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DOE Office of Civilian Radioactive Waste Management Systems Studies Plan - Fiscal Years 1991 and 1992

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August 1991

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
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operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,
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DOE OFFICE OF CIVILIAN
RADIOACTIVE WASTE MANAGEMENT
SYSTEMS STUDIES PLAN -
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SUMMARY

The Systems Engineering Management Plan for the DOE Office of Civilian Radioactive Waste Management, which defines the systems engineering process for the Federal Radioactive Waste Management System (FWMS), requires that systems studies to support the integration, evaluation, and optimization of the system be identified. These studies are generally directed toward further defining system or system-element functional requirements, including interface requirements, evaluating alternative system configurations or operational rules, or optimizing design features to achieve system integration. Because the decisions based on these studies are conducted within the overall configuration management process, a consistent and documented framework for the identification and conduct of systems studies must be available. A planned approach is needed so that results from defensible and referenceable systems analyses are available to make informed decisions in a timely manner. This Plan covers "top level" studies (i.e., those involving system requirements generally and the definition of requirements for system elements). This Plan is focused on the FY 1991 and 1992 period, and will be updated periodically as required to ensure its currency.

The objectives of this Plan are:

1. To describe the scope and role of systems studies in the development of the system and system elements.
2. To communicate proposed systems studies and to foster their review and formulation.
3. To identify major program decisions required to accomplish program objectives and resolve issues and supporting information.
4. To identify, describe, and prioritize the system studies needed to provide information to support system development.
5. To assure that the results of systems studies are presented in the most effective manner to support program decisions and integrate these results throughout the organization.
6. To provide a record of completed, ongoing, and planned systems studies.

7. To provide a forecast of relevant technical issues as a guide to the development and evolution of analysis capabilities.

The status of studies recommended in the FY90 Plan and the implications of findings to date in terms of the current FY91/92 Plan are discussed. A list of "system decision groups," on which the recommended studies are focused, is developed from a recent, unpublished analysis by Weston, Inc. Finally, a list of studies for conduct in FY 1991 and 1992, brief scope descriptions for these studies, and a schedule for their conduct is recommended. An appendix is included which provides brief abstracts of 57 previously published studies.

Proposed systems studies for FY 1991 and 1992, their recommended timing, and their relations to one another, current studies, and major program milestones are identified. In general, only those studies supporting monitored retrievable storage (MRS) design requirements are recommended for immediate initiation. The studies are grouped into five major decision groups to allow scheduling to support specific decision windows. The proposed system studies schedule is generally a conservative one, with studies occurring early in or before the associated decision window.

The proposed studies schedule is relatively tight for only one decision group window. Two critical milestones in the development of the MRS are the initiation of Title I design for the Simple Receipt Facility and the Spent Fuel Handling Building to begin the first quarter of FY 1992. Both facility designs need input from the MRS Design and Operational Study, MRS Infrastructure Requirements Analysis, and the Reference System(s) Description for NFBC Handling/Transport Study. These proposed studies are described in this Plan.

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1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The Systems Engineering Management Plan for the DOE Office of Civilian Radioactive Waste Management (DOE 1985), which defines the systems engineering process for the Federal Radioactive Waste Management System (FWMS), requires that systems studies to support the integration, evaluation, and optimization of the system be identified. These studies are generally directed towards further defining system or system-element functional requirements including interface requirements, evaluating alternative system configurations or operational rules, or optimizing design features to achieve system integration. Because the decisions based on these studies are conducted within the overall configuration management process, a consistent and documented framework for the identification and conduct of systems studies must be available. A planned approach is needed so that results from defensible and referenceable systems analyses are available to make informed decisions in a timely manner. This Systems Studies Plan was prepared to meet these needs by the Director of the Systems Engineering and Program Integration Division in the Office of Systems and Compliance. This Plan covers "top level" studies - i.e, those involving system requirements generally and the definition of requirements for system elements. Other "systems" studies will be defined and conducted within each element. This is the first update of the Systems Studies Plan, and is focused on the Fiscal Year (FY) 1991 and 1992 period. This Plan will be updated periodically as required to ensure its currency.

The objectives of this Systems Study Plan are:

1. To describe the scope and role of systems studies in the development of the system and system elements
2. To communicate proposed systems studies and to foster their review and formulation
3. To identify major program decisions required to accomplish program objectives and resolve issues and supporting information
4. To identify, describe, and prioritize the system studies needed to provide information to support system development

5. To assure that the results of systems studies are presented in the most effective manner to support program decisions and integrate these results throughout the organization
6. To provide a record of completed, ongoing, and planned systems studies
7. To provide a forecast of relevant technical issues as a guide to the development and evolution of analysis capabilities

Together, these objectives will facilitate the systems engineering process required to complete the development of the system. The following seven steps describe the systems engineering process used by OCRWM:

1. Define the mission
2. Set system requirements
3. Initiate system design
4. Develop system descriptions
5. Evaluate the performance of a reference system against the system requirements including identification of system tradeoffs
6. Refine the reference system
7. Refine or modify system requirements.

As shown in Figure 1.1 these steps constitute an iterative process. Systems analyses (the performance of systems studies) provide results which are used to evaluate/modify the system requirements and interfaces and/or system design until an acceptable design solution is reached. This structure of the Systems Engineering Process has an important implication for systems studies conducted at the "top" (OCRWM program) level. This is that the results of these studies should support definition of requirements for design of system elements. Thus each study, to be useful, must redefine specific qualitative or quantitative requirements to be met by one or more system elements. System studies should help define the "what," "when," and "how well" dimensions of element level requirements.

FIGURE 1.1. System Engineering Process

This focus on requirements definition also implies that top level systems studies should not define the "how" dimension for system elements - e.g., the design details of system elements are not generally appropriate subjects for top-level study.

Since the number of possible system configurations and operating rules is very large, even within the context of a simple system concept, and since the program is subject to changes in requirements and constraints from external influences, there is a potential for the systems engineering process to continue refinement of the requirements and system configuration at almost any stage of system development. By incorporating the planning of major systems studies in a centralized framework, the System Studies Plan can serve to balance potential gains in system improvement realized through this refinement against the time and dollar costs of conducting further study.

1.2 STRUCTURE OF THE PLAN

The structure of the FY91/92 Systems Studies Plan generally follows that of the FY90 Plan (an unpublished draft report submitted by G. H. Beeman [PNL] in October 1989). Section 2.0 describes the systems analysis process in terms of four basic types of system studies, and the processes leading to identification and formulation of studies. Section 3.0 describes procedures for studies, and provides a template for systems study reporting. Section 4.0 has been added this year, and reports on the status of those studies recommended

in the FY90 Plan and the implications of findings to date in terms of the current FY91/92 Plan. Section 5.0 develops a list of "system decision groups" on which the recommended studies are focused. This section is largely an extrapolation of a recent unpublished analysis by Weston, which identifies system decisions and the schedules implied for these decisions by Program Milestones. Section 6.0 is the Plan, including a list of studies recommended for conduct in FY91/92, brief scope descriptions for these studies, and a schedule for their conduct. An appendix is included providing brief abstracts of 57 previously published studies.

2.0 SYSTEMS ANALYSIS

2.1 APPROACH TO SYSTEMS ANALYSIS

In order for systems analysis to accomplish its objectives, a consistent approach for the performance of systems studies is needed. This approach consists of the following principal steps:

1. Develop a reference system description that is consistent with the Physical System Requirements/Functional Analysis (PSR/FA) (DOE 1991a). This reference system description will define the physical aspects and functional relationships of the system elements and sub-elements. (See McKee et al. 1991.)
2. Establish a reference scenario for system operation that includes a set of operating assumptions that are consistent with the PSR/FA. This reference scenario will define the system operation by identifying process parameters, such as capacities and times to perform by waste type for particular processes, ratios of input to output, times to failure and repair, and unit cost and dose factors.
3. Establish a performance baseline for a reference system that is consistent with the PSR/FA and operating assumptions. This baseline will serve as the benchmark for analyses of system configurations tradeoffs or other studies of system performance.

The use of this approach facilitates understanding the underlying reasons for changes in system performance, allowing differentiation between changes in system performance due to changes in system requirements, system configuration, reflected in the system description, and changes in system operating assumptions, reflected in the operational scenarios.

In the context of the systems engineering process, a systems study evaluates changes in system performance that result from changes in one or more of the elements of the Waste Management System, and predicts the effects of system-element interactions at a level of detail appropriate for the systems study being performed. Within this general definition, the systems studies required to support system development fall into four types.

2.2 TYPES OF SYSTEMS STUDIES

The four basic types of systems studies are discussed below.

2.2.1 Definition of Technical Basis for System Requirements

Studies that provide the technical basis for system requirements evaluate the system to produce technical or economic justifications for some of the requirements used as input to the design process. Some requirements (constraints) are clear, such as those in statutes, state and Federal regulations, or DOE Orders. Other requirements (performance requirements) are based on the interpretation of broad guidance, or may be self-imposed by OCRWM. Examples of the latter include the annual waste receipt rate and the design specifications for waste canisters.

2.2.2 Allocation of System Functions

Top-level system requirements and functions have been established and baselined in the PSR/FA (Vol. 1) (DOE 1991b) by the Functional/Physical Analysis Task Force. Systems studies developed under this plan will be used to determine the most appropriate allocation of these functions to the system-elements. An example of this is the systems studies to determine the need for and the allocation of the spent fuel consolidation function (or some other spent fuel preparation function) to the reactor sites, the MRS, the repository, or some combination of all three.

2.2.3 Evaluation of System Performance

Evaluation of system performance is a component of all systems studies but is also valuable when applied only to a single reference system. Such an evaluation of baseline system performance should be conducted periodically even if no changes have been made to the system. A comprehensive baseline evaluation would include an operations/logistics evaluation which simulates system operation and material flow, a system cost evaluation, a system safety evaluation, and a system reliability and availability evaluation.

2.2.4 Evaluation of Alternative Designs and Operational Scenarios

Systems studies supporting the evaluation of alternative designs and/or operational scenarios are designed to compare the performance of alternative systems which differ from the reference system in configuration or operation. System configuration encompasses functional and physical descriptions of the system. System operation refers to how specific facilities and equipment are

operated. An example of this type of an analysis would be a determination of whether the system should be operated to provide a waste stream of constant average thermal properties at the repository.

2.3 SYSTEMS STUDY CAPABILITIES

Conduct of systems engineering studies is constrained by the analysis capabilities available for use. Capabilities consist largely of system models, data supporting their use, and methods of linking and reporting various results. During the past several years, a program of model development has been under way to create an integrated set of systems analysis models. Such models have been partially developed as part of the Systems Integration Program, and are part of the Systems Integration Modeling System (SIMS).

These models are based on a detailed operational simulation of the material flow within the waste management system, and are thus heavily dependent on design details for the various system elements. While these models are useful in their current form for many of the studies identified in this plan, some studies may require adaptations of these models or different models entirely. No attempt has been made to constrain the scope of proposed studies to those for which the SIMS capability is adequate. In cases where other models appear to be required, model development activities are recommended.

The SIMS is an integrated system of capabilities, models, and data bases that are being developed for the purpose of performing system engineering studies of the Federal Waste Management System (FWMS). While some components of the SIMS are still under development, a brief overview of the current operational models, their capabilities and their interfacing is appropriate. Current operating models in the SIMS include the following:

- Waste Stream Analysis (WSA) Model generates waste stream logistics for the remaining models,
- Systems Operations & Logistics Model (SOLMOD) determines the feasibility and reliability of the described waste management system,
- Systems Engineering Cost Analysis Model (SECAM) calculates the total life-cycle cost of the system, and,

- Systems Engineering Dose Analysis Model (SEDAM) which calculates the total life-cycle public and occupational dose from the system.

The OSCAR User Interface utilizes detailed functional and physical descriptions, operational rules, and assumptions of the waste management system being modeled with the Systems Integration Data Base (SIDB) to generate information for the models needed to perform their respective analyses. The WSA Model uses scenario information provided by the OSCAR user interface in addition to data from the Waste Characterization Data Base (CDB), Integrated Data Base (IDB), and EIA Spent Fuel Discharge Projections.

2.4 IDENTIFICATION OF SYSTEMS STUDIES

Topics for systems studies arise in the routine conduct of the systems engineering process. Establishing system requirements and defining them in operational terms for design leads to the need for systems studies. The periodic need to confirm that the current set of system-element level designs function together to meet both system and system-element requirements also requires the use of systems studies. The development of the system configuration and the system-design is supported (and to some extent driven) by systems studies of alternative configurations, designs, and operating modes for the system. Several conditions and considerations that lead to the identification of needed systems studies are described below, and the relevance of these general modes of system study identification is summarized for the current version of the plan.

2.4.1 Ambiguity in External Requirements

Many of the system and element-level requirements are derived from regulatory and other external sources. The systems engineering process dictates that these requirements be interpreted or converted into a specific, and often quantitative form. This may require a formal systems study to document the technical basis for certain system requirements. An example of such a situation is NRC's requirement that radiation exposures be as low as reasonably achievable (ALARA). This requirement is purposely ambiguous to allow for interpretation, and requires an extensive systems study to derive a set of

minimum dose requirements for different parts of the system, and the associated design and operational modifications to achieve them.

2.4.2 Inconsistencies in External Requirements

Analysis of the system using the current set of external requirements may reveal that some of them have inconsistencies. Systems studies will be needed to support the reconciliation of these inconsistencies.

2.4.3 Lack of Basis for System Requirements

The current set of design requirements has evolved through a process of incorporating external system and element-level requirements, which incorporated results from element-level systems engineering efforts initiated prior to the specification of system-level requirements. This was followed by continuing definition and refinement of system requirements. Thus, there are requirements for which the technical basis is at best hard to trace, if there is, in fact, any valid basis.

2.4.4 Ability of Current System to Meet Requirements

By its nature, the design process seeks innovative ways to satisfy requirements in a simple and economic fashion. Part of the systems engineering function is the confirmation that several design solutions, taken together, do indeed satisfy requirements. Systems studies are also needed to evaluate the ability of the current system to meet new requirements any time the system requirements change (this is embodied in changes to the WMSR). In other cases, the systems studies may show that current requirements cannot be met with the current set of designs and reference system operating scenarios. This condition requires either redesign of the system, or redefinition of the requirements. In either case, systems studies must be used to evaluate possible solutions.

2.4.5 Invalidation of Previous Systems Study Assumptions

Since the results of systems studies constitute much of the basis for system development, changing assumptions affects the validity of system development and can lead to the need to recheck results from previous studies. This source of need for systems studies can be minimized by careful study

design and the conduct of broad scoping studies prior to detailed design-basis studies, but will still occasionally be necessary.

2.4.6 Proposed Alternative Configurations or Designs

Within the context of the systems engineering process there may still be alternative system configurations or element-level design solutions proposed by other organizations that will require evaluation by systems studies. These studies would be structurally similar to those evaluating the ability to meet requirements.

Any of the aforementioned six conditions can lead to the identification of needed systems studies, and to some extent have contributed to the list of proposed studies, as summarized below.

2.4.7 Summary of Study Identification Process for the Current Plan

Each of the several modes of potential study identification was utilized to some extent in formulating the list of proposed studies. A major review of system requirements, and the logical hierarchy within which they are organized, has been conducted during FY90 and early FY91 by the Functional/Physical Requirements Task Force. This process resulted in a list of issues dealing with the definition of functions, the specification of requirements, and the process for resolution of functional and physical requirements. From these issues the need to complete the Aggregate Receipt Rate Study was re-emphasized, and proposals were identified for a Retrievability Requirements Study, addressing the NRC's requirements for retrieving waste from the geologic repository, and an MRS Infrastructure Requirements Analysis, reviewing the MRS site support and storage functions of the facility.

The ability of the current reference system to meet existing requirements was analyzed formally for the first time during FY90 in the Reference System Performance Evaluation (RSPE). While this study had originally been intended (as defined in the 1985 SEMP) to be conducted on an annual basis, the current pace of system development now suggests that the logical schedule for a general reanalysis of the RSPE scope is upon completion of the next design phases for the MRS and Repository Facilities. There are, however, some specific "system definition" issues which arose during the conduct of RSPE. These

include the definition of reference handling and transport methods for non-fuel bearing hardware, and the definition of a reference storage/retrieval cycle for a "basic" as opposed to "integrated" MRS facility. Studies are recommended to address some of these questions in Section 6.0.

An analysis by Weston identified over 50-top level decisions that require resolution during development of the FWMS. These results, including a scheduling analysis derived from the current program milestone schedule, were made available to PNL during preparation of this Plan. This material was used both as a source of potential topical content for studies and to prioritize studies based on the schedule for decisions supported by various studies.

External events affecting the program have, to some extent, invalidated, or at least called into question, some previously common system study assumptions. Briefly, these include the first repository start date, and the assumption of Oldest-Fuel-First allocation of spent fuel acceptance, the extent of the economic incentive to complete spent fuel removal at shutdown reactors, and the technology to be used for spent fuel handling at an MRS.

Closely related to the above is a group of proposed alternative technologies for use in spent fuel transfer at an MRS or possibly at reactor sites. Several scoping-level studies of these technologies were conducted during the year, and an additional study proposal is based on the results of these studies.

3.0 DEVELOPMENT AND CONDUCT OF SYSTEMS STUDIES

This section outlines procedures for the scoping or development of systems studies and the conduct of those studies. All systems-level studies recommended in this plan should include the minimum content outlined here.

3.1 SCOPING OF SYSTEMS STUDIES

This plan attempts to provide only identification and brief description of proposed systems studies. The level of information presented here is intended to be sufficient only to support initial determination by RW-32 that proposed studies are worthwhile and timely, and subsequent description of study objectives for the purpose of developing a detailed work statement. After identification of a proposed study, and a determination by RW-32 that the study is relevant and timely, a detailed scope of work is developed by RW staff or contractors.

The conduct of a systems engineering study typically represents the expenditure of a considerable amount of time and money, and the consequences of the decisions based on these studies can be much greater. Therefore, time and effort expended in properly scoping such studies is very worthwhile. These scoping efforts should be complete enough to include the detailed information described below. As further assurance that the systems study will provide the analyses and results required, proposed work scope statements should be reviewed by the same technical group that will ultimately review the results of the study.

3.1.1 Requirements or Design Features Subject to Change

The scope of a study should reference the appropriate sections of the WMSR and WMSD, as well as the relevant reference system operating assumptions or element-level design descriptions that are the subject of the study. Where multiple alternatives are to be evaluated, a minimum list of these alternatives should be given in the study scope. This information will be needed in the determination of the appropriate QA requirements that must be completed prior to initiation of the work.

3.1.2 Range of System Parameters for which Results are Applicable

The scope of the study should specify the limits of the study. That is, the range of system configurations, designs, or operations for which the results of a study are considered valid should be explicitly stated. For example, if the models to be used are valid only for a one-repository system without an MRS, and using vertical emplacement, this should be stated in the scope.

3.1.3 Key Assumptions

Any assumptions which are used as input to the systems study should be listed, along with the following information about each:

- Specific values or ranges of parameters used
- A referenceable source or sources to be used for the assumption
- Plans for developing the assumptions, including a brief statement of technical rationale.

3.1.4 Technical Approach

The basic technical approach for most systems studies will be similar, in that it will involve utilizing a set of models to produce results which provide measures of system performance. The scope for a systems study should specify the models (and versions of each) to be utilized, and any additions to model capabilities that appear to be required. It should also specify the performance measures to be utilized in the study.

3.2 CONDUCT OF SYSTEMS STUDIES

The reason for conducting systems studies discussed in Section 2.0 fall into two basic types: 1) those in which the reference (baseline) system is being evaluated versus a selected set of requirements, and 2) those in which alternatives to the system, in terms of requirements, configurations, designs, or operational scenarios, are being evaluated. Figure 3.1 is a schematic of the first type of study, illustrating the use of the SIMS capabilities.

Figure 3.2 incorporates the same basic analytical structure in a process for defining and comparing system alternatives. Such a structure would be

FIGURE 3.1. Reference System Engineering Study

FIGURE 3.2. "Alternative" System Engineering Study

employed for studies examining the relative merits of requirements, configurations, design features, or operational scenarios.

In addition to this structural description of the performance of systems studies, some special considerations apply to studies in which alternative requirements are evaluated. This is due to the fact that: 1) some information on system design is required to predict the consequences of changing requirements, and 2) the current design is in response to a specific set of

requirements. Thus a study of alternative requirements must incorporate some model of, or assumption about "design response" to alternative requirements to determine their impact on system performance. One possibility for incorporation of this "design response" information is to include the element designers in the study development so that conceptual designs are prepared for each of several scenarios. This approach is exemplified by the "Report of the Task Force on the MRS/Repository Interface" (DOE 1986). This approach has the advantage that those in the best position to know make judgments about design responses. The primary disadvantages are the time required and the additional costs incurred.

An alternative approach is to model the design response in some parametric fashion. An example of this approach is the current PNL study of aggregate receipt rates, in which waste package loading and pitch were assumed to vary as a function of waste thermal output. This approach is quicker than the first but risks extrapolating properties of the current design beyond the point at which a reasonable designer might adopt an entirely new approach.

3.3 REPORTING SYSTEMS STUDIES

Systems study reports will document the results of analyses of system requirements and functions; system design, development and operations; system alternatives; systems costs; system risk and impact assessments; and other issues as may be appropriate for the particular study being conducted. These reports will be prepared by the organization responsible for the study under the guidance of the Director of the Systems Engineering and Program Integration Division in the Office of Systems and Compliance. The contents of the report will include the following as appropriate:

1. Requirements and functions. A list of the system or system-element requirements and functions that are the subject of the analysis or otherwise correspond to the subject of the report.
2. Identification of alternatives. A list of system or system-element function or operational alternatives or strategy options considered and the significant characteristics of each.

3. Assumptions and methods. A description of the simplifying assumptions used that may have a bearing on the results of the study. Also a description of the methods or models used, including a description of the system being analyzed. The suitability of computer models used in the analysis will be verified.
4. Analysis of health and safety risks and impacts on the environment. The results of the analysis of the radiological risks to the public and waste management system workers and the predicted impacts on the environment of functional and operational alternatives.
5. Analysis of programmatic and operational risks. The results of an analysis of the programmatic and operational risks associated with each function or design alternative.
6. Cost analysis. The results of the engineering cost analysis of the impacts of costs over the lifetime of the system will be presented to ensure that any decisions resulting from a review of functional, operational, or design alternatives are made only after proper consideration of their impacts on costs or cost effectiveness.
7. Licensability assessment. The results of an evaluation of the licensing impacts associated with each alternative.
8. Conclusions. The conclusions drawn from the results of the above analyses and substantiated with the technical, cost, or schedule data or any other data and assumptions deemed appropriate to support the conclusions.
9. Sensitivity analysis. The results of an evaluation of the sensitivity of the analysis conclusions to uncertainties in the alternatives or assumptions.
10. Recommendations. Specific proposals to change or retain system or element-level requirements, including the values of any quantitative performance criteria associated with requirements. Recommendations to initiate change control proceedings for the reference system description in the WMSD or equivalent documents.

4.0 STATUS OF ONGOING SYSTEMS STUDIES

This section reviews the status of those studies proposed in the previous Systems Studies Plan, including key results and expected progress during FY91. This material is integrated with the results of an analysis of "Program Integration Logic" (Weston, unpublished letter report)^(a) in Section 6.0 - Proposed Systems Studies Plan for FY91/92.

4.1 REFERENCE SYSTEM PERFORMANCE EVALUATION

This study was proposed as the first annual technical assessment of the Waste Management system to define a reference point for system performance so that subsequent systems studies can be compared on a consistent basis.

The study was undertaken by PNL, ORNL, and their subcontractors during FY90. Much of the calculation and modeling work is complete. A draft PNL report discussing this study is in preparation. Modeling to date includes Waste Stream Analysis (WSA), which characterizes the waste stream as a function of time and location, SOLMOD (operational) modeling, which simulates waste handling and material balance in the system, and SECAM (cost) modeling. Planned analysis of routine occupational doses (SEDAM model) has been delayed pending availability of sufficiently detailed SOLMOD output.

Key results to date are 1) that the system processing capability easily meets the required waste acceptance schedules assumed, 2) that there is little cost incentive or penalty for utilizing a "western strategy" of direct shipment from western reactors to a first repository, 3) that there is a very small cost penalty associated with MRS operation in which all spent fuel received at the MRS during the repository operating period passes through storage rather than being transferred directly to the repository, 4) that 8 out of 120 reactors considered (McKee et al. 1991) as sources of spent fuel

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(a) Clem, L. 1990. "Preliminary Draft OCRWM Integration Logic," Letter Report to W. Lemeshewsky, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, August 23, 1990, Roy F. Weston Inc., Washington, D.C.

were found to be unservable with current transportation casks based on available reactor capability data. Data from the Facility Interface Capability Assessment (FICA), which include a detailed assessment of reactor handling capabilities, was not available for this study. Two reactors were classified not serviceable due to non-standard SNF, while six had insufficient rated crane capacity for the smallest currently designed transport cask (25 ton legal weight truck cask).

While basically confirming the ability of the current reference waste management system (as described in McKee et al. 1991) to meet all system-level requirements, the study revealed several significant technical issues that require resolution.

First, the inability to serve eight reactors, if a valid finding, is a significant system performance issue. This analysis should be revisited using the more definitive reactor data from FICA. Second, the MRS analyzed in the Reference System Performance Evaluation (RSPE) is the MRS System Study store-only design (Woods et al. 1988), not the recently developed Parsons design for a spent fuel handling building that can be available by 1998. Third, the operations simulation conducted for RSPE takes no account of the within-year distribution of spent fuel loading and shipment activity. (Preliminary data indicate that reactor refueling outages may create a significant seasonal pattern in the delivery of SNF.) This is proposed for evaluation in a separate study (see Section 6.0).

4.2 EVALUATION OF SYSTEM REQUIREMENTS

While the majority of system requirements have their basis in legislation, state, and federal regulations, DOE orders, etc, some requirements, (system throughput for example), are set at the discretion of OCRWM. A technical basis is needed for these requirements that can be documented in the WMSR Rationale (or a similar) document. This study was proposed in the FY90 Plan as a general evaluation of these discretionary requirements, including the system throughput rate, cask fleet size and campaign length, and lag storage requirements.

A limited version of this study was undertaken during FY90, focusing only on the receipt rate requirements for the MRS and repository. This study, the Aggregate Receipt Rate study, is a logistics and cost analysis to determine if there are potential benefits to the high-level waste management system for receipt or emplacement rates other than the current 3,000 MTU/yr design-basis rate. The basic trade-offs in this analysis are between savings in facility capital cost achieved in low throughput systems and savings in facility operating costs achieved in higher throughput systems, and between potential savings in at-reactor storage costs and storage costs that might be achieved either by lower cost storage at an MRS and/or by faster acceptance at the repository. The scope of the analysis includes both a repository-only system and a storage-only SFHB or basic MRS system but did not include an MRS with a simple transfer facility. To allow for current uncertainties in facility startup scheduling, cases considering repository startup dates of 2010 and 2015 and MRS startup dates of 1998 and three years prior to the repository have been evaluated. A range of receipt rates ranging from 1,500 to 6,000 MTU/yr have been considered for both the MRS and the repository.

Results-to-date, assuming unconstrained MRS storage limits, show that higher receipt rates appear to be economically justified for both the repository and an MRS. For a repository-only system, minimum undiscounted system costs are found at a repository receipt rate of 6,000 MTU/yr. When a storage-only MRS is included in the system, minimum system costs are also achieved at a repository receipt rate of 6,000 MTU/yr. However, the MRS receipt rate for minimum system costs depends on the MRS startup date and ranges from 3,500 to 6,000 MTU/yr. The 3,500 MTU/yr figure is the least-cost MRS processing rate for the currently planned 1998 MRS start date. The added cost of providing the MRS is offset by reductions in at-reactor storage cost, and the total system cost is virtually the same as for the repository-only system. When costs are discounted in the range of 3% to 5%/yr, the total system costs are much less sensitive to processing rates.

Although the analysis to date has not included a case in which MRS capacity is constrained to the NWPAA limit, this analysis is planned for FY91. Since the constrained MRS case will result in higher average and incremental

costs for surface storage of spent fuel than the unconstrained case, and thus a greater incentive for emplacement, it is expected that this analysis will result in an optimal repository emplacement rate no less than the 6000 MTU/yr found for the unconstrained case. Given the need to proceed quickly with the MRS conceptual design, this becomes a high priority analysis.

The issues of cask fleet size, campaign length, and lag storage requirements, originally proposed for inclusion in this study, are part of a group of technically linked questions which also include the factors of seasonality in SNF loading and the optimal (least cost) operational reliability level for the system. None of these issues can be definitively addressed without the others. These issues were not addressed in FY90 due to modeling capability and data limitations, but are felt to be appropriate for analysis in 1991 and 1992. A study addressing these issues is outlined in Section 6.0.

4.3 IMPACT OF TSCs AND MESCs ON THE WASTE MANAGEMENT SYSTEM

Some utilities appear to favor TSCs (Transportable Storage Casks) and MESCs (Multiple Element Storage Canisters) for on-site storage. An evaluation of the use of TSCs and MESCs as an integral part of the Waste Management System was proposed for FY90.

The decisions for which this proposed study was targeted included 1) whether or not OCRWM should initiate development of a TSC, or support licensing studies for proposed TSC designs, which have not yet been licensed for dual use, 2) whether the storage of TSCs at an MRS should be included in MRS functional requirements, and 3) whether the receipt, handling, storage and disposal of MESCs should be part of MRS and/or MGDS design requirements.

While a single comprehensive study, as envisioned in the FY90 Systems Studies Plan, was not undertaken, there were several analyses conducted during FY90 which are relevant to the decision on TSC utilization within the FWMS. A study sponsored by EPRI and conducted by Nuclear Assurance Corp. (Casper 1989) also found little apparent economic incentive for large-scale deployment of TSCs, but concluded the option "should not be abandoned" by DOE-RW.

A scoping study by PNL/JAI (unpublished PNL letter report - Wood et al. 1990)^(a) examined TSCs as one means by which the federal waste management system could accept spent fuel in 1998, even without the hot cell capabilities of an MRS. While this option was felt to be the lowest technical risk option examined, other options utilizing cask-to-cask transfer of spent fuel, or transport of MESCs were projected to be less costly. Although this study did not provide a conclusive analysis for the purpose of a final decision on OCRWM sponsorship of TSC development, it identified two key sub-issues on which this decision hinges. The first of these is the relative purchase costs of TSC's and storage only casks (SOCs). While vendors indicate that transport capability may be achieved at a small cost premium over the costs of SOCs, this needs to be confirmed with the NRC in reference to a cask design and reference storage cycle that is clearly defined. The second key issue is the proportion of reactor sites which could use TSCs as a function of cask specifications. The reference TSC (NAC-STC) assumed in the study could not be employed at roughly 1/2 of reactor sites that required service in 1998 and 1999. Many of these sites could be served by TSC's using heavy-haul transport and ex-pool fuel transfer systems, but the current reference system does not include these capabilities.

A comprehensive study of several methods for early SNF acceptance was conducted by Sandia National Laboratory. This study (the Storage and Transport OPtions Study [STOPS]) provided interim results which were ambiguous on the decision for OCRWM development of the TSC option.

A major initiative to develop the licensing basis for TSCs, and demonstrate their use in a store-now-transport-later cycle, was included as a provision of the House Appropriation Committee Report (H 101-536) and the House/Senate Appropriations Conference Committee. A program is now being designed to provide for investigation of all key technical issues, using up to

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(a) Wood, T. W., R. I. Smith, E. R. Johnson, and N. B. McLeod. 1990. "Some Alternatives for DOE Acceptance and Storage of Spent Fuel in 1998 and 1999." Joint Letter Report, September 1990, Pacific Northwest Laboratory, Richland, Washington, E. R. Johnson Associates, Washington, D.C.

three casks and their associated support equipment, at the Rancho Seco site. Such a program, if appropriately structured, would answer key licensing questions and also resolve much of the uncertainty about relative fabrication costs of TSCs and SOC's.

The remaining question of whether RW should acquire and deploy significant numbers of TSCs now seems to depend largely on the success enjoyed by the MRS negotiator's office. This question could require an additional study, but not until late FY92 or FY93. (The OCRWM Program Logic Network for January 17, 1991 shows the MRS host/DOE agreement finalized in late calendar 1992.) Since the licensing basis for TSCs should be independently established by an at-reactor demonstration, delaying this study should not compromise RW's ability to use TSCs on a widespread basis in the future.

The question of MESC acceptance was addressed in the ORNL study (JAI 1990b). Options examined included acceptance of MESC's, refusal to accept MESC's, or acceptance subject to charges and/or conditions. This study found that the cost penalty associated with MESC acceptance is very sensitive to the quantity of fuel received. Thus DOE acceptance policy can be adjusted depending on the quantity of fuel eventually stored in MESC's. While this report provides an adequate technical basis for the decision on MESC acceptance, the decision point for development of an MESC cask (or special insert for the current rail-barge cask) should be determined. This would require a schedule analysis, however, and not a systems study.

4.4 WASTE ACCEPTANCE CRITERIA

Analysis of waste acceptance criteria issues has been under way for several years on two broad fronts. The first of these involves decisions on the acceptability of non-standard spent fuel and of non-fuel-bearing hardware. Included in non-standard SNF are failed, consolidated, and canistered fuel. Analysis of the conditions under which such fuel (and some categories of non-fuel-bearing hardware) should be accepted has been carried out by ORNL and JAI, and several studies related to these issues have been recently published (JAI 1989a, 1989b, 1990a, 1990c). Together, these studies furnish an adequate technical basis for decisions on acceptance of most categories of non-standard

fuel and fuel hardware. Two categories of hardware will require some future study to adequately define a reference handling procedure for use in calculating system logistics and costs. The first of these is BWR control assemblies. These assemblies, as discharged, occupy a cross-sectional area roughly equal to four BWR assemblies, and would require significant cask capacity for transport. Calculations during RSPE indicated that thousands of additional cask-trips would be required to transport these assemblies intact.

The second area in which reference system definition could be improved is with respect to BWR Flow Channels. An unpublished analysis by ORNL indicates that a large percentage of BWR fuel flow channels could not be transported in current cask designs.

An analysis was initiated at ORNL in December 1990 to evaluate the costs of SNF hardware transport. Results from this study are not yet available, but should be reviewed prior to further work in defining the reference transport operations for NFB hardware.

The analysis of incentives for selection of SNF from within the standard fuel category has been pursued by PNL, ORNL, JAI, LLNL, SNL, and OTSP (BCL) under "Task 8" of the Waste Acceptance Criteria initiative. This study is being completed, and will undergo peer review in April of 1991 with publication expected in June. This study involved analysis of the economic, operational, or performance incentives for selection of spent fuel, based on separate analyses of transportation systems, MRS, and repository operations. This study will recommend three spent fuel characteristic scenarios to be included in the design basis for Title I MRS design and repository advanced conceptual design.

In general, this study shows that 1) incentives for selection from a transportation perspective favor "coldest" or oldest-fuel-first selection, 2) MRS operations and costs (as estimated for a modified Parsons design as a basis facility) are largely insensitive to spent fuel characteristics, and 3) current repository strategy for minimizing waste package corrosion favors a class of scenarios in which the fuel emplaced has a constant long-term thermal energy deposition (kW-yrs).

Since the incentives for selection from the transportation and repository perspectives are not directly comparable, both preferred scenarios are recommended for inclusion in the design requirements. If a single design-basis spent fuel characteristics scenario is felt to be required, further analysis to compare these two preferred cases would be necessary. To reconcile the opposed selection incentives found for the transportation and repository elements, it would be necessary to estimate the cost of repository design adaptations that could achieve the same waste package performance advantages found for the constant energy deposition scenario, while using the lower source-term SNF stream preferred on cost grounds by the transportation element. These design adaptations could include variable borehole spacing, larger and or thicker SNF packages, or alternative SNF/DHLW co-emplacement strategies. While it is conceivable that these design modifications could be implemented for less than the monetary incentive for cold fuel in the transportation element (~\$200 million), this is felt to be unlikely. This study was not recommended in Section 6.0 for conduct during FY91 and FY92.

Task 8 also showed that spent fuel characteristics, in the aggregate, could be easily managed by simple at-reactor selection rules based on age and burnup, without violating the acceptance quantities prescribed for individual reactor sites under a variety of acceptance allocation rules. Since there are many rules which can achieve the desired effect from the DOE perspective, and since utilities will clearly have diverse views on selection rules, some continuation of analysis is recommended on this topic, in conjunction with utility representatives (see Section 6.0).

4.5 DETERMINATION OF WASTE GENERATOR CASK HANDLING CAPABILITIES

The development of transportation casks for use in transporting SNF assemblies has been ongoing for several years. This effort, referred to as Initiative 1 - From-Reactor Casks, has culminated in preliminary designs for a rail cask (the BR-100) and two truck casks (the GA-4 for PWR assemblies and the GA-9 for BWR assemblies). The design requirements for these casks specified an envelope of SNF assembly designs that the casks would be capable of transporting. Assemblies not transportable by any of these casks would be

transported in specialty casks resulting from an Initiative 2 transport cask design effort. However, these transportation cask design efforts were undertaken with only limited knowledge on the cask handling capabilities available at reactor sites.

A study to characterize these interface requirements imposed on the Federal Waste Management System by the physical limitations of power reactor sites has been underway for over two years. This study, the Facility Inter-face Capability Assessment (FICA), was conducted by ORNL and its subcontractor, NAC, and is essentially complete. It involved site visits and questionnaires to define the relevant dimensional, and operational limitations for reactor pools, buildings and sites insofar as SNF transfer is concerned.

Phases I and II of the FICA project have been completed. These involved making visits to 122 facilities on 76 different sites to collect data and assess the fuel storage and cask handling capabilities of these facilities. Individual assessments of facility capabilities to store and ship SNF have been completed. The main conclusion of these assessments is that current facility capabilities would not allow handling of any of the Initiative 1 casks at 44 facilities, representing about 36% of the total facilities. However, the cask handling capabilities of all but 1 of these facilities could be upgraded to handle the Initiative 1 casks. These upgrades vary from relatively minor license revisions to engineering modifications of plant items and equipment. Phase III of the project, yet to be initiated, proposes to make additional analyses of the accumulated data and facility capabilities and to make periodic revisions to the data base as needed.

Preliminary results of this study were used in the PNL Phase I study of Transportable storage casks to define the number of reactors which would handle the reference TSC. Opportunities for similar applications of this data will occur in the definition of the operational details of the transportation system, and in evaluation of the need for cask-to-cask transfer technology.

4.6 IMPACT OF WITHIN-YEAR SPENT FUEL CHARACTERISTICS ON THE WASTE MANAGEMENT SYSTEM

Studies of spent fuel characteristics to date have used data based on an annual average. These studies suggest that lag storage of 3,000 MTU (one year of spent fuel receipts for the current reference system) would be adequate to manage spent fuel characteristics as they change from year to year. However, this technique does not allow an assessment of the short-term variations in spent fuel characteristics, the extent to which these variations would impact the Waste Management System, and the minimum quantity of storage required to manage spent fuel characteristics. These questions were proposed for study in the FY90 Systems Study Plan, but were not undertaken due to limitations of the SIMS models.

During FY90, capabilities were added to the WSA model to permit analysis of intra-year variations in spent fuel characteristics. This analysis is again proposed for study during FY91. (See Section 6.0).

4.7 DEVELOPMENT OF RAM REQUIREMENTS FOR THE WASTE MANAGEMENT SYSTEM

Historically, there has been no technical basis for or specificity in guidance provided to system designers in the areas of reliability, availability, and maintainability (RAM). This lack of specificity can result in inconsistency in the design philosophies for the transport system, MRS, and repository, and large differences in design solutions to similar problems. Historically, this has manifested itself in large cost differences between surface facilities at the MRS and the repository. A consistent approach may be necessary to assure that the system is properly designed.

A scoping study was undertaken at PNL during FY90 to address two questions: 1) should there be a system-level operating reliability requirement? and 2) what parameter or parameters are appropriate as performance criteria at the system level? This study is currently under way, although it is too early to determine the answers to these questions. If they are answered in the affirmative, additional study will be required to set a system level

reliability requirement and to allocate it to system elements. Section 6.0 includes a proposal for such a study, to be undertaken if the answer to Question 1 above is in the affirmative.

4.8 PHYSICAL SYSTEM REQUIREMENTS/FUNCTIONAL ANALYSIS - RESOLUTION OF ISSUES

As part of the OCRWM Management System Improvement Strategy, a functional analysis will be performed on both the Physical System and the OCRWM Program. The reports resulting from these functional analyses will identify functions, constraints, requirements, system architecture and interfaces for: the Overall System, Accept Waste, Transport Waste, Store Waste and Dispose of Waste functions as well as the Exploratory Studies Facility.

A review of the program issues identified through the functional analysis efforts resulted in the following areas of concern which need to be addressed:

- Definition of the surface storage requirements at the repository for potential retrieval scenarios.
- Definition of the function of site support facilities of the MRS and their relation to the FWMS.

Resolution of these areas of concern could be facilitated through the completion of systems studies proposed in Section 6.0.

5.0 SYSTEM DECISIONS AND PROGRAMS MILESTONES INFLUENCING STUDY REQUIREMENTS

A recent unpublished analysis by Weston^(a) relates Program Milestones (as set forth in OCRWM's Program Cost and Schedule Baseline (PCSB) (Revision 1 draft report of January 17, 1991) to a series of decisions or information needs. This analysis was made available to PNL during preparation of this plan as an independent assessment of information needs and as a source of schedule-based priority information.

The Weston Analysis focuses on approximately 50 "first tier" (or top-level) systems decisions (SDs) and their relations to program milestones. Table 5.1 is a list of these decisions and their earliest and latest dates for resolution based on this Weston Analysis. Some of these decisions are "external" - of the sort that no amount of study (as used here) will ever finally resolve, e.g., SD-17, the MRS site selection decision, or SD-51, the first repository site selection decision. Many of the decisions in the first tier, while potentially having implications at the systems level, are essentially "design-specific" decisions. An example is SD-24, the choice of horizontal versus vertical waste package orientation in the repository. A few of the decisions are considered "element-level" and not "first-tier" system decisions, e.g., SD-27, which relates to the definition of operational procedures of the MRS. Some of the decisions cannot, under current institutional restrictions, be resolved within the timeframe covered in this plan and are therefore considered "premature". An example is SD-49, the decision on development of a second geologic repository. A small number of decisions were classified as "undefined" based on preliminary Weston input. *(These decisions may be reclassified based on final Weston input.)*

(a) Koske, B. 1991. "Logic Network Inputs, Outputs, and Assumptions," Letter Report to W. Lemeschewsky, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, January 31, 1991, Roy F. Weston Inc., Washington, D.C.

TABLE 5.1. First Tier System Decisions and Estimated Decision Windows

System Decision	OCRWM First Tier System Decision	Earliest Decision Date	Latest Decision Date
1	Decision on objectives of MRS	Jan-91	Oct-92
2	Decision on the waste types, forms, characteristics, priority ranking of waste acceptance	Jan-91	Oct-92
3	Decision on exclusion criteria and minimum requirements for negotiations and screening potential MRS host(s)	Jan-91	Oct-92
4	Decision on design features and requirements for MRS SRF, MRS SFHB, and transportation	Jan-91	Oct-91
7	Decision on transportation technology for initial shipments	Jan-91	Nov-93
8	Decision on MRS Simple Receipt Facility (SRF) storage technology	Jan-91	Nov-93
9	Decision on MRS Spent Fuel Handling Building (SFHB) technology	Jan-91	Nov-93
10	Decision on additional types of waste for disposal in MGDS	Jan-91	Nov-99
11	Decision on cask loading, unloading, and waste handling interface requirements	Jan-91	Nov-93
12	Decision on dual purpose casks for other purposes than initial shipments	Jan-91	Nov-99
13	Decision on exploratory shaft facility configuration	Jan-91	Mar-91
14	Decision on development of over-weight truck (OWT) casks	Nov-91	Nov-99
15	Decision on non-standard spent fuel (NSSF) and components cask(s) requirements	Nov-91	Nov-93
16	Decision on unique from-MRS cask	Nov-91	Nov-93
17	Decision on selection of MRS site(s)	Sep-91	Sep-92
18	Decision on preferred MRS configuration	Jan-91	Nov-93
19	Decision on capacity, mix, and waste acceptance rate of MRS SRF and SFHB	Jan-91	Nov-93
20	Decision on type(s) and amount(s) of utility fee adjustments	Jan-91	Nov-93
21	Decision on final terms of agreement with MRS host(s)	Oct-91	Sep-92
22	Decision on final MRS functions and design requirements	Sep-92	Nov-93
23	Decision on Defense and West Valley high level waste (HLW) cask(s) requirements	Oct-92	Nov-2000
24	Decision on horizontal vs. vertical emplacement of waste packages	Oct-92	Nov-99
25	Preliminary decision on waste pickup schedule for reactors	Jan-91	Nov-93
27	Decision on MRS and transportation procedures for operations	Oct-91	Nov-93
28	Decision on non-compatible reactor loading problems caused by casks, equipment, waste forms and characteristics	Jan-91	Nov-93

TABLE 5.1. (contd)

System Decision	OCRWM First Tier System Decision	Earliest Decision Date	Latest Decision Date
35	Decision on potential transportation routes to MRS	Sep-91	Jan-94
36	Decision on heat load of waste packages	Oct-92	Nov-99
37	Decision on waste package and engineered barrier system design	Oct-92	Nov-99
38	Final decision on rod consolidation at MGDS	Oct-92	Nov-99
39	Decision on preferred MGDS configuration	Oct-92	Nov-99
40	Decision on capacity, mix, and waste emplacement rate for MGDS	Oct-92	Nov-99
41	Decision on final MRS throughput rate	Jan-91	Nov-99
42	Decision on final operational logistics for MRS and transportation	Sep-92	Jan-98
43	Decision on size of cask fleet	Sep-91	Sep-96
44	Decision on cask prototype development for other purposes than initial shipments	Jan-91	Feb-94
45	Final decision on waste pickup schedule for reactors	Nov-93	Jan-97
46	Decision on additional at-reactor storage problems	Jan-91	Nov-99
47	Decision on transportation routes from MRS to MGDS	Sep-91	Oct-99
48	Decision on transportation routes from reactors to MGDS	Jan-91	Oct-99
49	Decision on development of a second repository	Jan-91	Nov-99
50	Decision on reactor decommissioning problems	Jan-91	Nov-99
51	Decision on first repository site location	Jul-91	Oct-2004
X	Decision on waste management system contingency plans	Jan-91	Nov-99

After elimination of the excluded system decisions for "external", "design-specific", "element-level", "premature", and "undefined" characteristics, the remaining decisions from the Weston Analysis were assigned to groups within which there was a high technical commonality e.g., groups within which the decisions are (reasonably expected to be) dependent and between which they are reasonably independent.

The resulting "system decision groups" (SDGs) focus on key milestones or groups of milestones in system development. Group 1 (SDG1) is the definition of the MRS mission. This decision corresponds to the definition of functional requirements for the MRS and is regarded as essentially complete. Group 2 (SDG2) consists of design and operating requirements for the MRS. There are several pending decisions in this group. Group 3 (SDG3) consists of requirements definition for the from-reactor transportation function. While several decisions have been made in this area, and are embodied in the Initiative 1 cask acquisition program, several others remain. Group 4 (SDG4) decisions are those required in support of repository Advanced Conceptual Design. The group of related decisions on system operating reliability, lag storage, and cask fleet requirements was designated Group 5 (SDG5). These decision groups typically correspond to previously identified proposed systems studies.

Table 5.2 summarizes the result of screening and grouping the Weston decisions in this manner. The resulting decision groups were analyzed for schedule priority by defining a "study window" which spans the interval between the latest early decision date and the earliest late decision date, over all decisions in each group. Figure 5.1 summarizes the study windows derived for the five major decision groups (SDG1 through SDG5).

Both the topical content (list of decisions) and the study windows were used as input to defining the proposed studies presented in the next section.

TABLE 5.2. System Decisions and Major System Decision Groups

		System Decision Groups			
System Decision	OCRWM First Tier System Decision	Early Decision Date	Late Decision Date	System Decision Group	Proposed Study Area ^(a)
1	Decision on objectives of MRS	Jan-91	Oct-92	SDG1	
2	Decision on the waste types, forms, characteristics, priority ranking of waste acceptance	Jan-91	Oct-92	SDG2	
4	Decision on design features and requirements for MRS SRF, MRS SFHB, and transportation	Jan-91	Oct-91	SDG2/SDG3	
19	Decision on capacity, mix, and waste acceptance rate of MRS SRF and SFHB	Jan-91	Nov-93	SDG2	MDR
22	Decision on final MRS functions and design requirements	Sep-92	Nov-93	SDG2	MDR
41	Decision on final MRS throughput rate	Jan-91	Nov-99	SDG2	MDR
11	Decision on cask loading, unloading, and waste handling interface requirements	Jan-91	Nov-93	SDG3	FRTRA
14	Decision on development of over-weight truck (OWT) casks	Nov-91	Nov-99	SDG3	FRTRA
15	Decision on non-standard spent fuel (NSSF) and components cask(s) requirements	Nov-91	Nov-93	SDG3	FRTRA
28	Decision on non-compatible reactor loading problems caused by casks, equipment, waste forms and characteristics	Jan-91	Nov-93	SDG3	FRTRA
44	Decision on cask prototype development for other purposes than initial shipments	Jan-91	Feb-94	SDG3	FRTRA
23	Decision on Defense and West Valley high level waste (HLW) cask(s) requirements	Oct-92	Nov-2000	SDG4	RDR
40	Decision on capacity, mix, and waste emplacement rate for MGDS	Oct-92	Nov-99	SDG4	RDR
43	Decision on size of cask fleet	Sep-91	Sep-96	SDG5	RAM

- (a) MDR - MRS Design Requirements
 FRTRA - From-Reactor Transportation Requirements Analyses
 RDR - Repository Design Requirements
 RAM - Reliability, Availability, and Maintainability Requirements

TABLE 5.2. (contd)

Excluded System Decisions				
System Decision	OCRWM First Tier System Decision	Early Decision Date	Late Decision Date	Excluding Characteristic(s)
7	Decision on transportation technology for initial shipments	Jan-91	Nov-93	Design
8	Decision on MRS Simple Receipt Facility (SRF) storage technology	Jan-91	Nov-93	Design
9	Decision on MRS Spent Fuel Handling Building (SFHB) technology	Jan-91	Nov-93	Design
18	Decision on preferred MRS configuration	Jan-91	Nov-93	Design
24	Decision on horizontal vs. vertical emplacement of waste packages	Oct-92	Nov-99	Design
36	Decision on heat load of waste packages	Oct-92	Nov-99	Design
37	Decision on waste package and engineered barrier system design	Oct-92	Nov-99	Design
39	Decision on preferred MGDS configuration	Oct-92	Nov-99	Design
27	Decision on MRS and transportation procedures for operations	Oct-91	Nov-93	Element Level
42	Decision on final operational logistics for MRS and transportation	Sep-92	Jan-98	Element Level
35	Decision on potential transportation routes to MRS	Sep-91	Jan-94	Element level, Premature
3	Decision on exclusion criteria and minimum requirements for negotiations and screening potential MRS host(s)	Jan-91	Oct-92	External
12	Decision on dual purpose casks for other purposes than initial shipments	Jan-91	Nov-99	External
13	Decision on exploratory shaft facility configuration	Jan-91	Mar-91	External
17	Decision on selection of MRS site(s)	Sep-91	Sep-92	External
20	Decision on type(s) and amount(s) of utility fee adjustments	Jan-91	Nov-93	External
21	Decision on final terms of agreement with MRS host(s)	Oct-91	Sep-92	External
46	Decision on additional at-reactor storage problems	Jan-91	Nov-99	External
51	Decision on first repository site location	Jul-91	Oct-2004	External
10	Decision on additional types of waste for disposal in MGDS	Jan-91	Nov-99	External, Premature
16	Decision on unique from-MRS cask	Nov-91	Nov-93	Premature
38	Final decision on rod consolidation at MGDS	Oct-92	Nov-99	Premature
45	Final decision on waste pickup schedule for reactors	Nov-93	Jan-97	Premature
47	Decision on transportation routes from MRS to MGDS	Sep-91	Oct-99	Premature, Element Level
48	Decision on transportation routes from reactors to MGDS	Jan-91	Oct-99	Premature, Element Level
49	Decision on development of a second repository	Jan-91	Nov-99	Premature, External
25	Preliminary decision on waste pickup schedule for reactors	Jan-91	Nov-93	Premature, "Done"
50	Decision on reactor decommissioning problems	Jan-91	Nov-99	Undefined
X	Decision on waste management system contingency plans	Jan-91	Nov-99	Undefined

FIGURE 5.1. System Decision Windows by System Design Group

6.0 PROPOSED SYSTEMS STUDIES PLAN FOR FY 1991 AND FY 1992

This section sets forth those studies which are recommended to be conducted in Fiscal Years 1991 and 1992. In most cases the content of a single study includes many discrete system decisions as discussed in the previous section. The objectives, scope, and key issues within each study are briefly described. The "plan" for conducting these studies consists of a recommended sequence for their conduct, the use of information that will be available from currently ongoing studies, and recommendations for supporting (e.g., modeling, data collection, development) activities that should accompany the studies. These items are addressed in the plan summary--Section 6.2.

6.1 RECOMMENDED STUDIES

6.1.1 Repository Evaluation of Increased Aggregate Receipt Rate

Studies conducted during FY90 showed a significant (roughly \$1.0 billion) incentive for repository replacement at a rate of 6,000 MTU/year. The studies assumed that many sub-functions inherent in repository operations (e.g., ventilation, handling of excavated materials, waste handling, etc.), and their associated costs, would increase according to an assumed set of scaling factors. These scaling factors incorporate the best available knowledge from a single repository design [i.e., - The Site Characterization Plan Conceptual Design (Sandia 1987)]. As such, they do not reflect a detailed analysis of the design response that could be required. Such an analysis is essential prior to changing the emplacement rate requirement to 6,000 MTU.

A required supporting analysis for this study will be the characterization of spent fuel at time of emplacement for the 6000 MTU/year (and perhaps other intermediate) scenarios. This scenario could be easily modeled with the Waste Stream Analysis model using selection rules similar to those already developed in Task 8, and is not included as a separate study in the Plan.

While repository design issues are generally lower priority than MRS design issues from a schedule perspective, the resolution of the emplacement rate requirement is deemed a high priority since it directly affects the length of the storage cycle required at an MRS, and potentially other MRS

design requirements. If this study confirms that a 6000 MTU emplacement rate is feasible from an operational and design perspective, additional studies on design details may be required prior to initiation of repository advanced conceptual design. This study supports decision groups 2 and 4 - MRS and repository design requirements.

6.1.2 Retrievability Requirements Study

Section 60.111 of 10 CFR 60 requires that spent fuel and high-level waste emplaced in a geologic repository be retrievable for a period of fifty years following the initiation of emplacement. There are no performance criteria associated with this functional requirement, and the range of potential retrieval scenarios covers a wide range in terms of disruption to repository operation, materials handling requirements, storage requirements, and cost.

If the retrievability requirement were to be exercised, key questions would include the rate at which retrieval is required, the volume of spent fuel and high level waste required to be stored after retrieval, where to store it, and the conditions under which this storage would be implemented. Some retrieval scenarios would allow continued operation of the repository while some would clearly preclude it. The surface storage limit at the repository, currently set at 750 MTU, conflicts with some potential retrieval scenarios. This conflict results in an issue of whether another facility is required for storage after retrieval, or is the 750 MTU storage limit considered applicable for all scenarios.

Based on a review of requirements by the Functional/Physical Analysis Task Force, a study to define this requirement in operational terms has been recommended. This study would involve developing a taxonomy of events which could lead to retrieval decisions, characterizing the required response to selected groups of these scenarios, and recommendation, if possible, of a reference retrieval scenario for use as part of the repository design basis.

6.1.3 MRS Design and Operating Requirements Study

The linkage between MRS operation and repository licensing, as set forth in the amended NHPA, will not meet the requirement for early acceptance of spent fuel under current repository schedules. The need to petition Congress

for relaxation of the schedule constraint is incorporated in current program strategy (Program Cost and Schedule Baselines) and planned for July 1992. Additional features of MRS design and operation, including the maximum capacity, design storage cycle, and operating life, are important inputs for Title I MRS design. The costs of the facility have been shown to be sensitive to some of these features, even within the context of a single design approach (Radin et al. 1989).

The number of possible operational envelopes for the MRS facility is large. (The MRS system study began with 2000 cases.) The strategy previously adopted for MRS design was to allow for almost any operational eventuality or combination of spent fuel receipts in the specification of facility design requirements. This results in "demanding" requirements for the facility, e.g., very hot design basis fuel, high operating reliability, capacity to process high fractions of BWR and truck receipts, etc. Both cost incentives and the probable need to be more specific concerning MRS operations during host state negotiations argue for tighter definition of this operational envelope.

While the simulation approach to systems analysis (as exemplified by SIMS) requires a great deal of calculation and many detailed assumptions to analyze this type of question, an alternative approach is available. This approach treats the design and operating requirements of the MRS as variables rather than assumptions, and seeks a least-cost operational scenario based on the assumed unit costs of various processing, transport, and storage operations, subject to various constraints on storage capacities, flow rates, etc.

This approach utilizes a network optimization algorithm and has been utilized extensively in transportation program analysis with the TRICAM model. The application of this model to the MRS requirements problem was demonstrated in a scoping study at PNL and BCL during FY90 (Wood et al. 1991). The network optimization approach can be used in a totally unconstrained fashion to guide RW policy on MRS design and deployment, or incorporating various policy or technical constraints as appropriate. In the former application, the set of MRS requirements (capacity, life cycle, annual receipts) that result represent an economically optimal MRS deployment plan. Constraints on various features,

including storage capacity, schedule, etc., can also be analyzed to examine the best operational policy for a given set of constraints. This allows assessment of any change in program constraints that may be imposed during host state or congressional negotiations, without repeating analysis for a large number of scenarios which span the possible ranges of values for all related assumptions.

Results of this study would be a comprehensive set of MRS operational requirements for use as design basis. These would include: operational rate, facility storage capacity, facility design life, storage module design life, annual throughput requirements, maximum annual % rail and truck receipts, maximum annual % PWR and BWR receipts, storage cycle statistics (distribution of residence times), and bounds for SNF characteristics at time of receipt.

6.1.4 MRS Infrastructure Requirements Review

The infrastructure, or site support systems, for the full-scale MRS facility described in the 1988 MRS action Plan Task B report (Woods et al. 1988) is estimated to cost at least \$500 million. For an MRS facility with limited storage capacity (~15000 MTU), this represents almost half of the total life cycle cost of the facility, and significantly influences the economic viability of the facility.

There is some question as to the MRS functional design requirements in relation to the basic FWMS function - Store Waste. Should it include pre-emplacement storage and repository retrieval storage? Is storage provided by a separate facility or by a part of the MRS site support facilities?

This activity is proposed as a follow on to or a part of the Physical System Requirements/Functional Analysis: Store Waste. It would review the MRS functional design requirements, along with the specific site support elements and costs that meet these requirements for the assessment design, to ascertain if there are requirements which can be reformulated to provide less costly site support facilities while preserving the safety and security of the facility.

This activity is not a systems study in the sense of involving simulation modeling, cost estimation, etc., but is regarded as a key supporting activity in system development.

6.1.5 Feasibility Evaluation and Development Requirements Study - Cask to Cask SNF Transfer Equipment

Several potential applications have been identified for cask-to-cask spent fuel transfer equipment that could be employed outside of a spent fuel pool or hot cell. Such equipment would provide for a method to handle leaking transportable storage casks at a shutdown reactor, thus allowing the spent fuel pool (and thus the reactor building) to be decommissioned. This equipment would allow for service (via a small transfer cask) to those reactors at which infrastructure may prevent direct loading of some larger transport cask designs. If available, this equipment might also be employed for routine-duty direct transfer from storage-only casks to transport casks during periods when an operating pool was otherwise occupied. Cask-to-cask transfer equipment has also been proposed (Wood et al. 1990) as an option for use at an MRS, prior to the time that hot cell capability is available.

Since there are several possible diverse applications for essentially the same set of functional requirements, a system-level analysis of these applications is proposed. This study would formulate scenarios for cask-to-cask transfer in each of the potential applications, and derive sets of functional and physical interface requirements in each application, based on current designs for transport casks, MRS storage casks, and at-reactor storage-only casks. A general functional requirements hierarchy developed by EPRI (Jones 1989) could be adapted as a framework for functional requirements.

These three or more sets of requirements could be integrated into a single set of requirements if sufficiently similar, and a preliminary design concepts analysis could be used to determine if separate types of equipment should be developed for each application.

A systems analysis could then determine the economic incentive for cask to cask transfer in each application. Based on the results of this analysis and the preliminary design concepts analysis, the study would make recommendations on the following decisions;

- should OCRWM develop technology for cask-to-cask transfer of spent fuel for
  - safety backup at shutdown reactor sites?
  - routine transfer of dry stored fuel to transport casks?
  - fuel transfers at a phase 1 MRS?
- Should this development be integrated or specialized to each feasible application?
- What are the functional and physical interface requirements for the recommended development programs, in terms of
  - Design basis fuel population?
  - Transfer efficiency (throughput)?
  - Design basis cask population (or dimensional envelope)?
  - transportability of equipment?
  - development schedule?

6.1.6 Evaluation of Intra-Year Variation in Spent Fuel Receipts

This is a data-definition study which provides necessary input to several systems decisions (via their associated studies). The central question is the extent to which seasonal bias in spent-fuel loading schedules at reactors, acting together with nominal uncertainty in transport and receipt operations, creates special lag storage, cask fleet, or processing rate requirements at a receiving facility. This study is defined separately from the MRS operational requirements analysis since it requires an operational simulation approach. The data produced in this study is an input to the Reliability Requirements/Lag Storage Study (see Section 6.1.7).

The study would use data from FICA, Task 8, and projected reactor operating cycles to project the intra-year distribution of spent fuel receipts at a DOE facility, characterizing the statistical distribution (quantity) of SNF receipts by type and transport mode, by day, week, month, and year.

6.1.7 System Reliability Requirements/Lag Storage Study

As summarized in Sections 4.2 and 4.7, the topics of operating reliability, lag storage capability, and cask fleet size are intimately related. This group of issues is also closely related to the operational reliability and seasonality of the spent fuel loading process, as described in Section 6.1.6. After characterization of the short-term and seasonal variation expected in the fuel loading process, and the completion of the current RAM requirements study, a study should be initiated to determine the values of any specific numerical reliability requirements for an MRS facility and the transport function.

This study would also determine the lag storage requirement and cask fleet size consistent with these reliability levels and the reliability of the (at-reactor) cask loading function. If specific system-level reliability goals are not required, the evaluation of variation in the loading process and the MRS availability requirements would be used as boundary conditions for an analysis of cask fleet size requirements.

6.1.8 From-Reactor Transport Requirements Analysis

This study is proposed as a comprehensive review of technical requirements for the from-reactor transportation system, leading to decisions on development of Initiative I casks and specific requirements for Initiative II casks. This study has been identified as a systems-level analysis due to the technical linkages between the technology selected for MRS storage, the deployment schedule and phasing for an MRS, and the from-reactor transport capability available for the first years of system operation. System decisions supported by this study are those in Group 5 - the development of OWT casks, the development of NFBC casks, and the development of TSC's. Background and summary description for some of the key technical questions follows.

Initiative I casks include a rail-barge design and a legal-weight truck design. The design basis for Initiative I casks included a specification of fuel designs, gross weights, dimensional limits, and average spent fuel

characteristics, but excluded consideration of reactor-handling capabilities and the probable variance in spent fuel characteristics.

This decision would be based on an analysis of cost incentives and institutional issues for postulated OWT designs. This analysis would make use of the FICA study data on reactor cask-handling capabilities.

Preliminary results (final results from the FICA are not available currently) from the RSPE analysis indicate that six reactor sites cannot be served with the existing cask designs. Even legal-weight truck casks at 25 tons exceed the estimated capabilities of these sites. An evaluation of the extent to which current designs will mesh with reactor capabilities would reveal the need to adapt existing designs and/or negotiate for upgrades in handling capabilities at specific sites. Another option for use at these reactors is a transfer cask system, in which a small transfer cask capable of handling in the reactor building is mated to a transportation cask, which is not then necessarily required to be handled in the pool area.

The issue of cask fleet efficiency - the number of casks required for a given spent fuel acceptance scenario - is not one which requires an immediate decision from the cask fleet development perspective, since orders for cask fleet fabrication are at least 3-4 years away. This issue is an important assumption in systems studies which will evaluate receiving and handling processing rate requirements and reliability, and the lag storage requirement which results from the interaction of these two sets of factors. For this reason, an analysis of the cask fleet requirements is proposed to be conducted as part of the RAM/Lag storage study (see 6.1.8).

The results of this study would be 1) determination of cask requirements as a function of time, 2) specification of any constraints on spent fuel selection rules consistent with the assumed cask-loading schemes, and 3) specification of "residual" spent fuel characteristics - e.g., that SNF which would require delay in acceptance using the current cask designs.

A very limited study of the requirement for intermodal transfer facilities is proposed as an input to the From-Reactor-Transport Requirements Analysis. This study would examine the economic and/or safety incentives for

intermodal transfer, either cask-to-cask or utilizing heavy haul to a rail-head. While essentially a transportation element level analysis, this study is defined separately from the general From-Reactor Requirements Analysis and it involves the use of cask-to-cask transfer technology, a topic common to several potential applications. An early determination of the need to consider this particular application could simplify the cask-to-cask technology development study.

6.2 PLAN SUMMARY

Figure 6.1 illustrates proposed systems studies for Fiscal Years 1991 and 1992, their recommended timing, and their relations to one another, current studies, and major program milestones. In general, only those studies supporting MRS design requirements are recommended for immediate initiation. Even in these cases, the currently planned start of MRS conceptual design cannot be supported with revised design and operating requirements. The output of these studies is scheduled to be available for the planned start of MRS Title I design in October 1991. These studies are also scheduled to provide information on the potential benefits of various MRS configurations during the time when potential MRS host state negotiations are in progress, if such information is required by the negotiator.

Figure 6.2 illustrates the relations between the proposed system studies and the decision windows for the five major decision groups derived in Section 5.0. The studies are grouped with the decision groups they are designed to support, and the relative timing is illustrated. As shown here, the proposed system studies schedule is generally a conservative one, with studies occurring early in or before the associated decision windows.

In the case of SDG 2, however, the decision window is closing relatively quickly, and the proposed studies schedules are tight. Two critical milestones in the development of the MRS are the initiation of Title I design for the Simple Receipt Facility (SRF) and the Spent Fuel Handling Building (SFHB) to begin the first quarter of FY 1992. Both facility designs need input from

the MRS Design and Operational Study (MDORS), MRS Infrastructure Requirements Analysis (MIRA), and the Reference System(s) Description for NFBC Handling/Transport Study (NFBCS).

FIGURE 6.1. Plan Summary - Recommended Studies and Their Relations to Program Milestones and Current Studies

FIGURE 6.2. System Study Schedule and Related Decision Windows

7.0 REFERENCES

Casper, R. M., D. M. Collier, W. J. Lee, and J. V. Houston. 1989. Evaluation of Potential Benefits of Transportable Storage Casks. Final Report, Research Project 2717-8, EPRI-NP-6375, Nuclear Assurance Corporation, Norcross, Georgia.

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E. R. Johnson Associates, Inc. (JAI). 1990b. Acceptance of Spent Nuclear Fuel in Multiple Element Sealed Canisters by the Federal Waste Management System. JAI-314, ORNL/Sub/86-SA094/6, March 1990, Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

E. R. Johnson Associates, Inc. (JAI). 1990c. Classification of Spent Nuclear Fuel (SNF), JAI-334, ORNL/Sub/89-SD841/1, March 1990, Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

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McKee, R. W., J. R. Young, and G. J. Konzek. 1991. System Description of the Basic MRS System for the FY 1990 Systems Integration Program Studies. PNL-7508, Pacific Northwest Laboratory, Richland, Washington.

Radin, A., D. E. Klein, F. L. Parker, and J. A. Axelrad. 1989. Nuclear Waste: Is There a Need for Federal Interim Storage? Final Report prepared by the Monitored Retrievable Storage Review Commission, November 1, 1989, Washington, D.C.

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U.S. Department of Energy (DOE). 1991a. Physical System Requirements/Functional Analysis. Office of Civilian Radioactive Waste Management, Washington, D.C.

U.S. Department of Energy (DOE). 1991b. Physical System Requirements/Functional Analysis: Overall System. Office of Civilian Radioactive Waste Management, Washington, D.C.

Woods, W. D., A. K. Jowdy, C. H. Keehn, R. M. Gale, and R. I. Smith. 1988. MRS Action Plan Task B Report: Analysis of Alternative Designs and Operating Approaches for a Monitored Retrievable Storage Facility. PNL-6770, Prepared by Ralph M. Parsons Company of Delaware for Pacific Northwest Laboratory, Richland, Washington.

Wood, T. W., D. G. Dippold, S. R. Rod, S. M. Short, and J. W. Williams. 1991. Rethinking the Economics of Centralized Spent Fuel Storage. PNL-SA-18782, January 1991, Presented at Second Annual High-Level Radioactive Waste Management Conference, Las Vegas, Nevada, April 28 - May 3, 1991.

APPENDIX

SYSTEM STUDY ABSTRACTS

APPENDIX

SYSTEM STUDY ABSTRACTS

1. Altenhofen, M. K., N. L. Seigny, K. I. Johnson, and R. E. Graves. 1987. The Impact of Spent Fuel Age and Exposure on Waste Package and Repository Area Thermal Loads. Draft Letter Report, Pacific Northwest Laboratory, Richland, Washington.

The effects of emplacing 5-, 10-, and 15-year-old pressurized-water reactor (PWR) spent fuel on waste package and repository area thermal loads in basalt, salt, and tuff geologic media were evaluated to determine the impact of spent fuel age and exposure on allowable waste package and repository area thermal loads. Separate methodologies were used to analyze waste package thermal loads and repository area thermal loads, and the results of the independent analyses were integrated to estimate the allowable waste package/repository area thermal design envelope for each spent fuel type and repository medium combination. In the results from the study, fuel age and exposure are shown to be significant in terms of their impact on allowable waste package and repository area loads when constrained by near-field host rock temperature. When the waste package and repository area loads are constrained by host rock temperature, their sensitivity to age and exposure is significantly influenced by the waste package and emplacement strategy chosen.

2. Brentlinger, L. A., S. Gupta, A. M. Plummer, L. A. Smith, and S. Tzemos. 1989. MRS Systems Study, Task F: Transportation Impacts of a Monitored Retrievable Storage Facility. BMI/OTSP-07, Office of Transportation Systems and Planning, Battelle Nuclear Systems Group, Columbus, Ohio.

Provisions of the Nuclear Waste Policy Amendments Act of 1987 (NWPAA) focused repository site characterization solely at Yucca Mountain, Nevada; authorized a monitored retrievable storage (MRS) facility with specific links to the repository; and established an MRS Review Commission. These provisions affected the configuration of major elements of the Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) waste system (which consists of the repository, MRS, and waste transportation). This report documents resulting differences in transportation costs and radiological doses in hypothetical waste management systems with and without an MRS. The analysis is limited to the effects of activities related directly to the hauling of high-level radioactive waste (HLW), including the capital purchase and maintenance costs of the transportation cask system. Loading and unloading effects are not included in this study because they are treated as facility costs in other task reports.

3. Casper, R. M., D. M. Collier, W. J. Lee, and J. V. Houston. 1989. Evaluation of Potential Benefits of Transportable Storage Casks, Final Report, Research Project 2717-8. EPRI-NP-6375, Nuclear Assurance Corporation, Norcross, Georgia.

A cash-flow methodology was developed to compare various spent-fuel management system scenarios and evaluate the use of transportable storage casks. The scenarios were taken from H&R/JAI 1987, with cost parameters modified to those of Nuclear Assurance Corporation (NAC). These scenarios considered spent fuel management including spent fuel storage at generating power reactors; rail shipment to an MRS facility; lag storage (of intact fuel), fuel consolidation, and interim storage (of consolidated fuel) at MRS; and rail transport of consolidated fuel from MRS to a repository. Except for the interim storage at MRS (assumed to be in concrete casks) metal casks were used for all storage and transportation functions. Handling and disposition of NF8C hardware from consolidation were not considered. Cost differences arose primarily from alternative use of shipment-only casks (SOCs), transport-only casks (TOCs) and transportable storage casks (TSCs) for the various functions. Costs were calculated as net present values of total lifetime costs, assuming discount rates of 0%, 3%, 5%, and 10% per year. The base case assumed use of both SOCs and TOCs but no TSCs. Indicated costs for the "best" TSC case ranged from \$39 million less than the base case at 10% discount to \$175 million less at 0%. These differences indicated savings of about 13% compared to the base case. The report concludes that potential cost savings and reduced handling of spent fuel and casks can be obtained with integrated use of TSCs.

4. Clark, L. L., and S. M. Short. Preferred Repository Receipt Rates Based on Waste Management System Costs, Risk and Logistics Impacts. 1986. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

Alternative receipt rates for the first high-level radioactive waste repository are evaluated in this study by comparing waste heat rates, system logistics, and system costs under a variety of scenarios in order to determine an optimum receipt capacity. Conclusions of the study were that the repository facility design capacity should be in the range of 4000 MTU/year because 1) a larger facility provides flexibility to accommodate uncertainties and to optimize operating strategy and 2) total systems costs are not very sensitive to receipt rate variations between 2200 to 4000 MTU/year.

5. Clark, L. L., A. L. Doherty, R. W. McKee, and S. M. Short. 1986. Interim Report on Preferred Repository Acceptance Rates Based on Spent Fuel Thermal Characteristics. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

The cost of storing, transporting, and receiving spent fuel at the first two high-level waste repositories may be significantly reduced by additional cooling of spent fuel before it is emplaced. Two methods for reducing the heat generation rate of spent fuel were examined in this

study. The first method was to reduce the acceptance rate for the repositories, which would decrease the average age and the average heat generation of spent fuel accepted for disposal. The second method of heat rate reduction would be to reschedule the startup date of the second repository, which would increase the average age and reduce the average heat generation rates of spent fuel accepted for disposal. This report concluded that reducing spent fuel heat generation rate by either of the two methods could reduce waste management system costs by approximately \$500 million to \$1 billion.

6. Clark, L. L., and R. S. Myers. 1989. MRS Systems Study Task I Report: Waste Management System Reliability Analysis. PNL-6875, Pacific Northwest Laboratory, Richland, Washington.

This study evaluates the relative reliability of monitored retrievable storage (MRS) in high-level radioactive waste management systems by examining two systems: one with both repository with MRS storage and one with repository storage only. The report concludes that MRS enhances waste system reliability because it has fewer potential technical problems such as unanticipated geologic characteristics to delay or interrupt waste acceptance; MRS provides adequate surface storage to accommodate repository construction and startup delays; a repository with MRS has two acceptance facilities; and an MRS system could continue to accept waste for up to a year after a major disruption of emplacement operation at the repository.

7. Dabat, R., G. Merle, and C. Bonnet. 1988. Large-Scale Spent Fuel Cask Dry Unloading at La Hague. COGEMA-SGN, France. Presented at American Nuclear Society Winter Meeting, San Francisco, California, November 26-30, 1989.

This paper describes a dry unloading facility for unloading of spent fuel shipping casks, which was added in 1986 to the COGEMA reprocessing plant at la Hague. The facility was designed to unload 800 MTU of fuel (200 casks) per (215-day) year. The unloading facility includes a cooling well to reduce the temperature of incoming fuel prior to its placement in a storage basin. The design, R&D, initial operating results for the unloading facility are discussed. The facility, initially placed in service in 1986, attained rated capacity in 1989. During 1988, when 157 casks were unloaded (about 75% rated capacity), average annual occupational dose within the facility was 50 mrem. Unloading of a typical cask (TN-12) filled with 12 PWR fuel assemblies requires about 60 hours; for 32 BWR assemblies in the same cask, about 80 hours are required for unloading.

8. Daling, P. M., J. C. Lavender, and S. A. Nilson. 1987. SYSRISK: A Spreadsheet-Based Model for Evaluating Waste Management System Risk Tradeoffs. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

A spreadsheet-based model called SYSRISK has been developed to perform systematic tradeoff studies of the spent fuel and high-level waste management system. The model evaluates the risk tradeoffs for postulated alternative system configurations, component and facility designs, and system operating strategies. SYSRISK evaluates three categories of radiological risk: public routine exposures, public accident risks, and occupational routine exposures. Risk relationships are programmed into the model function-by-function. At-reactor spent fuel management, transportation, MRS facility, and repository operations are each analyzed in the model, and interactions among the various components of the system are accounted for.

9. Daling, P. M., et al. 1990. Preliminary Characterization of Risks in the Nuclear Waste Management System Based on Information in the Literature. PNL-6099, Pacific Northwest Laboratory, Richland, Washington.

This report presents preliminary information on the radiological and nonradiological risks in the nuclear waste management system, which is currently expected to be developed by the Department of Energy (DOE). The study reviewed literature containing information on risks in the waste management system and used the information to develop preliminary estimates of the potential magnitude of these risks. The study assessed risks at the repository, the integral monitored retrievable storage (MRS) facility, and the transportation system that supports the repository and the MRS facility. The study addressed a wide range of risk categories over the facility life-cycle phases of construction, operations, decommissioning, repository retrieval, and repository postclosure performance. Although the study was not comprehensive, its preliminary conclusions were that risks in the waste management system are small, there are fewer radiological risks in the system than nonradiological risks, and there are fewer risks to the public than to the waste management system workers.

10. Daling, P. M., P. J. Pelto, and J. A. McBride. 1986. Preliminary Assessment of OCRWM Risk Assessment Activities. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

At present, probabilistic risk assessments (PRAs) are only required to evaluate the postclosure performance of high-level waste repositories. However, radiological and nonradiological impact analyses are required to support repository licensing, design, and operating decisions. And states and the public have requested detailed risk assessments for transportation, monitored retrievable storage, spent fuel rod consolidation, and others. This study discusses potential requirements and needs for risk assessment and presents a survey of past and ongoing research programs that are doing PRAs for waste management facilities or that are developing data applicable to PRAs. Finally, this study identifies potential risk assessment needs that are not currently being addressed.

11. Dippold, D. G., K. L. Basinger, P. L. Hofmann, and S. Tzemos. 1990. Selection of Spent Nuclear Fuel for Transport: A Comparison of Optimal and Non-optimal Rules. Project Technical Memorandum. Office of Transportation Systems and Planning, Battelle Energy Systems Group, 505 King Avenue, Columbus, Ohio. Limited Distribution Document.

The Department of Energy's Standard Contract for Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste (10 CFR 961) requires that priority for acceptance of spent nuclear fuel from a utility be based on age of the fuel since discharge from a reactor, with oldest fuel being accorded the highest priority. However, 10 CFR 961 is ambiguous in its reference to the way in which specific spent fuel assemblies are to be selected by utilities for transport, at a given time, to an MRS facility or a repository for disposal. Specific patterns of spent fuel selection can have differing effects on costs to the utilities, to DOE's costs of transport, and to the costs of the waste management system as a whole. Costs to DOE are highly dependent on being able to ship casks completely filled with fuel to the maximum extent possible. Cask capacities are limited by weight and geometric considerations. In addition, if very "hot" (highly radioactive) fuel assemblies are shipped, reduction of the loading of a cask may be needed to meet limits on radiation levels near the cask. The analysis reported herein considered five separate fuel allocation (priority-setting) scenarios, including the "oldest-fuel-first" scenario of 10 CFR 961. For each scenario, six selection "rules", or methodologies, for selection of specific fuel assemblies were analyzed, and the total number of cask shipments required for transport of 63,000 MTU of spent fuel was estimated using operations analysis techniques (including calculations of cask "deratings" required when "hot" assemblies were shipped). The total "lifetime" shipments were considered a measure of total lifetime shipping costs. Selection rules evaluated were ranked according to minimization of DOE shipping costs, and recommendations to DOE on potential contract changes to reduce DOE costs were made.

12. E. R. Johnson Associates, Inc. 1989a. Acceptance of Failed SNF Assemblies by the Federal Waste Management System. JAI-325, ORNL/Sub/86-SA094/5. Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

The standard contract between utilities and the Department of Energy (DOE) for disposal of spent nuclear fuel (SNF) provides for disposal of standard fuel, non-standard fuel, and failed fuel. Failed fuel is generally of three types: fuel with visual failure or damage, fuel with radioactive leakage, or fuel that is encapsulated. DOE may defer accepting failed fuel or, if DOE determines that failed fuel has been improperly classified by the utility, the entire delivery schedule may be held in abeyance until such fuel is properly reclassified. However, some issues about waste acceptance criteria and scheduling of receipt of SNF require clarification: the definition of failed fuel and a method to determine if a given SNF assembly constitutes failed fuel and the rationale for delaying acceptance of failed fuel. In response to these

issues, this report had the objectives of 1) establishing a quantitative definition of failed fuel, 2) obtaining estimates of the amount of failed fuel that might be delivered to DOE and the nature of the failures involved, 3) estimating the handling and cost impacts of receiving failed fuel in order to identify the extent to which delaying acceptance of failed fuel could be functionally justified, and 4) providing recommendations for failed SNF waste acceptance criteria.

13. E. R. Johnson Associates, Inc. 1989b. Supplement to ORNL/Sub/86-SA094/1 on Use of Transportable Storage Casks in the Nuclear Waste Management System. JAI-315, ORNL/Sub/86-SA094/4. Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

A report titled Use of Transportable Storage Casks in the Nuclear Waste Management System contained an analysis of the use of transportable storage casks (TSCs) and storage-only casks (SOCs) in the utility and the Department of Energy (DOE) spent fuel management systems. Subsequently, a supplemental study was performed on this subject in order to determine whether and under what circumstances a loaded TSC or SOC might be acceptable to DOE as a deliverable waste form under the Standard Contract between DOE and the utilities for spent nuclear fuel disposal. This report describes the supplemental study and its results and develops a composite summary of the results of both studies.

14. E. R. Johnson Associates, Inc. 1989c. Acceptance of Canisters of Consolidated Spent Nuclear Fuel by the Federal Waste Management System. JAI-322, ORNL/Sub/86-SA094/7. Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

The standard contract between utilities and the Department of Energy (DOE) for disposal of spent nuclear fuel (SNF) provides for disposal of standard fuel, non-standard fuel, and failed fuel. However, fuel forms other than standard fuel may be subject to delayed acceptance because of special handling that may be necessary. Among the types of non-standard fuel is consolidated fuel rods. Some utilities are interested in consolidating spent fuel in order to increase the capacity of their reactor storage pools and there have been some demonstration consolidation projects. This report is the result of a study that was conducted to estimate the cost and handling impacts on the Federal Waste Management System that might result from accepting reactor-consolidated fuel; the study was done in order to identify the extent to which delayed acceptance of this fuel could be justified.

15. E. R. Johnson Associates, Inc. 1990. Supplement to ORNL/Sub/86-SA094/1 on the Use of Transportable Storage Casks in the Nuclear Waste Management System. ORNL/Sub/86-SA094/4 (JAI-315). Prepared for Oak Ridge National Laboratory by E. R. Johnson Associates, 10461 White Granite Drive, Suite 204, Oakton, Virginia.

As the title indicates, this report is an update of H&R/JAI 1987 (ORNL/Sub/86-SA094-1), which assessed the use of transportable storage casks for spent fuel storage and transport in the Federal Waste Management System, and of a supplemental study expanding on the results of the 1987 study. The current update principally brings into account the introduction of horizontal storage modules (HSMs), utilizing multi-element sealed canisters (MESCs); updates of costs, utility storage situations, and the requirements for and characteristics of the federal waste management system, are also included. Storage alternatives considered in the study are transportable storage casks, storage-only metal casks, vertical concrete casks, and horizontal storage modules. The report concludes that storage of spent fuel at-reactor will be more costly in TSCs and SOC's than in modular concrete units. Use of TSC and SOC's at reactors can benefit the Federal waste management system overall, but only for a limited number of TCS/SOC's, and only if they are delivered early in the receiving cycle, to eliminate the need for purchasing additional shipping casks. Alternatives for recompensating utilities providing TSCs for the "premium" costs paid for their use in at-reactor storage are discussed.

16. H&R Technical Associates, Inc. and E. R. Johnson Associates, Inc. 1987. Use of Transportable Storage Casks in the Nuclear Waste Management System. ORNL/Sub/86-SA094/1. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This study was done to determine whether transportable storage casks (TSCs) and storage-only casks (SOCs) that might be used to transport spent nuclear fuel to the Department of Energy (DOE) on a one-time basis were viable for use in the Federal Waste Management System. The viability of using TSCs and SOC's was evaluated in terms of the cost and savings of using them, the sensitivity of these costs and savings to changes in the capacity and fabrication cost of the casks, the effects of variation in cask design on cost and radiation exposure of personnel, and their prospective use in the transport of defense high-level wastes. The study concludes that a limited number of TSCs or SOC's in specific situations could be used cost effectively and makes recommendations for further decisions about their use.

17. Fisher, F. H., and P. M. Daling. 1986. Reliability, Availability and Maintainability (RAM) Plan in Support of the Nuclear Waste Systems Integration (NWSI) Program. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

One task of the Nuclear Waste Systems Integration (NWSI) program is to analyze the reliability, availability, and maintainability (RAM) for the Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCWRM) baseline and alternative nuclear waste management systems. This report discusses the value of a comprehensive RAM plan in evaluating and implementing alternative configurations and/or deployment strategies for the waste management system. It also includes a detailed description of RAM activities planned for FY 1986, and it emphasizes

analysis of the major elements of the waste management system to determine the impacts of RAM on the system's ability to accept and process nuclear waste as a function of waste acceptance commitments. The appendix describes recommended activities and analytical techniques involved in a RAM program for a large-scale project.

18. Jackson, M. E. 1989. Monitored Retrievable Storage Systems Study, Task H: Licensing. BMI/OWTD-4, Office of Waste Technology Development, Battelle Nuclear Systems Group.

This report is the eighth in a series of ten studies on monitored retrievable storage (MRS) that the Department of Energy (DOE) requested in its "Action Plan for Systems Studies to Support the MRS Commission." The report combines several MRS facility configurations into five licensing scenarios, identifies and addresses pertinent licensing considerations, and evaluates each scenario according to the identified licensing considerations. The report's general conclusions are that all five scenarios are licensable; the licensing scenario that includes a storage-only MRS is the simplest to license and would provide the earliest acceptance of spent fuel from utilities; repository licensing time is unaffected by the scenario selected; and an MRS will not affect repository licensing.

19. Libby, R. A. 1986. Issue Paper on Burnup Credit and Burnup Meter Requirements. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

Current cask designs for spent fuel transportation are based on the assumption that the casks could be used to ship unirradiated fuel or fuel that has not reached its exposure goal (burnup). The nature of this fuel reduces the efficiency of these cask designs (less fuel is shipped in each cask) and requires that more shipments be made. Fuel that has a higher fuel burnup (such as spent fuel) should require casks with a smaller capacity. If credit can be taken for the actual exposure of the fuel, fuel casks can be more efficient (smaller and lighter). There could also be corresponding reductions in overall system risk because fewer shipments are required and in capital and operational costs. This study reviewed the problems associated with high burnup fuel, and proposed solutions for these problems in terms of "burnup credits," instrumentation, and experiments required to implement the proposed solutions.

20. Libby, R. A. 1986. An Analysis of Spent Fuel Pool Capacities. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

Approximately one-third of all nuclear fuel assemblies are removed from utility reactors each year and stored in spent fuel pools at the reactor sites. The utilities estimate the capacity of their spent fuel pools each year, but a review of the capacity reports indicates that utility estimates of this capacity increase each year. The increase suggests that the maximum capacity of these pools is not known for a variety of

reasons. This report describes an analysis that uniformly estimates maximum storage capacities of reactor spent fuel storage pools using assumptions consistent with pool storage densities at the upper end of the utility-reported estimates.

21. Libby, R., C. Forsberg, M. Maskewitz, C. Wilson, and J. Yount. 1986. Integration of Robotics/Remote Handling into the Federal Waste Management System. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

Objectives of the Federal Waste Management System that can be met with robotics and remote handling include minimization of radiation exposure to facility staff and the public to levels as low as reasonably achievable (ALARA) and maintenance of the system's throughput rates. This paper defines robotics and remote handling systems for the waste management system, identifies their potential benefits to the overall waste management program, and describes the issues and additional studies needed to integrate robotics and remote handling systems.

22. Luksic, A. T. 1989. Spent Fuel Assembly Hardware: Characterization and 10 CFR 61 Classification for Waste Disposal. PNL-6906, Pacific Northwest Laboratory, Richland, Washington.

The U.S. Department of Energy plans to dispose of spent fuel as required by the Nuclear Waste Policy Act of 1982 and is considering the effects of consolidating that fuel. After the spent fuel is consolidated and repackaged, approximately 30 kg of radioactive hardware remains for each assembly and must be disposed of. This report presents a methodology for estimating the radionuclide inventory in radioactive spent fuel hardware. Volume 1 documents the development of scaling factors to be used with ORIGEN2 computer code calculations to estimate activation of spent fuel assembly hardware. Volumes 2 and 3 present the calculated flux profiles of spent nuclear fuel assemblies for pressurized water reactors and boiling water reactors, respectively.

23. Luksic, A. T. 1988. Characterization of Pressurized Water Reactor Spent Fuel Assembly Hardware. Paper presented at the Tenth Annual DOE Low-Level Waste Management Conference, Denver, Colorado, September 1, 1988.

Understanding the nature of a waste stream is critical to designing a system to properly handle, package, store, and dispose of that waste. Currently, many utilities are considering consolidating their spent fuel. Consolidation leaves approximately 30 kg of hardware per assembly, which will also enter the waste stream. This paper presents a characterization of a Westinghouse 14X14 fuel assembly, measurements of the radionuclide concentrations in samples of irradiated hardware from the fuel assembly, and measurements of the elemental composition of each of the samples in order to correlate radionuclide generation and the parent isotope.

24. Luksic, A. T. 1988. Characterization of Activated Metals in Spent Fuel Hardware. Paper presented at the INNM Spent Fuel Management Seminar V, Washington, D.C., January 21, 1988. PNL-SA-15540, Pacific Northwest Laboratory, Richland, Washington.

The components that make up the structural portion of spent fuel assemblies have been analyzed to identify the materials used in them, the quantities of those materials, and options for disposing of the components. This paper discusses the preliminary results of the analyses of the activated metals in these components that were characterized in terms of the radionuclides and radionuclide concentrations present in them. The methodology used to estimate the radionuclide concentrations was validated by comparing computer calculations of those concentrations with laboratory measurements of activated metals.

25. Luksic, A. T., R. W. McKee, P.M. Daling, G. J. Konzek, J. D. Ludwick, and W. L. Purcell. October 1986. Spent Fuel Disassembly Hardware and Other Non-Fuel Bearing Components: Characterization, Disposal Cost Estimates, and Proposed Repository Acceptance Requirements. PNL-6046, Pacific Northwest Laboratory, Richland, Washington.

An evaluation was made of two classes of non-fuel bearing components (NFBC) associated with power reactor fuels that are considered likely to require geologic disposal in a repository: 1) fuel assembly hardware resulting from the disassembly of spent fuel prior to consolidation of the fuel rods for disposal in a repository, which is likely to fall into a "greater-than-Class C" designation, and 2) non-fuel-bearing (NFB) reactor components associated with fuel (control rods, BWR fuel channels, core instrumentation, etc) that are designated in 10 CFR 961 Appendix E as items to be accepted by DOE for disposal. The evaluation report includes descriptions of design specifics of fuel types from major vendors; estimates of quantities and rates of generation of each NFBC class likely to require disposal; elemental composition and estimated radiation levels and decay heat generation rates of the various NFBC hardware and non-fuel items; costs estimates for NFBC waste preparation, volume reduction, transportation, packaging for disposal, and disposal (both repository disposal and shallow-land burial were considered). Accompanying the cost estimates, a set of proposed repository acceptance requirements was developed, based on existing acceptance requirements for other waste classes and current Federal regulations governing waste disposal.

26. McKee, R. W., and J. R. Young. 1989. Conceptual Modular Description of the High-Level Waste Management System for System Studies Model Development. Draft Report, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

This report describes possible alternative components for the Federal Radioactive Waste Management System (FWMS) and procedures for combining modular system components in order to describe alternative configurations of the FWMS. Both physical and functional descriptions are

described for the four major components of the system: the waste generators, waste transportation, monitored retrievable storage (MRS) and the final geological repository. These descriptions are intended to give enough information on the activities, facilities, and equipment to develop a systems integration model and systems engineering studies.

27. McKee, R. W., T. W. Wood, and N. B. McLeod. 1986. Consolidation of Spent Fuel System Planning Perspective. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

Consolidation of spent fuel rods (the process of removing the spent fuel rods from the fuel assembly and closely packing them into a canister) could make it possible to cut the fuel rods' volumes by one-half. This report discusses the implications of spent fuel consolidation for the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM). The report's objectives are to describe current knowledge about consolidation, discuss reasons for consolidation, identify remaining development questions, derive implications for future demonstration projects, clarify the relationships between future projects and OCRWM decisions, and outline a plan for resolving outstanding issues.

28. McKee, R. W., T. W. Wood, and R. A. Libby. 1986. Considerations Bearing on the Timing for a Second Geologic Repository. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

The Nuclear Waste Policy Act (NWPA) requires the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) to identify and characterize sites suitable for a second geologic repository for spent fuel and high-level radioactive waste. However, the uncertainties in project waste disposal requirements for the first repository have raised questions about the need and timing for a second repository. This study explores the issues involved in decisions about the need for and timing of the second repository and analyzes key factors in these decisions. The issues include regional equity (in locating the facility), the value of flexibility in a two-repository system, system costs and transportation considerations, projected disposal requirements, and the adequacy of repository capacity.

29. McKee, R. W., J. S. Polykala, J. J. Tawil, A. F. Rosenfeld, M. E. Schutz. 1987. At-Reactor Spent Fuel Storage Requirements With and Without Acceptance Rights Trading. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

In accordance with the requirements of the 1982 Nuclear Waste Policy Act (NWPA), the U.S. Department of Energy (DOE) and the nuclear power utilities have agreed to the terms of a standard contract for disposal of spent nuclear fuel. This contract includes a provision allowing reactor sites to trade their rights for spent fuel acceptance into the DOE waste management system. A site with insufficient storage capacity might be able to exchange some of its later acceptance rights with another site

that has early acceptance rights and excess storage capacity. This report presents the results of an analysis of reactor storage requirements for spent fuel and the effects of trading spent fuel acceptance rights among reactor sites; it concludes that the potential savings from trading acceptance rights could result in cost savings of \$1 million to \$10 million in storage facility costs.

30. McKee, R. W. 1986. Potential OCRWM System Issues Arising from Disposal of Miscellaneous Wastes. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

The U.S. Department of Energy (DOE) is responsible for providing permanent disposal for a number of radioactive waste types besides commercial spent fuel, high-level wastes, and DOE/defense program waste. These miscellaneous wastes may become the responsibility of DOE's Office of Civilian Radioactive Waste Management (OCRWM). Several issues involving the disposal of miscellaneous wastes are emerging as a result of the Nuclear Regulatory Commission's pending definition of high-level waste, the Low-Level Radioactive Waste Amendments Act of 1985, some provisions of the DOE/Nuclear Utility Standard Contract, and the nature of the wastes themselves. This report summarizes characteristics of the miscellaneous wastes and describes how their disposal may be affected by the regulations. It also identifies features of the legislation and regulations that could affect the OCRWM's responsibilities in disposing of the miscellaneous wastes and identifies several issues that OCRWM may appropriately address.

31. McLeod, N. B., J. M. Reilly, and T. W. Wood. 1986. System Issues Arising from the Inclusion of Defense High-Level Waste in the Civilian Radioactive Waste Management System. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

A decision to dispose of defense high-level waste in civilian repositories rather than in a separate Nuclear Regulatory Commission (NRC) repository for defense wastes could bring up technical issues and equity and regulatory issues for the waste management system. Technical issues would result from the differences in the physical characteristics and amounts of civilian and defense wastes; equity and regulatory issues would arise from the need to establish equitable sharing of costs and disposal rights and from the need to integrate portions of previously separate programs. This report discusses the technical, equity, and regulatory issues that could result from the decision to use civilian repositories for defense waste and describes directions for further technical and policy investigations.

32. Oak Ridge National Laboratory. 1989. Systems Integration Modeling System (SIMS) Exercise - 89/1: Report on the Demonstration of SIMS as a Decision-Support Tool. Draft Report, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) must assess the benefits and performance of Federal Waste Management System (FWMS) configurations and operations from an overall system perspective; these assessments require analysis of several performance characteristics, such as system cost and system operability. The OCRWM System Integration Branch developed a basic framework and objectives for a Systems Integration Modeling System (SIMS) that is capable of analyzing integrated systems to help assess alternative operating strategies and system designs. A demonstration of SIMS in May 1988 showed that the integrated modeling system can and does work, and it highlighted technical areas that required further development in order to transfer data more efficiently. The second SIMS demonstration, called SIMS 89/1, was done in November 1988. This demonstration used system configuration alternatives and operating strategies from the monitored retrievable storage (MRS) studies to demonstrate the capability of SIMS as a decision support tool. This report discusses the results of that demonstration.

33. Otis, P. T., M. R. Shay, R. A. Sovers, and T. P. Sovers. 1987. Lag Storage Requirements for a Generic Repository Under Normal Operating Conditions. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

Lag storage capacity at a nuclear waste repository is the amount of storage maintained for the shipping casks, spent fuel assemblies, canisters, and packages. The minimum required lag storage capacity is the amount of spent fuel capacity that the repository surface facilities and the transportation system must have for the system to function smoothly. This report identifies four types of lag storage that may be required in transporting, accepting, consolidating, and emplacing spent fuel assemblies: transportation casks, spent fuel assemblies, consolidation canisters, and emplacement containers. The report's results determined the minimum required lag storage and corresponding buffer capacities required for a repository. The results also indicated that the spent fuel assembly lag storage is the most cost effective lag storage buffer in the current conceptual repository designs.

34. Pelto, P. J., and J. C. Lavender. 1989. Preliminary Dose Comparisons for the MRS Systems Study. PNL-6857, Pacific Northwest Laboratory, Richland, Washington.

This report provides preliminary information on radiological doses to the public and workers for the alternative system configurations proposed in the monitored retrievable storage (MRS) systems study. Information published in the MRS Environmental Assessment (published by the Department of Energy in 1986) was used as a basis for this analysis. The risk differences between the alternative MRS configurations were found to be small and should not be viewed as a major factor in selecting alternative configurations, the report concludes.

35. Reilly, J. M., R. W. McKee, T. W. Wood, and M. R. LeBlanc. 1986. Allocation of DOE Nuclear Waste Acceptance Capacity and Utility Behavior: Overview and Status. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

The "Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste" recognizes that the Department of Energy (DOE) nuclear waste management facility may not be able to meet the delivery commitment schedule (the delivery commitment schedule identifies spent nuclear fuel and high-level waste to be delivered to the DOE facility). This report examines the relationship among the acceptance priority rankings, delivery commitment schedules, and acceptance of specific fuel assemblies as described in the contract between DOE and the nuclear power utilities for spent fuel disposal. It focuses on utility decisions about at-reactor storage, trading of delivery commitment schedules among utilities, and choosing spent nuclear fuel to deliver; and it focuses on the way those decisions relate to waste management design decisions and regulatory and operating rules of the waste management system.

36. Rennich, M. J., C. R. Attaway, and L. G. Medley. 1989. A Cask Maintenance Facility. Presented at the Ninth International Symposium on Packaging and Transportation of Radioactive Materials (PATRAM) 1989 in Washington, D.C., June 11-16, 1989. Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

A cask maintenance facility (CMF) for the Federal Waste Management System will be used to test and maintain each waste cask in the fleet to comply with regulations; clean and decontaminate casks and vehicles; maintain, repair, and rework casks and auxiliary equipment; maintain cask system documentation; replace and inspect baskets; and store cask system spare parts. This feasibility study, which used a stand-alone CMF as its initial concept, estimated the CMF construction costs to be \$83 million. Construction time from conceptual design to start of operations was estimated to be 110 months, and the CMF could be built using existing technology and procedures. The study highlights constraints on the development of the CMF, particularly the refinement of an operational definition, the establishment of the cask fleet size and configuration, and the selection of a specific site.

37. Roberts, F. P., N. L. Harms, and R. A. Libby. 1987. Safeguards Aspects of Spent Fuel Rod Consolidation. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

The Federal Waste Management System will be accepting limited to large quantities of spent fuel that have been consolidated (removed from the fuel assembly structure and closely packed into a separate canister). Fuel rod consolidation may also be a function of monitored retrievable storage facilities. The design of consolidation equipment and facilities needs to take into account features that are required to meet Nuclear Regulatory Commission (NRC) and International Atomic Energy

Agency (IAEA) safeguard requirements. This report discusses the NRC and IAEA safeguard issues of the consolidation process, as well as the issues associated with design and operation of facilities that perform rod consolidation activities.

38. Ross, W. A., L. L. Clark, and K. H. Oma. 1987. Treatment Alternatives for Non-Fuel-Bearing Hardware, PNL-6098, Pacific Northwest Laboratory, Richland, Washington.

Four alternative methods for volume-reduction of non-fuel-bearing hardware resulting from the consolidation of LWR spent fuel were evaluated based on comparisons of 1) system life-cycle costs for volume reduction, placement in disposal canisters, transportation to a repository, and emplacement for disposal; 2) characteristics of the waste forms during and following treatment; and (3) selected process considerations grouped as factors affecting operational safety, simplicity of the process, and the status of technological development of each process. The comparisons were based on processing of consolidation hardware in a monitored retrievable storage (MRS) facility or at a repository, from consolidation of 62,000 MTU spent fuel at a rate of 2,500 MTU per year. Volume reduction processes considered were shredding, low-pressure compaction, supercompaction, and melting of the metals; combinations of metal shredding with one of the remaining processes were also considered. Based on these evaluations, both melting and supercompaction were recommended for further testing and evaluation.

39. Schneider, K. J., P. J. Pelto, P. M. Daling, J. C. Lavender, and B. A. Fecht. 1986. Preliminary Assessment of Radiological Doses in Alternative Waste Management Systems Without an MRS Facility. PNL-5872, Pacific Northwest Laboratory, Richland, Washington.

This study analyzes the radiological dose effects of nine hypothetical changes in the operation of a radioactive waste management system without a monitored retrievable storage (MRS) facility. It analyzes the commercial spent fuel handling activities at the reactors and at the surface facilities of a deep geologic repository, and it analyzes the transportation of spent fuel by rail and truck between the reactors and the repository. The study concludes that the largest contribution to radiological dose per unit of spent fuel for both the public and workers results from the use of truck transportation casks. Reducing the number of shipments by increasing cask sizes and capacities would reduce radiological doses in all cases. Consolidating spent fuel at the reactors would reduce the radiological doses to the public but would increase the doses to the occupational workers at the reactors.

40. Schneider, K. J., et al. 1987. Analysis of Radiation Doses from Operation of Postulated Commercial Spent Fuel Transportation Systems. DOE-CH/TPO-001, prepared for DOE Chicago Operations Office by Pacific Northwest Laboratory, Richland, Washington.

This study estimates radiation doses to the public and to workers which result from the transport of spent fuel from commercial nuclear power reactors to a geologic repository. It uses a postulated reference rail/legalweight truck transportation system based on current transport technology. The study concludes that major reductions in transportation system dose and cost would probably result from using higher-capacity rail and truck casks, especially if legalweight truck casks were replaced with advanced design overweight truck casks. The greatest annual dose reduction to the highest exposed individual workers (those at the repository) would probably be achieved by using remote handling equipment for cask handling at the repository. Additional shielding on the postulated reference legalweight truck cask would also reduce dose to radiation workers at the reactor and the repository and to transport workers. Short stopping times at truck stops are found to reduce the radiation dose to the public.

41. Shay, M. R., M. K. White, and R. C. Walling. 1985. Demand for Spent Fuel Acceptance Based on Minimum Age Acceptance Criteria. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

Current contracts between the Department of Energy (DOE) and nuclear power utilities for spent fuel disposal do not commit DOE to accept spent fuel on a specific schedule; therefore, these contracts do not provide a basis for utilities to plan for meeting their storage needs. This study analyzes at-reactor storage requirements and DOE spent fuel receipt rates that would result from a DOE commitment to begin receiving fuel from reactor pool storage at a sufficient rate to allow subsequent reactor discharges to be stored in those pools. The study uses two minimum fuel ages (10 and 15 years) for acceptance; for each fuel age, the study evaluates 1) the impact on storage and on DOE receipt rates of accepting fuel from those reactors whose pools are full and that have fuel that meets the minimum age criterion and 2) the impact on storage and on DOE receipt rates of accepting fuel from all reactors with fuel that meets the minimum age criterion.

42. Smith, R. I. 1986. Waste Management System Issues Arising from the Acceptance and Handling of the NUHOMS Canister. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

This study examines the effects on the Federal Waste Management System (FWMS) of transportation, receiving, lag storage, canister opening, and canister disposal of spent fuel that has been stored dry at a reactor site in the NUTECH Horizontal Modular Storage System (NUHOMS). The study concludes that unloading fuel from the NUHOMS canister and transferring it to a conventional shipping cask at the reactor would have little impact on the FWMS, although it would require additional equipment and operations at the reactor. However, if the sealed NUHOMS canisters were shipped directly to the waste management facility, there would be significant effects on the transport costs, the cask handling

and unloading capacity at the receiving facility, the design and capacity of the incoming lag storage pit, the cask processing operation, the low-level waste treatment facility, and the low-level waste disposal costs.

43. The CONSTAR-28 Dry Spent Fuel Storage System, Undated. B&W Fuel Company, Lynchburg, Virginia.

This report-style booklet describes the CONSTAR-28, a spent fuel storage cask constructed of high-density reinforced concrete with a carbon-steel liner. A stainless steel flange welded to the top of the liner mates to a stainless steel cover plate; metallic O-rings seal the cask closed. The cask can be configured to hold 28 intact PWR assemblies, fuel rods from 48 consolidated PWR assemblies plus four hardware canisters, or 63 intact BWR assemblies; different internal baskets are used for the various configurations. Cooling of the cask is accomplished by heat pipes, which transfer heat from the liner through the concrete body; external fins around the upper portion of the cask body serve as heat rejectors. Loading and unloading of the casks utilizes a shielded transfer cask and a movable platform providing mating between the storage cask and the transfer cask.

44. Triplett, M. B., and J. Yount. 1986. OCRWM Program Plan for Robotics/Remote Handling Technology Transfer and Application. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

Because of the need to coordinate ongoing and projected U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) activities that are related to developing and applying robotics and remote handling (R/RH) technology, this program plan provides an initial framework for ensuring that sound judgments are made on R/RH technology to be included in waste management system facilities. It identifies OCRWM's role in developing and applying R/RH technology; managing and controlling system and technology development, common facility, and component technology needs; R/RH technology assessment and transfer; and an integrated approach to technology application and development.

45. Triplett, M. B. 1987. Remote Systems Technology Assessment Plan: Proposed Activities. Draft Report, Pacific Northwest Laboratory, Richland, Washington.

The U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) believes that remote systems (RS) technology needs to be transferred and applied to meet the requirements and design objectives of the Federal Waste Management System in the repositories, in a monitored retrievable storage (MRS) facility, and in a transportation system. This report identifies a plan to assess application of RS technologies to support design and deployment of the waste management system. OCRWM does not intend to mandate the use of RS technology in waste facility designs; this plan is intended to provide facility designers with information on available technologies so that

decisions may be based on the best available information. The overall objective of the plan is to ensure coordination of assessment and testing activities, to avoid duplication of effort, and to identify essential tasks that will assess the merits of RS technology in various OCRWM design applications.

46. Triplett, M. B., and R. I. Smith. 1984. Evaluation of Concepts for Monitored Retrievable Storage of Spent Nuclear Fuel and High-Level Radioactive Waste. PNL-5176, Pacific Northwest Laboratory, Richland, Washington.

The Nuclear Waste Policy Act (NWPA) of 1982 directed the Department of Energy (DOE) to present a proposal to construct one or more monitored retrievable storage (MRS) facilities for spent commercial nuclear fuel and high-level waste on or before June 1, 1985. This report describes the evaluation of eight MRS concepts to support DOE's selection of a primary and alternative MRS concept. The MRS mission requires that the MRS system should not constrain the operation of the total waste management system, but should be designed to be integrated into the total system and accommodate the operational requirements of at-reactor storage, transportation, and the repositories. To fulfill these requirements, this study evaluated the concepts on seven criteria: safety and licensing, environmental impacts, socioeconomic impacts, siting requirements, cost, concept maturity, and flexibility. The two MRS concepts that this report recommended were the field drywell (stationary, near-surface containers or drywells arrayed in a field) and the concrete cask (large reinforced concrete cylinders stored either on a surface foundation or in a trench in the ground).

47. U.S. Department of Energy. 1986. Report of the Task Force on the MRS/Repository Interface. DOE/RW-0044, Washington, D.C.

Preliminary evaluations suggested that it would be advantageous to integrate a monitored retrievable storage (MRS) facility into the waste management system being proposed by the Department of Energy (DOE). DOE established a task force to analyze the design, licensing, cost, and schedule effects of such a facility in April 1985. The task force defined and analyzed five scenarios using waste facilities with and without MRS and concluded that 1) a waste management system with an integral MRS facility has a functional capability not available to the system without an MRS facility, 2) there are greater costs for a facility with an MRS of 5% to 8% of the life-cycle estimated system cost, 3) the waste management system schedule is better for the scenarios with an MRS facility, 4) encapsulation of consolidated spent fuel or defense high-level waste in disposal containers at the MRS facility may cause increased costs, and 5) an MRS facility would increase the overall licensing workload for the waste management system, but would reduce the licensing workload for the repository.

48. U.S. Department of Energy. 1989. MRS System Study Summary Report. DOE/RW-0235, June 1989. Washington, D.C.

The passage of the Nuclear Waste Policy Amendments Act (NWPAA) of 1987 prompted the Department of Energy (DOE) to reexamine the role of the monitored retrievable storage (MRS) facility in the waste management system; a series of systems studies was conducted, and the results of those studies are summarized in this report. The system studies concluded that an MRS facility, whose principal function initially is to receive and store spent fuel, would enhance the waste management system by providing early spent fuel acceptance and flexibility for the system; however, these advantages would be gained at an increase in cost. The studies did not identify any significant benefit in consolidating or packaging spent fuel at the MRS facility. The results of this study were used to develop the DOE's position on the role of the MRS facility in the waste management system.

49. U.S. Department of Energy. 1989. Final Version Dry Cask Storage Study. DOE/RW-0220, Washington, D.C.

This report was prepared in response to a requirement of the Nuclear Waste Policy Amendments Act. The Act directed the Secretary of Energy to study dry cask storage technology for storing spent fuel at civilian nuclear reactors until a geologic repository is available. Because it is necessary to take into account other options for meeting storage needs in evaluating dry storage at reactor sites, this study covered all forms of at-reactor storage. It examined the expected requirements for dry cask storage, the various technologies that are available for such storage, potential costs and other impacts, and the extent to which monies from the Nuclear Waste Fund can and should be used for such storage. The report's conclusion was that existing technologies for dry cask storage are feasible, safe, and environmentally acceptable options for storing spent fuel at the reactors until a geologic repository is ready.

50. U.S. Department of Energy. The DOE Position on the MRS Facility. 1989. DOE/RW-0239, Washington, D.C.

This report summarizes the position of the Department of Energy (DOE) on the monitored retrievable storage (MRS) facility. The DOE supports the integration of an MRS facility into the waste management system because the MRS would allow DOE to meet its objectives of timely disposal, timely and adequate waste acceptance, schedule confidence, and system flexibility. An MRS facility would receive, stage, and store shipments of intact spent fuel to the repository, and it could be expanded in the future to perform additional functions that are required or that may be beneficial as the system design matures. This report also discusses the DOE's preferred procedures for siting the MRS facility.

51. Wood, T. W. 1986. Analysis of an Energy Research Advisory Board Recommendation Relating to International Collaboration in Repository Economics. Draft Letter Report, Pacific Northwest Laboratory, Richland, Washington.

This letter report was written in response to a request from the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) for the Systems Integration Planning Project at Pacific Northwest Laboratory (PNL) to analyze a recommendation from an Energy Research Advisory Board (ERAB) report. That report recommended international collaboration on high-level waste form and repositories to develop more economical waste management systems by increasing the number of potential waste forms and repositories. Because it is probably not feasible to broaden the choices of storage media for the first U.S. repository, given the current status of the federal repository program, the Systems Integration Planning Project felt that collaboration on repository research would not be beneficial. The Project also considered the benefits of international collaboration on investigations of fuel form and concluded that these investigations, which center around fuel compaction techniques, should be deferred until the current discussions on fuel consolidation are complete.

52. Wood, T. W., D. G. Dippold, A. M. Plummer, and S. M. Short. 1989. Spent Fuel Acceptance Scenarios Devoted to Shutdown Reactors: A Preliminary Analysis. PNL-7143, Pacific Northwest Laboratories, Richland, Washington.

Spent fuel acceptance schedules and the allocation of federal acceptance capacity in the Department of Energy (DOE) Federal Waste Management System (FWMS) have important operational and cost consequences for the operators of commercial nuclear power reactors. A DOE monitored retrievable storage (MRS) study done in 1989 investigated some alternative allocation schemes; this report supplements those investigations by examining acceptance schemes in which the acceptance capacity of the FWMS (which includes transportation, MRS, and one or more geologic repositories) is allocated primarily to shutdown commercial power reactors. The report also extends the scope of the allocation investigation to include considerations of at-reactor cask loading rates.

53. Wood, T. W., M. K. Altenhofen, S. M. Short, C. A. MacKay, and M. G. Woodruff. 1989. MRS Systems Study Task G Report: The Role and Functions of Surface Storage of Radioactive Material in the Federal Waste Management System. PNL-6876, Northwest Laboratory, Richland, Washington.

This study is one of nine undertaken by the U.S. Department of Energy (DOE) Office of Civilian Waste Management (OCRWM) to provide a technical basis for re-evaluating the role of a monitored retrievable storage (MRS) facility. It investigates the functions of surface radioactive material storage within the Federal Waste Management System (FWMS),

including accepting spent fuel from utilities, scheduling waste preparation processes within the system, enhancing system reliability, and conditioning the thermal (decay heat) characteristics of spent fuel emplaced in a repository. This analysis focuses particularly on the effects of storage capacity and DOE acceptance schedule on power reactors. In general, this report concludes that a FWMS with an MRS functions better in the areas of spent fuel acceptance, process scheduling, reliability enhancement, and heat management. In addition, storage of spent fuel can help integrate the federal and at-reactor storage systems by making it possible for utilities to plan for storage and equipment reuse with more certainty.

54. Wood, T. W., and M. B. Triplett. 1986. Technical Questions and OCRWM Decisions Relating to Spent Fuel and High-Level Waste Acceptance - An Initial Overview. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

Spent fuel and high-level waste acceptance is the process of transferring the fuel and waste from its current owners to the Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) to be processed and disposed of. This study describes the complex technical questions and the corresponding OCRWM decisions on waste acceptance using five "decision groups": 1) acceptance criteria, 2) aggregate acceptance rate, 3) allocation of acceptance rights among generators, 4) procedural matters, and 5) logistics. The relationships among these five groups suggest a preliminary plan for analysis of the issues; this plan is described in detail in this report.

55. Wood, T. W. 1986. Review of the Status of Recommendations for Study Arising from the PRDA Process. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

In 1984, the Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) issued a Program Research and Development Announcement (PRDA) with the objective of identifying and examining alternative concepts for spent fuel handling, packaging, shipping, storage, and disposal that would improve the performance of the Federal Waste Management System (FWMS). Five contractors issued reports in response to the PRDA; in 1986, Roy F. Weston published a document summarizing findings of a DOE working group that evaluated the results of these five studies and recommended additional studies in several areas. This letter report evaluates the recommendations of the Weston report within the framework of current OCRWM studies and suggests new studies that could fulfill those recommendations.

56. Wood, T. W., and A. F. Rosenfeld. 1988. Structure for Description of Operational Scenarios at Level 1 - Spent Fuel. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

This report, prepared for the Department of Energy's Office of Civilian Radioactive Waste Management (OCRWM), defines a data structure that can be the initial basis for the Reference System Analysis Database for the Federal Waste Management System (FWMS). It refines the structure for describing an operational scenario, or set of operating rules, that specifies how the system would be used, which 1) captures operating scenario possibilities so that they may provide input to the various systems analysis models; 2) allows the organization of the trial study or operational test assumptions; and 3) is general enough to be used for more complex systems analysis problems and to serve as an organizing structure for the Reference System Analysis Database in the future. The report also summarizes questions about long-term model structure and function that were raised by this study.

57. Wood, T. W. 1985. Design Guidance and System-Related Requirements for Repository Advanced Conceptual Design. Letter Report, Pacific Northwest Laboratory, Richland, Washington.

This document provides guidance to ensure that the repository advanced conceptual design (ACD) is compatible with the Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) Federal Waste Management System (FWMS). The guidance is based on a combination of system studies that address key system issues such as system design strategy, system waste acceptance rates and capacities, consolidation, waste characteristics and canistering, and the location of certain functions within the FWMS.

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