring, other techniques should be explored to ensure adequate safeguards.

System-Wide Data Bases

As part of their site visits, the committee was requested to review two DOE-wide systems for assembling and processing facility information on nuclear material movement, location, and measurement.

<u>Nuclear Material Management and Safeguards System</u> The NMMSS assembles and records required facility reports to the DOE on SNM shipments, receipts, and inventories, and synthesizes certain information ultimately going to Congress.

The concept of NMMSS appears to be reasonable concerning DOE requirements for data condensation, reporting, and evaluation with respect to the ownership and management of nuclear material. It can in principle be used to profile, analyze, and report on many aspects of the DOE program involving SNM, including compliance by facilities with material accounting requirements. However, the existing NMMSS was not designed to support the site-specific MC&A systems, but rather to be a nuclear materials business management system, principally serving the production complex by providing an up-to-date record of where the DOE's inventory of SNM is to be found. Consequently it is not surprising that the committee found no indication that NMMSS is used for safeguards purposes during its several site visits.

Little development of the system has taken place since 1975, a time when computer science was not nearly as advanced as today. The questions asked of MC&A today are considerably more complex and detailed than they were in 1975, and the answers are not usually found at the level of aggregation provided by NMMSS.

Systems Analysis for Material Control and Technology The Systems Analysis for Material Control and Technology (SAMCAT) currently being developed at Argonne National Laboratory is directed more toward measurement information than material management. As reported to the committee by Argonne: "The program focus is the development of a management tool for decision support in evaluating MC&A upgrades, and for validating the MC&A aspects of the Master Safeguards and Security Agreements (MSSA) effectiveness. The approach is the computerization of the nuclear materials flow charts, identification of key measurement locations in the production fuel cycles, and processing of data information at each measurement location."

SAMCAT can be useful as a mirror of the system of SNM processing and flow in the DOE. It can be and is used for educating new personnel in safeguards and processing, and for visualization in detail and as a whole.

Recommendations on System Wide Data Bases

o DOE should (perhaps in conjunction with the intersite working group recommended to transfer and share information between sites on data bases and safeguards information systems) readdress the nature and extent of centralized processing of facility data required for safeguards purposes, and the ability of existing systems to provide it.

o DOE should re-address the type of information and data that are reported upwardly to it in NMMSS.

o DOE should evaluate the need to either replace or upgrade NMMSS in light of the advances that have taken place in computer science, so as to simplify input, improve output and auditability, provide error checking at the source, add response capability for a broad range of questions, and provide for future expansion.

Balance in Safeguards Functions

Using Redundancy

While MC&A is primarily directed at insider threats, and physical protection is primarily directed at outsider threats, there are elements in each that assist the objective of the other. Perimeter control in physical protection funnels all personnel and materials entry and exit through one or a few instrumented and protected portals. MC&A has importance in scenarios involving a combined force of insiders and outsiders, by identifying diversion of materials within the protected area by the insider, prior to the validity of conceivable claims that material has been stolen and is in the possession of outsiders.

These interactions and cross-currents in safeguards measures should not be interpreted as meaning that protection against insider threats can substitute for protection against outsider threats or combined insider/outsider threats. But they should be recognized as affecting the balance in safeguards, and the conclusions drawn as to the effectiveness of the system as a whole.

The total system as currently conceived, achieves a more logically structured safeguards system than in the past. The shift to performance standards is also a distinct step forward, though it must be realized that such standards are harder to administer and interpret than are the simpler fixed requirements that formerly existed.

The problem of balance in safeguards functions as between physical protection and MC&A has been addressed by recent DOE orders. These orders explicitly recognize the need to complement the primarily outsider oriented physical protection systems with safeguards activities designed to be effective against actions by insiders (who are part of the work force or guard force), and to set performance standards for these activities. This has already resulted in increased attention paid to the role of material control and accounting.

The result of the revised DOE orders will be a highly robust and redundant safeguards system with multiple lines of detection, protection, and defense that should continue to be effective against both outsider and insider threats. However, the existence and effectiveness of this redundancy is not taken into account in defining the urgency associated with actual or alleged incidents such as a discovery of excessive values of inventory difference, the setting off of a process control alarm, and other signals of unusual incidents which trigger an investigation.

Though the new DOE orders define conditions that are to lead to reporting the occurrence of unusual incidents, no procedure has been defined in the orders for maintaining a dossier on an incident or for closing out an investigation of an incident. Such procedures should explicitly take advantage of redundancies provided by the entire safeguards system.

Meeting the Assurance Objective

One objective of the safeguards system is the development of assurance to the Department of Energy and to any third party, that special nuclear material in the possession of the Department and its contractors has not been diverted from authorized uses and locations. This assurance is provided by the use of some balanced application of all of the safeguards techniques that are available: physical protection, material control, material accounting, and human reliability.

Material accounting in particular has the capability of providing assurance that material has not been stolen or diverted in ways that may have failed to trigger physical security or material control alarms. Material accounting also can provide assurance that material has not been stolen or diverted when false alarms are generated by other components of the system. The quality of this third party assurance by material accounting depends on:

- The precision and accuracy of the measurement procedures used to obtain the data that are entered into the material balance.
- The freedom form error of the entry of data into the system, and the storage and processing of the data.
- The completeness and correctness of the mathematical manipulations involved in the accounting process and in the analysis of the material balance.

It is also dependent on the time frame within which accounting results can be obtained and analyzed. In addition, it is influenced by some process conditions such as the unavoidable or inadvertent occurrence of true losses, fluctuations in unmeasured in-process inventory, and hard-to-measure scrap and process residues.

The committee believes that there has been too much emphasis on the ID-LEID comparison as a measure of safeguards effectiveness. Because of the factors discussed above, it is often not possible to reduce the error in inventory difference on a timely basis to a value low enough to make ID an adequate measure of this effectiveness. For this reason, the direction suggested by items 4, 5, and 6 of the scope of work (see Preface) are considered to be less important than others that would take advantage of other ways to improve estimation of effectiveness. These alternatives are discussed in the next few sections of this report.

The value of material accounting is not reduced by this observation. Material control procedures are directed not only toward the validation of accounting results but they also serve the safeguards function of immediate protection against the insider threat. They provide assurance, approaching real-time in character, that material in process remains present and that material not in process is securely stored. They also provide for timely detection of anomalies in material handling and in the recording and processing of data on material movements. Finally they provide for access controls on material which make it difficult for insiders acting alone or in concert to take all of the actions necessary for a successful theft or diversion.

Alarms and Reporting of Incidents

The committee would like DOE to take note of the inferences and actions that are called for by DOE orders as a result of actuation of alarms built into the material control and accounting systems. The committee believes that explicit advantage should be taken of significant redundancies in the safeguards system when investigations are made and conclusions drawn regarding the significance of such alarms. As an example, a statistically significant inventory difference in a material processing area surrounded by an exceptionally reliable perimeter control systems, should be considered a lower risk indicator than the same ID in a less secure zone. Similarly, material tracked by a near real time accounting system should be considered less at risk than otherwise.

A related point is that the DOE orders (particularly 5633.3) lack a procedure for docketing and subsequently closing out incident investigations with findings as to the implications or significance of the event in question. These findings would be more helpful (as stated above) if the assessment took into account the additional assurance provided by the redundancies in the safeguards system, and all of the factors contributing to a steady and even desirable rate of false alarms in control and accounting. An improved balance in safeguards allocation needs to consider these important points of integration between MC&A and physical security.

As is well known, an ideal accounting system for special nuclear materials based on alarms set at the present two-sigma standard deviation point on inventory difference (ID), compared to the limit of error in inventory difference (LEID) will lead to an alarm about 5 percent of the time. (See following section on "Evaluating System Performance".)

Recommendations on Balance in Safeguards Functions

- A process for docketing and eventually closing out alarm-based incidents should be added to DOE Order 5633.3.
- Redundancies in the safeguards system and the normal rate of occurrence of false alarms should be taken into account in attributing significance to the individual alarm signals that occur in the course of the material control and accounting.

Evaluating Systems Performance

Performance Based Measures

The safeguards system, including the use of material control and accounting, is moving toward performance criteria as the basis for designing methods of operation. This increases the importance of objective performance measures, based on processes for assessing effectiveness. The performance-based measure of effectiveness most used is the difference between the measured inventory difference (ID) and the computed limit of error in ID (LEID).

Concern for ID Reporting

Other means of measuring effectiveness are also available. The internal self-audit methods to be employed by management responsible for on-site operations are not as well defined in the orders as are the methods to define an effective system. Moreover, there is no DOE-wide process for providing the public with independent assurance as to the effectiveness of the safeguards system, except for the semi-annual report on inventory differences. This report is an incomplete and possibly misleading statement of the actual status of safeguards, inasmuch as it seems to imply that there is a single measure of the effectiveness of the system. It can easily lead to the false notion that the effectiveness of a safeguards program with its four components (physical protection, human reliability, material control and accounting) can be judged primarily on the analysis of observed IDs in the light of their associated limits of uncertainty (LEID). Where IDs are reported as having exceeded the estimated LEIDs, there is a corollary report that follow-up investigations established the absence of diversion. (See previous section on "Balance in Safeguards Functions".)

Unusual Events

Other events other than IDs occur in plant operations and in accounting systems involving instrumentation and operating and control procedures which are unusual in the sense that they do not conform to anticipated or expected performance. These events are investigated and usually resolved without raising any indication of unauthorized possession or use of special nuclear material. In some instances, material control and physical security exercises are used to directly test the effectiveness of system elements for further assurance in the face of existing IDs. Additional critique of ID's stemming from measurements and other sources is provided in the succeeding section. What follows here relates mainly to the larger problem of safeguards system performance, of which IDs are but one indicator.

Problems in Evaluation Tools

Other methods for assessing effectiveness also exist, and a number of these are often used without balanced credit being given for them. Problems in developing and applying additional evaluation tools for the design of safeguards include:

o The difficulty in modeling the performance of the system as a whole so as to recognize redundancies in the safeguards system, and the relative importance of its component activities; and,

o A lack of recognition of how the differences between sites and processes influence the effectiveness of the component activities.

Problems in after-the-fact evaluation are largely associated with:

o The kinds of performance indices considered;
o The balance between them; and,
o The lack of a clear-cut distinction between those indices that measure adherence to a predetermined MC&A program (compliance) or the extent to which a desired result is achieved (performance).

The unauthorized possession of nuclear material could in principle be achieved in a large number of ways. Even if the problem of its prevention were restricted to detection of covert activities, the number of possible diversion paths and concealment possibilities is large. Furthermore, the completeness of any particular enumeration can always be questioned.

Conversely, it is usually difficult to agree on a basis for delimiting the possibilities to be considered when designing the system and ascribing to them a relative importance. A complete systems analysis would consider the effectiveness of all possible safeguards activities with respect to the detection of typical or more likely selected diversion or concealment paths, and determine a system achieving the desired effectiveness. Systems designed to cover such a mix of possible diversion threats will inevitably (and correctly) be redundant, and this redundancy should be recognized and credited when requirements are established and effectiveness is evaluated.

Signals from MC&A Activities

These principles place an emphasis on the large number and variety of signals that may arise from MC&A activities. To the extent that multiple signals collectively confirm the absence of proscribed activities, they provide enhanced verification of system effectiveness. The difficulty with emphasis on the observation of multiple signals is that the requirement for investigation and resolution of anomalies can become correspondingly large. Clearly not all signals would be equally important indicators of threats to safeguards. Cases where a signal is uniquely and positively associated with diversion and misuse will be rare, since diversion and theft would themselves be statistically rare events in comparison with the frequency of alarm signals. A careful balance is required, taking into account the importance of the signal and the difficulty of determining whether it arose from a safeguards concern or some other cause.

Signals of the above kinds can provide an in-process ongoing measure of the safeguards effectiveness of the system. Those that are based on processes including randomness (such as the LEID-ID comparison) fulfill such a function through conformance to statistical expectation, and by triggering investigation of anomalies. Other systems of signals without statistical content, (other than that resulting from true error) accomplish their objective through lack of their occurrence, and with investigation when they do occur.

Documenting Case Histories

In order to ensure the safeguards effectiveness systems achieve their purpose, a process is needed for generating a documented case-history each time an alarm is actuated, indicating an abnormality that may imply theft or a diversion. This case-history would correspond to a docket, and would be assigned an identifying code. All investigations directed at ascertaining the cause of alarm signals should be documented for inclusion in a similar set of dockets permitting a trend analysis to be conducted. Individual dockets would be closed by findings of cause or probable cause of the signal. This system would then establish a quantitative data base for use in estimating safeguards effectiveness.

Internal Audit Process

There is an additional requirement to superimpose on such a system a basis for subjective judgement of the overall adequacy of the system. This involves an internal audit process maintained by the operating organization. Such audits should be concluded by a safeguards review group, composed of individuals not directly responsible for the operations or the safeguards. Attention would be given to such questions as a continued sensitivity to the existence of inadequacies of vulnerabilities in the system, the historical record of alarms and their resolution, quality control in the system (including the measurement system), and the long term behavior of such accounting quantities as the ID. An internal safeguards committee functioning in this way would provide an impetus for a continued search for excellence in safeguards management.

Finally, it is suggested that the Department of Energy would profit from the periodic formation of a blue ribbon review panel, to review the entire departmental safeguards system and to report on its adequacy and its effectiveness. The subjective judgement of independent experts, reinforced by objective analysis of performance at individual sites, would serve the highly useful function of providing assurance as to the integrating of the DOE-wide safeguards effort, and be a source of useful recommendations.

Recommendations on Evaluating System Performance

o There should be a systematic development and exploitation of a range of performance indicators and measures of effectiveness in addition to the ID-LEID comparison;

o A system for the reporting into a central data bank of unusual incidents in safeguards should be implemented within the DOE complex, with identifiable dockets and investigations leading to conclusions as to the cause, and closure of the docket when the issue is resolved.

o Self-audit systems should be enlarged, such as safeguards committees to identify, investigate, and report anomalous occurrences or events, on an on-going basis, and to assess safeguards effectiveness by whatever means available.

o A blue-ribbon committee should be convened at periodic intervals (e.g. two to four years) to assess the continued effectiveness of safeguards on SNM across the DOE complex.

Management of Inventory Differences

Inventory differences cannot be properly interpreted or understood without their associated limits of uncertainty. The procedures and techniques being used across the DOE complex to compute LEIDs are not consistent and are sometimes invalid. This is not surprising, because there are difficult statistical questions at the base of formation of such a quantity as LEID. Error propagation procedures do not consider all sources of error, and as a consequence the limits of error are usually understated. Undue emphasis is placed on reducing measurement error, a practice which quickly becomes cost-ineffective in the presence of large unmeasured inventory variations due to other causes such as holdup. The consequence is that a large fraction of IDs are declared "unusual" for reasons not associated with loss or diversion.

In the following, the term "ID discrepancy" is defined as a situation in which the ID substantially exceeds the estimated LEID.

Most ID discrepancies precipitate costly actions on the part of the operations staff, to effect resolution. The financial consequences of these actions as related to the probability of loss are rarely considered. These actions are required in spite of the absence of any physical evidence as to diversion and notwithstanding a historical record of underestimation of LEIDs. The only real discrepancies which should affect an ID apart from statistical aberrations are unreported or unrecognized elements of the actual activity not reelected in the accounting model. These are exactly the omissions, whether deliberate or inadvertent, that the material accounting system is designed to detect. All of the other effects are deviations of the accounting model from the activity being modeled, which reflect sources of error in the measurement system. The effectiveness of the material accounting process as an indicator of real occurrence, or as a source of assurance that none are present, depends on the ability to take into consideration the pseudo-effects due to the accounting process itself.

In all accounting systems there will be mistakes in reporting, recording, and processing the accounting data due to improperly designed accounting procedures and errors in data processing, both human and instrumental. All accounting systems have control and audit procedures for minimizing error rates and identifying and reconciling discrepancies. Audit trails leading to source data are an important part of this process. In principle, an exact, error-free accounting system which truly reflects all real discrepancies is possible. In practice there are limits as to the amount of resources that should or could be expended to produce a totally error-free system.

There seems to be much emphasis on investigation of potential causes of individual's IDs, and too little emphasis on their collective analysis. Some part of the error is an artifact of the accounting and measurement system, or at least contains a significant unreal contribution from this source. Most of the information they contain relates to measurement problems, not real deviations of the accounting model from reality. This suggests that it would be more productive to limit investigation of those cases where there is a reasonable assurance that no real effects exist, and spend more time extracting from the observed IDs the information they contain concerning the causes of ID behavior. A recent report (Sanborn, 1987) concludes that this problem of analysis "is the most fundamental, and is at the same time the most neglected" of the elements necessary to improve material accountancy. A new approach to the investigation, analysis, and reporting of IDs is an obvious and critical necessity.

Even when an ID is due to a real effect, the cause may be a process aberration or a modeling inadequacy or a numerical error in data input, and not a loss or diversion. Investigation and resolution of these sources of real variability is an important part of improving the ability of the system to detect losses and diversions, and hence improve the assurance provided that safeguards procedures have been effective.

Recommendation on Management of Inventory Differences

- More definitive instruction should be provided to field offices and contractors as to procedures by which limits of error on inventory differences are to be computed. Such procedures should be based on sound statistical principles and in particular should force estimation and inclusion in the limits of all reasonable sources of error including immeasureable inventory variations.
- Workshops and training sessions should be conducted for DOE personnel on the estimation of LEIDs such as is currently being done for MSSA implementation, so as to bring a sense of competency and conformity to this activity.
- For reporting systems involving inventory differences, and in particular those directed to public information, statistically nonsignificant differences should simply be reported as such. On the other hand, all apparent values of ID should be retained in analytical systems using trend analysis and DOE should study the long-term implications of ID.
- The current semiannual ID report should be revised to provide specific understanding of the reasons for any abnormally large IDs that are listed, and to add information on the level of safeguards assurance provided by all of the components of the system. This should specifically make it clear to the reader that even where material

accounting indicates the existence of an apparent nonzero ID, there is no true ID where safeguards measures other than accounting provide sufficiently compelling assurance that the ID incident is resolved. The report should include other measures of effectiveness in addition to ID.

o Other decision indices should be developed based on sound statistical principles for determining courses of action.

Management of Shipper/Receiver Differences

Current DOE procedures require that both the shipper and the receiver of SNM conduct measurements of the SNM transferred between them. Measured differences are then reported as shipper/receiver (S/R) differences, regardless of the degree of physical evidence of security during the process, such as from tamper indicating devices, escorts, constant radio contact, continuous surveillance devices, etc., that no loss or diversion occurred in transit. Statistically significant S/R differences under secure circumstances are not reliable indicators of possible loss or diversion. They are most important as indices of the quality of the measurement systems that generated the differences. In these conditions, actions precipitated as a result of such differences should address improvement of measurement quality rather than a possible diversion or loss. Furthermore, the reporting of S/R differences when it is "obvious" from other considerations that none exist, complicates and confuses the public perception of the effectiveness of the safeguards system.

It is important in the accounting system to distinguish those operational procedures which involve actual processing of the special nuclear material from those which do not. If item identity is destroyed by processing, the estimation of material content of the feed, waste, and product streams becomes an inherent part of the material accounting process, and measurement errors are introduced into the computed IDs. If items are merely moved physically to a different location, material accounting and item accounting become equivalent unless there is deliberate or inadvertent loss of special nuclear material from individual items. The validity of the material balance depends only on proof that such changes in individual items have not occurred. S/R differences comprise only one class of indicator, and not necessarily the best one, concerning the possibility of such changes.

Recommendations on Shipper/Receiver Differences

o S/R reporting should simply state that evidence supports there being no difference statistically insignificant if the error in estimation of the value is small and explainable, and there is otherwise positive assurance that no material has been stolen or lost. This recommendation does not suggest that measurements should not be made by both the shipper and the receiver, or that individual measurements or single or combined limits of uncertainty should not be a basis for action. It simply says that where there is evidence that no loss or diversion has occurred, report it as such. It also means that under such circumstances, the action should be focused on review of the measurement systems rather than on looking for phantom losses.

- o If a single number is necessary in reconciling accounting, procedures should be defined by which one arrives at this number whether the differences are statistically significant or not.

MONITORING AND EVALUATION OF SAFEGUARDS

The final topic relates to how the DOE measures the quality of safeguards achieved by its program. Evaluation of field practices results in recommendation on upgrades, and also influence DOE's determination of policy and guidance relating to the safeguards system.

The Process of Inspection and Assessment

In 1986 the Office of Safeguards Evaluation (OSE) was established directly under the assistant secretary for defense programs, to assist in assessing the status and effectiveness of safeguards and security for the secretary of energy. An early activity was to organize a DOE-wide task force to define standards and criteria for judging the performance of the safeguards and security programs by the facilities and the DOE field offices. These standards and criteria described MC&A activities in great detail. OSE inspected for conformance with these criteria and, when appropriate, conducted exercises to assess the performance of selected safeguards activities.

On committee site visits and during the workshop, various individuals commented that the standards and criteria were too inflexible, considering the variety of operations at the different DOE facilities, and that the system used by the OSE to grade the performance of facilities resulted in the facilities being rated according to compliance with the standards and criteria, rather than encouraging them to develop cost-effective measures more appropriate for their individual situations.

More recently, the DOE has adopted a performance-oriented approach for the safeguards requirements, as is illustrated in the DOE order 5633.3 for MC&A. DOE inspection and evaluation programs (e.g., field office surveys) will have to develop methods more appropriate for evaluating the performance of systems and subsystems, and to replace the previous inspections for compliance with specifically defined safeguards activities.

Recommendations on Monitoring and Evaluation of Safeguards

- o OSE is the proper organization at DOE headquarters to provide direct support to the assistant secretary for defense programs, to discharge his responsibility for an independent assessment of the status and effectiveness of the DOE safeguards program to be provided to the Secretary of Energy and the public.

o The primary responsibility for inspection on a timely basis should be assigned, as in the past, to the field offices.

o OSE should, as the present orders state, perform independent assessments on behalf of the assistant secretary for defense programs, to assess the field offices and the safeguards program as a whole.

o OSE should consider itself a part of the process for solving safeguards problems, as well as identifying them. One interesting suggestion made at the Workshop was that OSE should conduct its assessments on two levels. Some assessments would serve to identify problem areas and constructively suggest improvements. Others would be the basis for judgements as to adequacy of the program.

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APPENDIX A

MINORITY REPORT ON COST-EFFECTIVENESS EVALUATION

A CONCERN FOR COST-EFFECTIVENESS

by Dr. Jerome Bracken

This minority report is occasioned by the terms of reference of the study, which include the determination of the cost-effectiveness of safeguards of special nuclear material.

To consider the cost-effectiveness of safeguards expenditures, one should have a conceptual scheme for thinking about safeguards. Two conceptual schemes will be discussed below, and several ancillary issues addressed. Specific comments on the Executive Summary will follow the discussion.

The cost-effectiveness of safeguards has two aspects, which are interrelated. They are the overall effectiveness of the system, and the allocation of the budget, associated with the effectiveness of the individual components of the system. The overall level of effectiveness and budget is often characterized by the question, "How much is enough?" The committee was charged with addressing this question.

Both conceptual schemes were suggested by William A. Niskanen (former assistant director of the budget in the Nixon administration, chief economist of the Ford Motor Company, and senior member of President Reagan's Council of Economic Advisers, among other professional and academic positions). He formulated these schemes in reaction to several suggested general models of the problem, and personally presented his results at the committee's workshop.

The first model comprises the United States alone. It states that to obtain the optimal level and mix of safeguards resources requires minimizing the total cost to society, consisting of cost of safeguards plus expected cost of damage. Expected cost of damage is equal to probability of attempt times probability of obtaining material times probability of making and delivering bomb or bombs times value of damage to society. At the optimal level of safeguards expenditure, marginal expected value of damage saved will equal marginal expenditure on safeguards. The allocation of the mix of safeguards within the DOE complex can be derived in detail across all of the facilities as a part of this methodology.

The second model comprises the United States within the world. It addresses a far more interesting and controversial topic. It is motivated by predictions that the amount of separated plutonium in the worldwide commercial nuclear power activities in the period 2000-2010 will be about 1.5 times the present amount of plutonium in the combined weapons arsenals of the United States and the Soviet Union. Niskanen's second model asserts that the United States should not make safeguards expenditures beyond those necessary to lower the probability of obtaining material in the United States to the level of the probability of obtaining material outside of the United States. Any further expenditures are wasted within the framework of cost-effectiveness--terrorists can easily obtain material elsewhere in order to build weapons to detonate in the United States.

An item of interest in both models is the value of destruction. On the basis of the number of people who might be killed in densely populated cities, value of human lives (perhaps adjusted for the higher productivity of high-income people in some urban areas), and value of physical assets destroyed, the value of the damage due to the detonation of one or more fairly large weapons could be set at on the order of $1 trillion. Several economists have suggested that the figure should be closer to $0.5 trillion. But the general point is made--the damage would be extremely costly.

Another specific item is motivated by an analogy. A basis for standard-setting for the protection of nuclear material might be found within the area of nuclear reactor safety. The standard for protection of the people residing near nuclear reactors is presently set at .000001. If the population centers targeted by nuclear terrorists might involve at least 10 times as many people as reside near a typical nuclear reactor, should a standard at least ten times more stringent be set for nuclear safeguards?

In general, after review of the DOE processes at all levels, it can be concluded that there is essentially no conceptual thinking about cost-effectiveness of nuclear safeguards. Improvements are made, and budgets set, on the basis of engineering and operational judgments, taking into account threat inputs from the intelligence community, but there is no overall conceptual framework. Also, the assessment models (ET, SAVI, and MI$ER) are in early developmental stages from the point of view of obtaining numerical estimates of probability of failure of nuclear safeguards.

SPECIFIC COMMENTS ON EXECUTIVE SUMMARY

Background, The Facilities

With respect to the cost-effectiveness of the DOE safeguards system, both level and mix of safeguards resources must be addressed. The level of safeguards resources cannot be set independently of the vulnerabilities of other sources of nuclear material, and hence the other domestic and foreign facilities cannot logically be outside the scope of the study.

The Nature of the Problem

These three bullets (see Chapter 1) convey an incomplete description of the problem. In general, the problem is to determine the societally optimal level and mix of safeguards expenditures and their implementation in safeguards programs. The optimal level might be higher or lower than at present.

Principal Observations and Recommendations

Introductory Section

The Committee has no quantitative measure of protection, so how can it make the determination that the level of protection is not unacceptable? What is acceptable protection?

Management has not provided itself with the means to determine quantitative measures of effectiveness. Nor does it have a conceptual framework for thinking about the cost-effectiveness of the system. Therefore, it has not provided itself with the basis for developing the safeguards effort in a systematic manner in the future.

Increasing the cost-effectiveness of safeguards may involve reducing budgets and reducing effectiveness if both are presently too high. This may be the case in the broader context of both of the models presented by William A. Niskanen (U.S.-only and worldwide).

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APPENDIX B

AGENDA FOR THE COMMITTEE'S WORKSHOP

National Academy of Sciences
Workshop on Special Nuclear Materials Safeguards
November 17-19, 1987

U.S. Department of Energy
Germantown, Maryland

[All sessions classified unless otherwise designated.]

TUESDAY, NOVEMBER 17

AUDITORIUM

Introduction to the Work of the Committee
Herbert Kouts, Chairman

Welcoming Address
Troy Wade, Acting Assistant Secretary
for Defense Programs

DOE Reasons for the Study
Michael Seaton, Former Deputy Assistant Secretary
for Security Affairs

SESSION 1: (AUDITORIUM)
PANEL ON THREATS AND RISK MANAGEMENT [UNCLASSIFIED]

8:25 - 10:25 Part 1: Threat Assessment Overview

10:35 - 12:35 Part 2: Principles of Risk Management

12:35 - 1:15 L U N C H

SESSION 2: (ROOM A-453)
PANEL ON MATERIAL CONTROL AND ACCOUNTING

1:15 - 3:15 Part 1: MC&A Objectives, Organizations and Activities

3:25 - 5:25 Part 2: Material Accounting Practices

WEDNESDAY, NOVEMBER 18

SESSION 2: (ROOM A-410)
PANELS ON MATERIAL CONTROL AND ACCOUNTING

8:25 - 10:25 Part 1: Material Control Practices
10:25 - 12:35 Part 2: Analysis and Evaluation

12:35 - 1:15 L U N C H

Joint Panel Discussions--Panels 2 & 3

SESSION 4:
PANEL ON RESOURCE ALLOCATION

1:15 - 3:15 Part 1: Functional Allocation Within Sites
Part 2: Allocation Among Sites

THURSDAY, NOVEMBER 19

SESSION 5: (ROOM A-410)
PANEL ON PERFORMANCE EVALUATION

8:25 - 10:25 Problems and Methods

SESSION 6:
MANAGEMENT TOOLS

10:25 - 12:25 Part 1: Approaches to Human Reliability

12:25 - 1:15 L U N C H

1:15 - 3:15 Part 2: Guidance, Reporting, and Inspection

SESSION 7:

3:25 - 5:25 Summary Reports by Committee Rapporteurs

ADJOURN

APPENDIX C

WORKSHOP PANEL MEMBERSHIP

Committee on Material Control and Accounting
for Special Nuclear Materials
Workshop on Safeguards for Special Nuclear Materials
November 17-19, 1987

Organization of Panels

PANEL 1: Threat Assessment and Risk Management

Chairman:
Dr. Edwin Zebroski

Rapporteurs:
Dr. Jerome Bracken
Dr. Harrison Shull

Panelists:
Dr. Gerald F. Tape
Dr. William A. Niskanen (Cato Institute)
Mr. Frank Arsenault
Dr. Jorge H. Menzel (USACDA)
Dr. Robert Burnett (NRC)

PANEL 2: Material Control

Chairman:
Mr. William A. Higinbotham

Rapporteurs:
Dr. Walter Brown
Dr. Gregory Choppin

Panelists:
Dr. N. L. Roberts (LANL)
Mr. Donald Jewell (DOE, Albuquerque)
Dr. Jonathan Sanborn (Brookhaven National Laboratory)
Mr. Roy Cardwell (Martin Marietta, Oak Ridge)
Dr. Carleton Bingham (DOE, New Brunswick Laboratory)
Ms. Yvonne Ferris (Rockwell, Rocky Flats)
Dr. Robert L. Carlson (Westinghouse/Hanford)

PANEL 3: Materials Accounting

Chairman
Dr. Carl Bennett

Rapporteurs
Mr. Charles M. Vaughan
Dr Fred H. Tingey

Panelists:
Dr. James Tape (Los Alamos National Laboratory
Mr. Donald Jewell (DOE, Albuquerque)
Dr. Jonathon Sanborn (Brookhaven National Laboratory
Mr. Roy Cardwell (Martin Marietta, Oak Ridge)
Dr. Carleton Bingham (DOE, New Brunswick Laboratory)
Ms. Yvonne Ferris (Rockwell, Rocky Flats)
Dr. Robert L. Carlson (Westinghous/Hanford)

PANEL 4: Resource Allocation

Chairman
Dr. Kaye D. Lathrop

Rapporteurs
Dr. Walter L. Brown
Dr. Jerome Bracken

Panelists:
Mr. Gordon Fee (Martin Marietta Y-12, Oak Ridge)
Mr. John Meinhardt (DOE)
Mr. James Jackson (Los Alamos National Laboratory)
Dr. Donald Ofte (DOE, Idaho)
Dr. James Shipley (Department of State)
Mr. Dennis Miyoshi (Sandia Laboratories)

PANEL 5: Performance Evaluation

Chairman
Dr. James S. Tulenko

Rapporteurs

Mr. Charles Vaughan
Dr. Fred H. Tingey

Panelists:
Mr. Robert Garvin (DuPont, Savannah River)
Ms. Rokaya Al Ayat (Lawrence Livermore)
Mr. Al Walker (DOE, Hanford)
Dr. James Shipley (Department of State)
Mr. Brian Smith (PNL, Hanford)

PANEL 6: Management Tools

Chairman
Mr. Frank Baranowski

Rapporteurs
Mr. William A. Higinbotham
Dr. Edwin Zebroski

Panelists:
- Mr. Thomas Clark (DOE, Las Vegas)
- Mr. James Jackson (Los Alamos National Laboratory)
- Mr. Robert Burnett (Nuclear Regulatory Commission)
- Mr. Gordon Fee (Martin Marietta, Y-12, Oak Ridge)
- Mr. Robert Garvin (DuPont, Savannah River)
- Mr. Herman Roser (Former Asst. Secretary DOE, Defense Programs)
- Mr. Jack Keating (DOE/Richland)
- Mr. Carl Builder (RAND Corporation)
- Mr. William Knauf (Battelle Memorial Institute)