1 of 2

DOE/RW-0051/REV3

Office of Civilian Radioactive Waste Management

OCRWM Systems Engineering Management Plan (SEMP)

Revision 3

June 1994

U.S. Department of Energy
Office Of Civilian Radioactive Waste Management
Washington DC, 20585

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
PROGRAM CHANGE CONTROL BOARD
REVISION/CHANGE RECORD

(1) DOCUMENT NUMBER: DOE/RW-0051

(2) DOCUMENT TITLE: OCRWM Systems Engineering Management Plan

(3) REVISION DATE/ NUMBER	(4) DCP NUMBER	(5) REVISION/CHANGE DESCRIPTION	(6) PAGES AFFECTED
2/14/90 1	19	The proposed change is a complete revision of the OCRWM SEMP to reflect changes in the Program brought about by the Nuclear Waste Policy Amendments Act, the latest OCRWM reorganization, the modifications to reference documents (e.g. DOE Order 4700.1 and the PMS Manual). This revision also incorporates pertinent information from the Program Elements SEMP (PE-05) and, when approved, will supercede that document.	All
1/5/93 2		This revision of the OCRWM SEMP reflects the initiatives of the Management Systems Improvement Strategy (MSIS) of August 1990, including the reorganization of OCRWM, the new document hierarchy, and the rigorous implementation of the systems engineering process throughout the Program and projects. It is a joint SEMP in that it addresses the roles of both OCRWM and the M&O Contractor in implementing the systems engineering process. This revision also establishes the Interface Control Working Group.	All
6/20/94 3	BCP-00-94-0002	Three areas of change include: (1) issuance of Human Factors Engineering Program Plan as Appendix G, reserving Appendices E, F, and H for program plans for three other engineering specialties, and changes to Section 4.3.1 and Table 4-1 to delete Engineering Specialty Plan document and recognize plans as appendices; (2) changes to Sections 4.1.1.1, 4.2.1, 5.3.3.1, 5.4.1.3, 5.4.1.4.1, 5.4.1.4.2, 5.4.2.1, 5.4.3.1, and deletion of Appendix A to reflect that the interim technical requirements baseline has already been replaced by the technical requirements baseline defined in the document hierarchy and to clarify the description of IFS and ICDs (in Section 4.2.1 changes); and (3) corrections to Software Control section 4.2.3.6 and its subsections to resolve outstanding comments on Rev. 2, which led to other changes to reflect the new QARD and new documents that address software QA and impacted Section 4.2.4 and Appendices B & D.	All pages replaced as text shifted. Content changed on Rev 2 pages: vii,viii, ix,18,20, 25,27,29, 33,34,41, 43-47,55, 58-60,64; B-1,2,3; & D-1,2. Deleted Appx A. Inserted Appx G. Inserted Appx E,F, & H title pages.

Office of Civilian Radioactive Waste Management

WBS: 9.2.1
QA: N/A
Page: 1 Of: 1

BCCB CHANGE DISPOSITION SUMMARY RECORD

1. BCP NUMBER	REV.	3. ORIGINATOR'S NAME	5. CHANGE LEVEL	6. PRIORITY LEVEL	7. DISPOSITION DATE
BCP-00-94-0002	0	Thanhtan Van	☐ 0 ☑ 1 ☐ 2 ☐ 3	☑ ROUTINE ☐ FIELD ☐ PRIORITY ☐ EMERGENCY ☐ URGENT	
2. DATE REC'D		**4. ORIGINATOR'S ORGANIZATION**			**8. BCP TYPE**
04/29/94		RW-32			☐ TECHNICAL ☑ MANAGEMENT ☐ DEVIATION ☐ ADMINISTRATIVE

9. BCP DESCRIPTION/TITLE
Title: OCRWM SEMP, Revision 3
Description: See originating BCP

10. DISPOSITION RECOMMENDATION: ☐ ESAAB ☑ PROGRAM ☐ PO YMP ☐ PO MRS PROJECT ☐ FIELD ☐ CONTRACTOR

BOARD MEMBER SIGNATURE	RECOMMENDATIONS (See Block 10 Instructions)
L. Barrett, RW-2 (see attached RFD)	Approve
D. Horton, RW-3 (see attached RFD)	Approve with Conditions (conditions resolved, see RFD)
J. Saltzman, RW-4 (see attached RFD)	Approve
J. Saltzman, RW-5 (see attached RFD)	Approve with Conditions (conditions resolved, see RFD)
S. Russo, RW-10/50 (see Attached RFD)	Approve (non-conditional comments resolved, see BRD)
R. Nelson, RW-20 (see attached RFD)	Approve
D. Shelor, RW-30 (see attached RFD)	Approve
R. Milner, RW-40 (see attached RFD)	Approve with Conditions (conditions resolved, see RFD)

DIRECTIVE

11. CHANGE DISPOSITION: * SEE BLOCK 13
☑ APPROVE ☐ DEFER*
☐ APPROVE WITH CONDITIONS*
☐ DISAPPROVE* ☐ CANCEL*

12. BCCB CHAIRMAN SIGNOFF:
PRINT Daniel A. Dreyfus
SIGN [signature] DATE 6-20-94

13. CHAIRMAN'S JUSTIFICATION/CONDITIONS/LIMITATIONS

☐ See Continuation Page

14. BCCB DIRECTIVE/IMPLEMENTING INSTRUCTIONS FOR DOCUMENT(s)
Issue/distribute Program SEMP Revision 3 as approved. OCRWM Project organizations shall review existing project documention and initiate action to revise these documents as necessary to bring them into compliance with current program policy as defined in the revised Program SEMP.

☐ See Continuation Page

15. BCCB DIRECTIVE/IMPLEMENTING INSTRUCTIONS FOR AFFECTED CONFIGURATION ITEM(s)

☐ See Continuation Page

0244 (12/03/92)

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

Page

THIS PAGE INTENTIONALLY LEFT BLANK.

1. INTRODUCTION

The Nuclear Waste Policy Act of 1982 established the Office of Civilian Radioactive Waste Management (OCRWM) in the Department of Energy (DOE) to implement a program for the safe and permanent disposal of spent nuclear fuel and high-level radioactive waste. To achieve this objective, the OCRWM is developing the Civilian Radioactive Waste Management System (CRWMS), an integrated waste management system consisting of four system elements: the waste acceptance system, the transportation system, the monitored retrievable storage (MRS) facility, and the mined geologic disposal system (MGDS). The development of such a system requires management of many diverse disciplines that are involved in research, siting, design, licensing, construction, and external interactions. The OCRWM has contracted with a Management and Operating (M&O) contractor to manage these diverse disciplines, integrate the activities of the many participants contributing to the system development, and provide the systems engineering to integrate the CRWMS. The M&O is charged with implementing policy set forth by OCRWM for the development of the CRWMS. The purpose of this Systems Engineering Management Plan (SEMP) is to prescribe how the systems engineering process will be implemented in the development of the waste management system including the responsibilities assigned to the M&O and to elements of the OCRWM.

Systems engineering will be used by OCRWM to manage, evaluate, integrate, and document all aspects of the technical development of the waste management system and its system elements to ensure that the requirements of the Program are met. Systems engineering will be applied to all technical activities to (1) specify the sequence of technical activities necessary to define the requirements the waste management system must satisfy, (2) to develop the waste management system, (3) to relate system elements to each other, and (4) to determine how the waste management system can be optimized to most effectively satisfy the requirements. Furthermore, systems engineering will be used in the management of technical activities at the program and project levels by specifying procedures, studies, reviews, and documentation requirements.

THIS PAGE INTENTIONALLY LEFT BLANK

2. SCOPE, APPLICABILITY, AND CONTENTS

2.1 SCOPE

The OCRWM SEMP specifies the technical management approach for the development of the waste management system, and specifies the approach for the development of each of the system elements--the waste acceptance system, the transportation system, the MRS facility, and the mined geologic disposal system, which includes site characterization activity. The SEMP also delineates how systems engineering will be used by OCRWM to describe the system development process; it identifies responsibilities for its implementation, and specifies the minimum requirements for systems engineering. It also identifies the close interrelationship of system engineering and licensing processes. This SEMP, which is a combined OCRWM and M&O SEMP, is part of the top-level program documentation and is prepared in accordance with the direction provided in the Program Management System Manual (PMSM). The relationship of this document to other top level documents in the CRWMS document hierarchy is defined in the PMSM and depicted in Figure 2-1.

A systems engineering management plan for each project, which specifies the actions to be taken in implementing systems engineering at the project level, shall be prepared by the respective project managers. ["Program" refers to the CRWMS-wide activity and "project" refers to that level responsible for accomplishing the specific activities of that segment of the program.] The requirements for the project level SEMPs are addressed in Section 4.2.2.2. They represent the minimum set of requirements, and do not preclude the broadening of systems engineering activities to meet the specific needs of each project.

2.2 APPLICABILITY

The principles and procedures specified in this SEMP apply to scientific and engineering activities related to the development and management of the CRWMS technical baseline. Other activities authorized by the Nuclear Waste Policy Act as amended--such as cooperation with other countries in waste management activities, Federal interim storage, and siting negotiations--are not covered by this plan. Responsibilities assigned to the M&O and other contractors are subject to Program authorization and technical direction by OCRWM.

2.3 CONTENTS OF THE SEMP

The contents of this SEMP comply with DOE Order 4700.1 guidelines and include specific sections tailored to the CRWMS Program. The SEMP consists of the following:

- **Section 1** provides a brief introduction to the CRWMS Program and the SEMP

- **Section 2** describes the scope, applicability, and contents of the SEMP

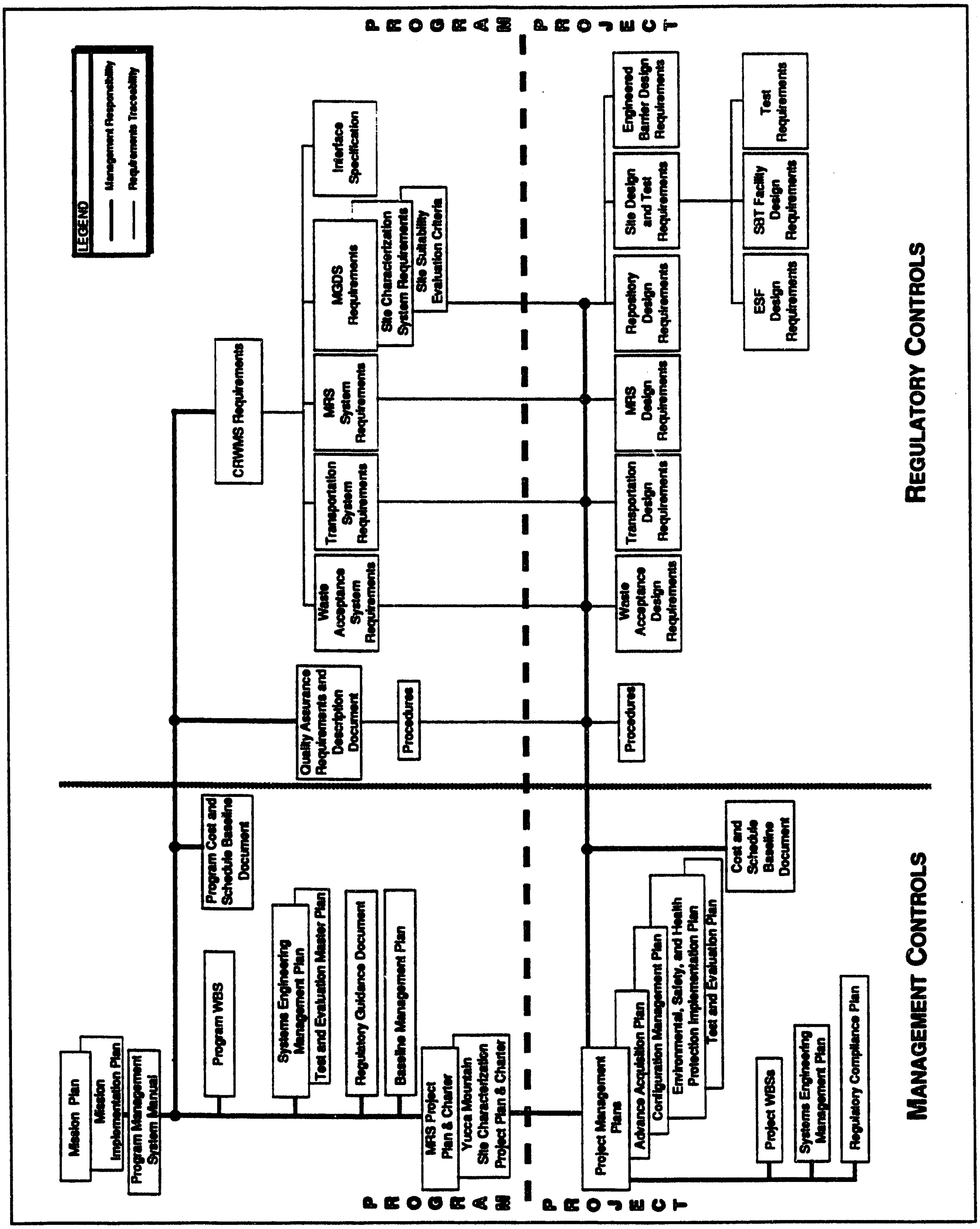

Figure 2-1. OCRWM Document Hierarchy

- **Section 3** describes the CRWMS organization and responsibilities of OCRWM and the M&O, including the organizational and management interfaces

- **Section 4** describes how systems engineering will be managed and implemented for this Program. It is composed of three major sections: Section 4.1 describes the systems engineering process for synthesizing requirements and defining design; Section 4.2 describes the technical planning and control activities including technical baseline definition and verification responsibilities; and Section 4.3 describes the integration of engineering and programmatic specialty activities

- **Section 5** summarizes how the principles and processes described in the previous section are being applied to each element of the CRWMS including prerequisites for each major milestone in the design process for each element

- **Appendix A** is Reserved

- **Appendix B** provides a list of acronyms

- **Appendix C** provides a Glossary

- **Appendix D** provides a list of reference documents.

- **Appendices E, F, G and H** are to provide engineering specialty program plans:

  E. Integrated Logistics Support Plan

  F. Reliability, Availability, and Maintainability Program Plan

  G. Human Factors Engineering Program Plan

  H. System Safety Program Plan

THIS PAGE INTENTIONALLY LEFT BLANK.

3. PROGRAM ORGANIZATION AND RESPONSIBILITIES

3.1 OCRWM ORGANIZATION AND RESPONSIBILITIES

The Office of Civilian Radioactive Waste Management is responsible for the management of the Civilian Radioactive Waste Management Program and the development of the Civilian Radioactive Waste Management System. OCRWM is headed by a Director who has been appointed by the President with the advice and consent of the Senate. The Director is responsible for executing the functions of the Secretary of Energy under the Nuclear Waste Policy Act as amended, and reports directly to the Secretary of Energy. Overall policy planning and management of the program are carried out by the Director, either directly or through his principal subordinates. The OCRWM organizational structure, shown in Figure 3-1, consists of eight major offices, all reporting directly to the OCRWM Director. These offices and their responsibilities are as follows:

- **Office of Quality Assurance,** which is responsible for developing quality-assurance requirements and overseeing compliance, and for interfacing with the U.S. Nuclear Regulatory Commission on quality-assurance matters

- **Office of Strategic Planning and International Programs,** which conducts strategic, long-range, and contingency planning, and manages relations with the waste management programs of other nations

- **Office of External Relations,** which manages intergovernmental relations, education and public information programs, and public outreach

- **Office of Program and Resources Management,** which is responsible for maintaining the program cost and schedule baseline, managing financial and other resources, developing TSLCC estimates, interfacing with the Office of Program/Project Management and Control (PR-20) on issues related to the Energy System Acquisition Advisory Board (ESAAB), Independent Cost Estimating (ICE), managing information resources, and providing administrative support, including the acquisition and development of human resources

- **Office of Geologic Disposal,** which is responsible for directing the Yucca Mountain Site Characterization Project including the scientific evaluations needed to determine whether the Yucca Mountain candidate site in Nevada is suitable for a geologic repository and for waste package and repository design and development

- **Office of Systems and Compliance,** which establishes system requirements for the program, oversees regulatory compliance, the licensing process, and the implementation of program requirements; conducts program self-assessments, integrates the overall system, and is the office of primary responsibility for systems engineering and the OCRWM SEMP

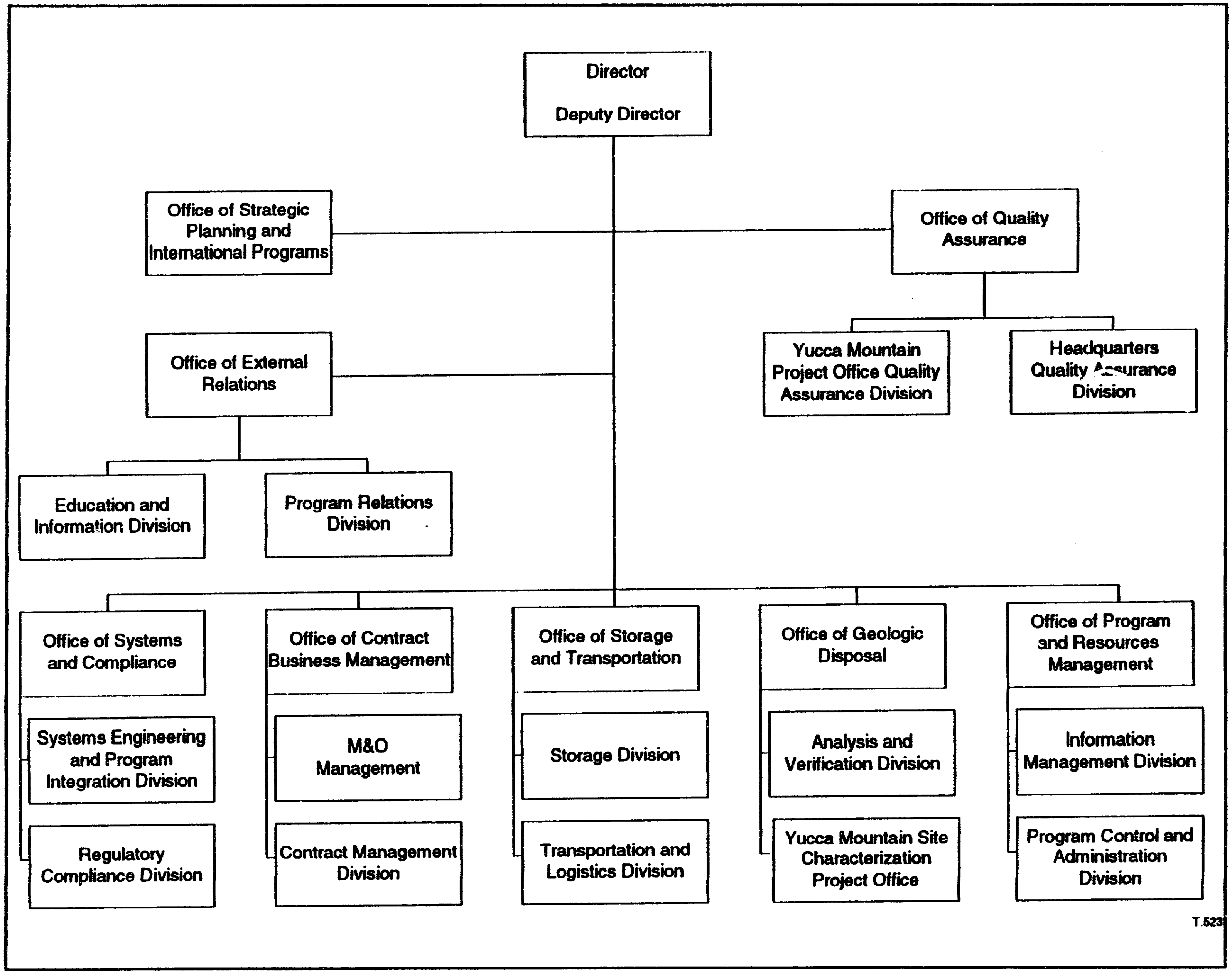

Figure 3-1. OCRWM Organization

- **Office of Storage and Transportation,** which is responsible for directing the MRS project, developing a transportation system, developing shipping casks, developing systems for spent-fuel acceptance, and transportation system scheduling

- **Office of Contract Business Management,** which manages business relations with the Management and Operating (M&O) contractor and support services contractors, consolidates contractor services, and oversees assignment of work to Field Offices.

3.1.1 OCRWM's Systems Engineering Organization

3.1.1.1 Systems Engineering at the Program Level

Program-level systems engineering functions at OCRWM fall within the responsibility of the Director of the Systems Engineering and Program Integration Division (SEPID) of the Office of Systems and Compliance (OSC). This division is composed of the Systems Engineering Branch (SEB), the Systems Planning and Integration Branch (SPIB), and the Configuration Management Branch (CMB).

The Chief of the Systems Engineering Branch is responsible for the development of the technical/performance requirements for the overall system and system elements, including their interfaces. In addition, the SEB is also responsible for system engineering studies, including trade off and optimization analyses, systems model development, and technical data base activities needed to support systems studies. The Branch is responsible for establishing the Program technical baseline. The SEB is a participant in systems engineering and design review activities.

The Chief of the Systems Planning and Integration Branch is responsible for the development of the Program-level Systems Engineering Management Plan. The Branch is responsible for the delineation and control of Program-level programmatic and performance requirements.

The Chief of the Configuration Management Branch establishes procedures, maintains, and directs the implementation of a configuration management system and all OCRWM Change Control Boards. The Chief, CMB, serves as the Secretary for OCRWM Change Control Boards, and the M&O provides the Secretariat support function. The Chief, CMB, is responsible for the development of the OCRWM Baseline Management Plan (BMP), which implements the OCRWM Baseline Management System. The Chief, CMB, also reviews and concurs with the M&O Configuration Management Plan and monitors the M&O Change Control Boards.

Within OCRWM, the Director of the Program Controls and Administration Division (PCAD) of the Office of Program and Resource Management is responsible for establishment of the Program cost and schedule baseline. PCAD interacts with program and project organizations to minimize program costs associated with the design, development and operation of the CRWMS while expediting the program schedule for these same activities.

3.1.1.2 Systems Engineering at the Project Level

Projects critical to fulfilling a DOE mission are funded and controlled as Major System Acquisitions (MSAs). The two current OCRWM MSAs are the Yucca Mountain Site Characterization Project (YMP) and the Monitored Retrievable Storage (MRS) Project. The MRS Project includes the storage, transportation, and waste acceptance functions. Each Project is managed by an Associate Director (AD) who reports to the Director, OCRWM.

The Yucca Mountain Site Characterization Project (YMP) is managed by the Yucca Mountain Project Office (YMPO), within the Office of Geologic Disposal (OGD), headed by the Associate Director for Geologic Disposal (ADGD). Systems engineering within the YMPO is the responsibility of the Engineering and Development Division.

The Project Office for the MRS MSA has not yet been established; it is pending selection of the MRS site. The organizational structure of the MRS Project Office is expected to parallel that of YMPO and interactions between Program and project systems engineering organizations are anticipated to be similar to those established for the YMP. Currently, MRS Project activities are being conducted under Program direction and control.

3.1.1.3 Program-to-Project Systems Engineering Interfaces

The primary systems engineering related interactions between the Program and the projects occur in two areas - the integration of change control and the flowdown of program requirements. Interfaces are maintained between YMPO's Engineering and Development Division and OSC's System Engineering and Program Integration Division to facilitate these interactions for the YMP. Similar interfaces will be established for the MRS Project when the SAR design phase is initiated. Currently, system engineering interfaces involving the MRS Project are being conducted between SEPID and the Storage and Transportation & Logistics Divisions of the Office of Storage and Transportation.

This Program SEMP incorporates DOE Order 4700.1 guidance and is tailored to provide consistency among multiple MSA/Projects specific to the CRWM Program. Project SEMPs are derived from this Program SEMP and conform to the systems engineering methodology and requirements outlined in Section 4.2.2.2. Each project SEMP addresses the specific systems engineering activities to be performed for that project and expands upon the methodology delineated in the Program SEMP. Project SEMPs are developed and approved by the project. The ADSC reviews each project SEMP.

Project Configuration Management Plans (CMPs) are developed in accordance with the Program Baseline Management Plan (BMP). Technical, cost, and schedule baseline changes at the project-level must be approved at the program level when Program-level change control thresholds are exceeded. Project CMPs are approved by the Chairman of the Project Office Baseline Change Control Board (POBCCB). The ADSC reviews and concurs on all project CMPs.

Program-to-project systems engineering interaction is performed to ensure that flowdown and traceability of requirements from the program-level to engineering requirements defined at the project-level successfully captures all applicable requirements and interprets them appropriately. This goal is accomplished through the use of regular informal technical interchanges between Program and project systems engineering organizations and formal technical reviews at major milestone points.

3.2 M&O ORGANIZATION AND RESPONSIBILITIES

The M&O contractor is responsible for implementing the systems engineering, development, and management functions necessary to achieve OCRWM's objectives in accordance with the policies established by OCRWM. The M&O organization, shown in Figure 3-2, is headed by the General Manager who directs the M&O and is responsible for all aspects of M&O performance. He is supported by the internal organizations described below.

3.2.1 Systems Organization

The Systems Organization develops the system concept, establishes the system requirements, and maintains the technical baseline. It consists of the following offices:

- Systems Engineering - responsible for the implementation of systems engineering plans, policies, and procedures; development of system requirements; verifying conformance with requirements; support to the baseline control process; and conduct of studies and analyses

- Requirements and Licensing - responsible for identifying regulatory requirements, ensuring their integration with the systems engineering process, and supporting OCRWM in the management and conduct of the licensing process

- Performance Assessment and Models - responsible for integrating performance assessment activities and developing and executing system models that support the program

- Outreach Support - responsible for identifying institutional and public acceptability issues and providing support to the OCRWM Office of External Relations.

3.2.2 Operations Organization

The Operations Organization helps establish and subsequently implements the technical baseline and provides management controls and information systems support to CRWMS. It consists of the following offices:

- Storage and Transportation - Responsible for MRS design and engineering, establishing MRS design requirements, MRS siting, Transportation, and Waste Acceptance.

- Management Systems - Responsible for monitoring changes to the technical baseline and estimating cost and schedule impacts resulting from those changes.

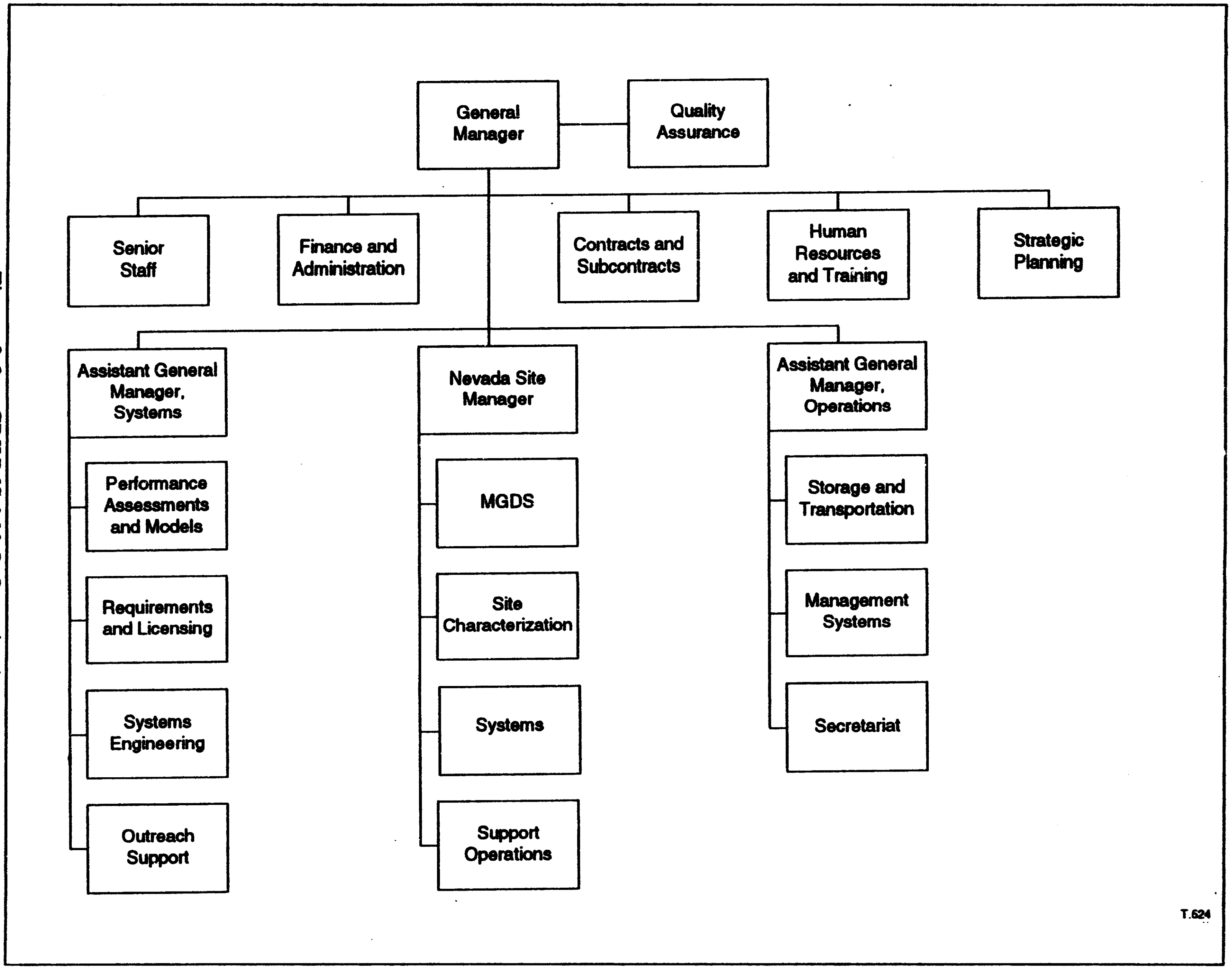

Figure 3-2. CRWMS M&O Organization

- Secretariat - Responsible for supporting the major functions of publications, records management, and information systems.

3.2.3 Nevada Site Organization

The Nevada Site organization is responsible for supporting the M&O functions in Nevada, including integrating the work of the YMP participants. It consists of the following offices:

- MGDS - Responsible for establishing MGDS design requirements, repository surface and subsurface design, engineered barrier system (EBS) design, and MGDS integration with all CRWMS elements including change control activities.

- Site Characterization - Responsible for characterization of the Yucca Mountain site, including Surface Based Testing and Exploratory Studies Facility activities.

- Systems - Responsible for systems support activities including performance assessment, and licensing and regulatory considerations at Yucca Mountain.

- Support Operations - Responsible for project management support (e.g., budget, administration).

3.2.4 Systems Engineering Program Relationship

Within the M&O organization the Systems organization is responsible for implementing OCRWM policy in establishing the CRWMS technical baseline and ensuring performance to this baseline. Major responsibilities in support of OCRWM include: development of system concepts and requirements; analysis of system performance; development and control of all software tools used in quality affecting work to support the license application process; development and control of the technical baseline; and ensuring that the program activities support a successful license application process. The Systems organization consists of the following offices: Performance Assessment and Models, Requirements and Licensing, Systems Engineering, and Outreach.

The Performance Assessment and Models Office is responsible for the integration of system-level performance assessment and modeling activities and developing, maintaining, and executing system and subsystem level models which support the Program decision-making process and regulatory compliance demonstrations. In addition, responsibilities include developing and maintaining systems engineering technical databases; verifying and validating software developed by the M&O; and, managing the configuration of all quality affecting software (models and databases).

The Requirements and Licensing Office is responsible for ensuring that regulatory requirements are incorporated in the Systems Requirements Documents in the technical baseline and for supporting OCRWM in the management and conduct of the licensing process. This includes the collection, documentation, and interpretation of the system requirements established by regulatory agencies and DOE directives. This office is also responsible for managing/sponsoring the requisite analyses and reports necessary to support the licensing process.

The Systems Engineering Office is responsible for CRWMS overall integration and optimization. Working directly with SEPID, this office implements systems engineering plans, policies, and procedures; develops the program level System Requirements Documents; manages the analysis of design packages to ensure compliance with established system requirements; supports Program requirements definition and design activities in specialty engineering disciplines; manages the development and control of system interfaces; supports and implements the OCRWM Baseline Management System; and defines and conducts studies and analyses to support resolution of system requirements and performance issues.

The Outreach Office is responsible for identifying institutional and public acceptability issues for integration into the systems engineering process and for providing support to OCRWM in the development and implementation of effective outreach programs. The Outreach Office supports the integration of public policy into the overall CRWMS Program.

3.3 THE OCRWM M&O INTERFACE

3.3.1 Organizational Interface

The Director, OCRWM, in concert with his staff, has primary responsibility for execution of the Civilian Radioactive Waste Management Program by establishing programmatic and technical policies and providing authorization for conducting technical activities. The M&O's role is to perform certain technical and management functions and integrate the effort of various program participants. The M&O will work with and support OCRWM offices as illustrated in Figure 3-3. The M&O organizations are shown in the shaded areas next to the OCRWM offices with which their functional responsibilities are most closely aligned. For example, the M&O Systems Engineering office will interface primarily with SEPID. In like fashion, the entire M&O contractor organization will work with the OCRWM organization providing systems engineering, development, and management support to help ensure the successful development of the Civilian Radioactive Waste Management System. Other program relationships and general responsibilities are described in the PMSM.

3.3.2 Management Interface

The OCRWM has primary responsibility for program systems engineering. This involves establishing the policies and activities to be implemented, authorizing funds, and managing resources. The M&O implements the policies set by the OCRWM and performs the systems engineering functions necessary to achieve the OCRWM mandated objectives. The focal point of this effort within OCRWM is the Office of Systems and Compliance (OSC). The OSC and the M&O have worked together to develop this SEMP to prescribe the systems engineering process that will be used to plan, implement, and control the technical baseline for the CRWMS. This SEMP is the top-level plan governing this engineering effort. It is a joint document describing the collective actions required of OCRWM and the M&O to develop and manage the CRWMS technical baseline.

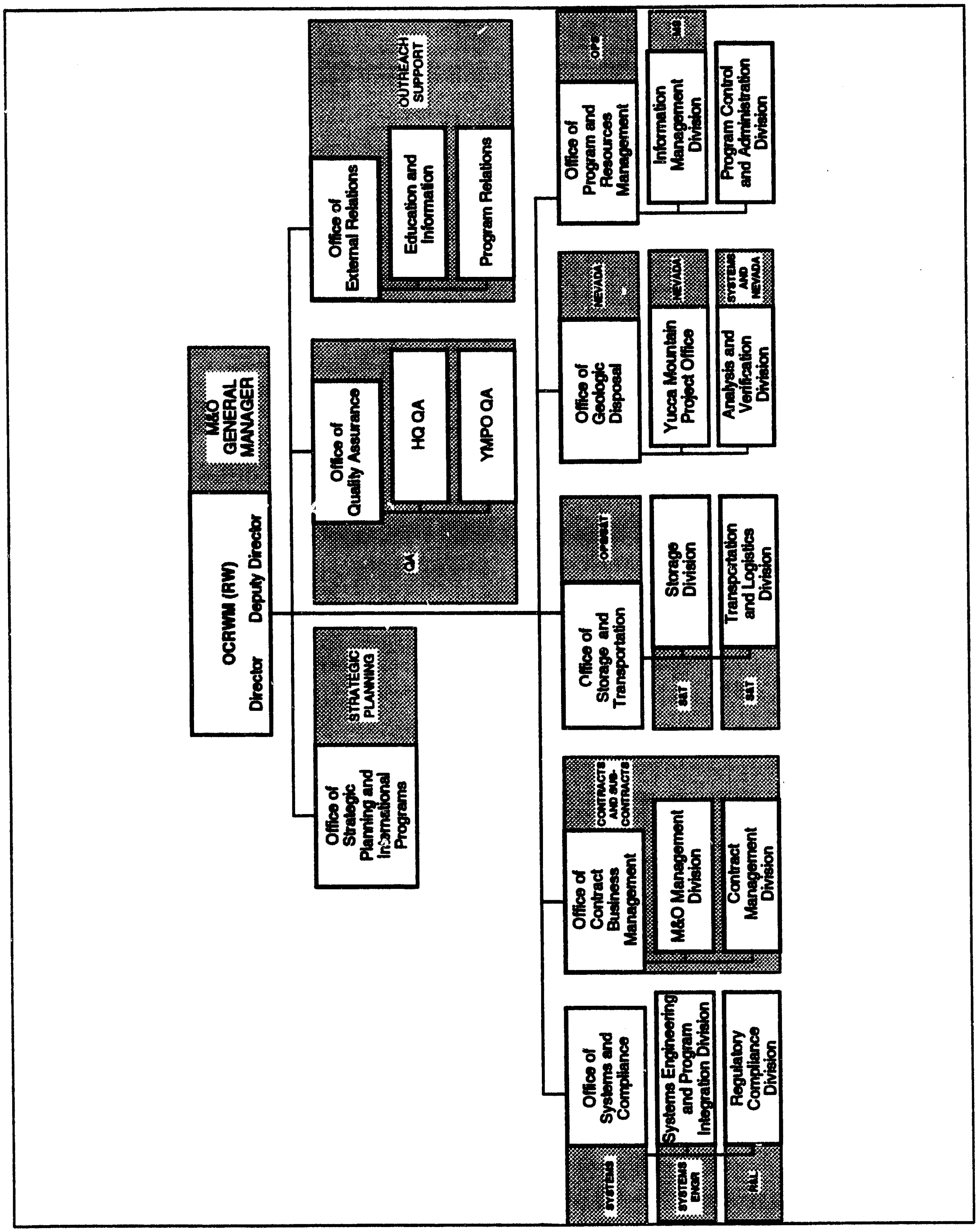

Figure 3-3. OCRWM/M&O Primary Interface Associations

The interactive implementation of the joint OCRWM-M&O management responsibilities is referred to as the management interface. The primacy of the OCRWM responsibilities characterizes this OCRWM-M&O interface and extends over the breadth of the program. Policies implemented, responsibilities executed, and actions initiated by the M&O are on behalf of OCRWM and are an application of the responsibilities of the M&O contractor. The OCRWM management policies are established in several top-level documents including the Mission Plan, the PMSM and OCRWM Directives addressing specific policy matters. This SEMP is in conformance with these documents and the guidance provided in DOE Order 4700.1. It describes the systems engineering activities to be performed to implement these policies.

The OCRWM-M&O management interface is inherent throughout the systems engineering activities defined in this plan. This interface is both formal and informal. The formal interface occurs through the Work Authorization System (WAS), which defines contract direction. The WAS is the mechanism by which the responsible OCRWM organization establishes the scope of deliverable work to be performed by the M&O in implementing the OCRWM policies. The informal interface that provides program guidance, coordinated positions, and progress evaluation is effected through technical interchange meetings, technical reviews, working group meetings, progress reviews, and other personal interactions.

4. SYSTEMS ENGINEERING

Systems engineering for the CRWMS program is described in detail in the following sections; Section 4.1 describes the systems engineering process, Section 4.2 describes technical planning and control, and Section 4.3 addresses engineering and programmatic specialty integration.

4.1 SYSTEMS ENGINEERING PROCESS

The systems engineering process will be used to define, allocate, document, and verify requirements and conformance to requirements for the CRWMS. Approved system requirements will be documented and controlled in the technical baseline to ensure that all program participants use the same information in the development of the CRWMS; that changes to the baseline are evaluated and controlled; and that the impact of changes to system requirements is traceable down to the appropriate level of related documentation. The systems engineering process synthesizes technical requirements to provide a design that is complete, at each level of detail, from a total system viewpoint. The process provides for continuing focus on primary technical objectives with consistent emphasis on the product. It provides for the timely and appropriate integration of traditional engineering with the engineering specialties including safety, human factors, and integrated logistics.

The systems engineering process emphasizes the analysis and evaluation of requirements to define the technical baseline in a disciplined environment controlled by configuration management. It will be used to manage, integrate, and document all aspects of the technical development of the CRWMS to ensure that program objectives are achieved. The two principal functions of the systems engineering process are to: 1) determine the appropriate requirements, and 2) verify conformance with those requirements. All systems engineering activities contribute, over the life cycle of the program, to performance of one of these functions. This is summarized in Figure 4-1, which shows the technical baseline evolving from the requirements analyses, and ultimately resulting in the built system. This evolution occurs under the protective umbrella of change control and is supported by a foundation of continual verification.

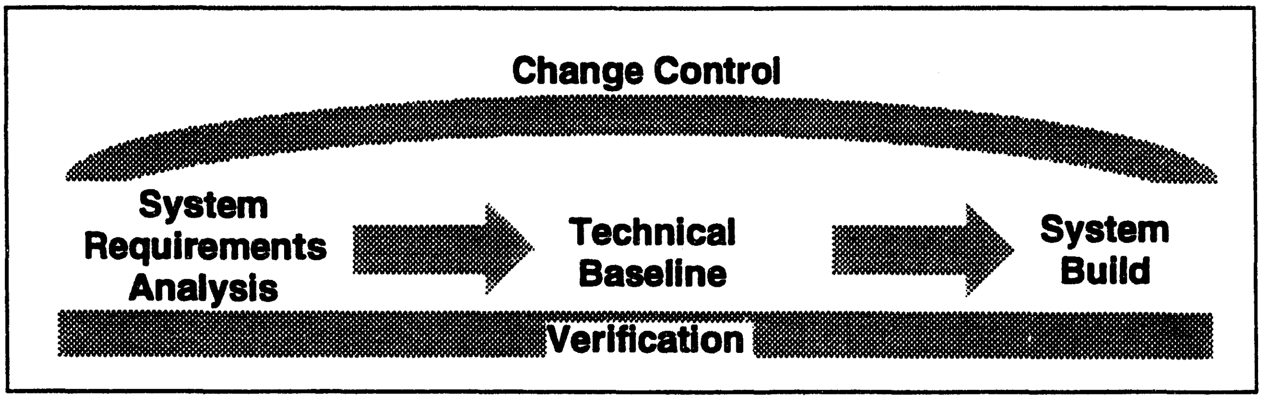

Figure 4-1. Systems Engineering Overview

Initially, the requirements are defined and allocated. Then, as the program matures, emphasis shifts to evaluating change and verifying conformance. The systems engineering process, as it applies to the CRWMS program, is shown in Figure 4-2. It begins with the various components that constitute the systems requirements analysis; proceeds through system design; and results in construction and operation of the system. In addition, because this program has the additional task of obtaining NRC licenses for the major projects, the traditional systems engineering process must be augmented to incorporate licensing considerations and effect a responsive interface between the licensing process and the engineering process. This task is absolutely crucial to program success and will be accomplished by expanding the requirements process to ensure appropriate licensing and institutional requirements and constraints are identified, and tailoring the verification activity to ensure licensing and institutional activities are included. Thus, as depicted in Figure 4-2, the licensing activity is an integral part of the overall process for those projects where it is required.

4.1.1 System Requirements Analysis

The initial step in the systems engineering process is the system requirements analysis, which is an iterative process in itself. It begins with identification of the mission need, program objectives, and regulatory constraints; proceeds through functional analysis and allocation to a conceptual design; integrates specialty engineering and institutional considerations; and provides an initial system architecture. This is evaluated, tradeoffs are considered, alternatives studied, and the process repeated as necessary to result in a final design that best meets system requirements.

4.1.1.1 Functional Analysis and Requirements Allocation

Functional analysis and requirements allocation are key components in the systems engineering process. The identification of system requirements from mission objectives and their allocation to functions and then to configuration items (facilities, hardware, software) is one of the primary functions of systems engineering. The CRWMS top-level requirements and functions were documented in the Waste Management System Requirements (WMSR) documents and, more recently (1991), in the Physical System Requirements (PSR) documents. The requirements in these documents are based on public law, the Code of Federal Regulations (CFR), and DOE orders. The functional requirements baseline, as documented in these requirements documents, was transitioned to the technical requirements baseline. The functional requirements were analyzed and the documentation used to develop the top-level CRWMS Requirements Document (CRD). These analyses and documents were expanded and extended to lower levels of detail; system objectives were analyzed; functions and subfunctions were identified; and technical performance requirements were developed for each function. These were defined in four System Requirements documents: Waste Acceptance, Transportation, MRS, and MGDS. These documents form the technical requirements portion of the technical baseline, and are the top-level requirements for the CRWMS Program. Every requirement and function that affects the system design is decomposed, restated in terms applicable to an engineering specification, and allocated to the specific facility, hardware, or software configuration item(s).

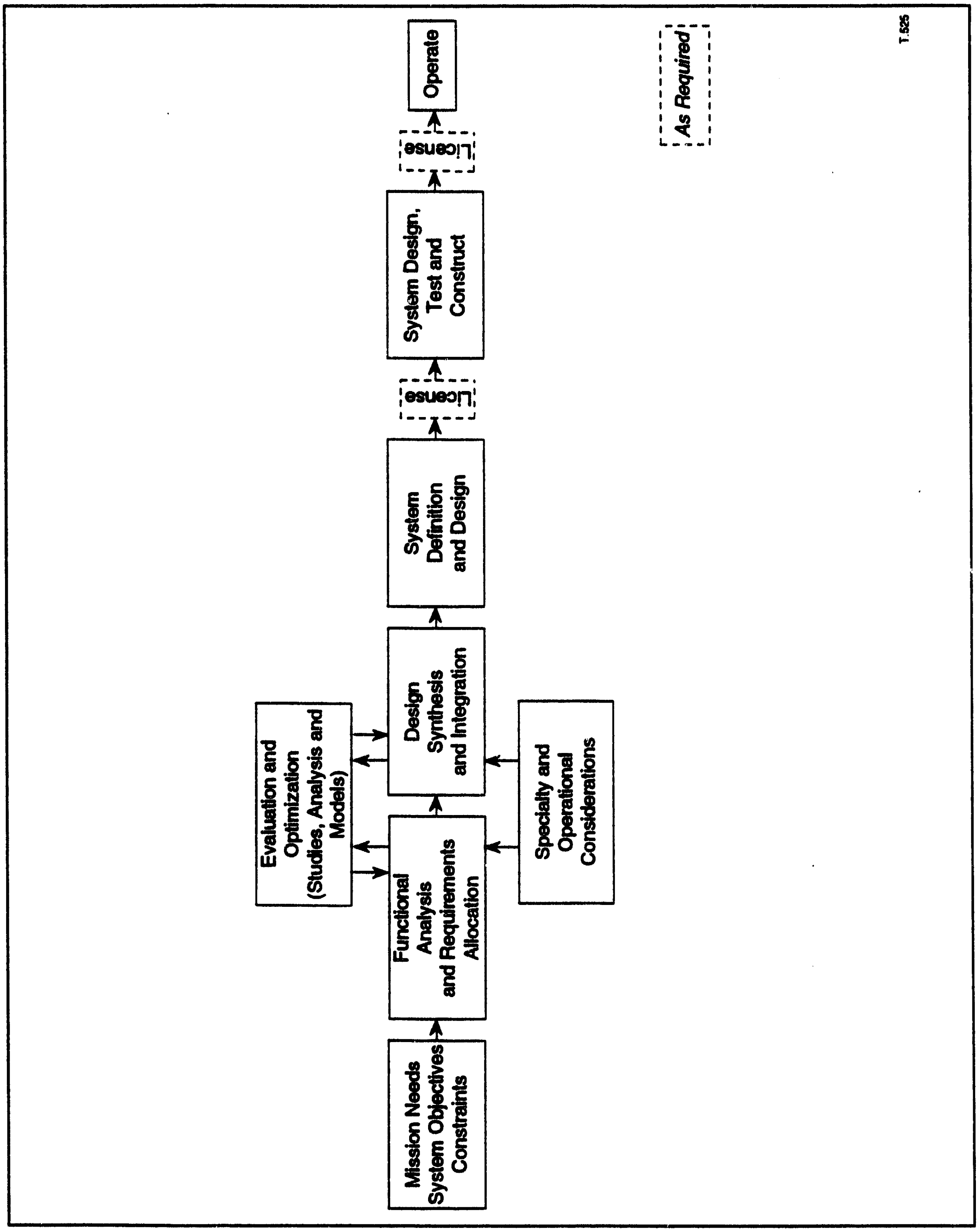

Figure 4-2. Systems Engineering Process

All currently existing requirements are accounted for. The decomposed, restated, and allocated functions and requirements form the basis for design synthesis, system optimization tradeoffs, and cost analyses.

Collectively, these performance requirements describe the complete system at each level. As the functions are decomposed to the next lower level, the number of sub-functions increases, each with its own interfaces. This process continues until the lowest level is reached at which discrete tasks can be satisfied and defined. During the development of the requirements, a Functional Flow Block Diagram (FFBD) is used to depict functional sequences and relationships. The FFBD illustrates the sequential relationship of all functions that must be accomplished by a particular segment of the system, thus defining the interfaces and initiating the interface identification and control process. In this manner, the interfaces between the system segments will be identified, analyzed, allocated, and controlled.

4.1.1.2 Design Synthesis and Integration

Once the top-level system requirements have been identified, and the performance requirements developed and allocated to specific physical components of each system segment, a design concept is created. Specialty considerations (engineering and programmatic) described in Section 4.3 are also identified and integrated into the design synthesis. All system functions must be considered before developing an integrated overall conceptual design. The functional requirements provide the basis for the conceptual design. Then, as the conceptual design is finalized, it is reflected back in the systems requirements document.

4.1.1.3 Evaluation and Optimization

Throughout the requirements analysis and design integration process, evaluation and optimization activities will be performed. Potential cost effective design tradeoffs among stated operational needs, engineering design, project schedule and budget, affordability, and life-cycle costs will be identified and evaluated. Tradeoff studies will evaluate design alternatives to satisfy the allocated functional performance requirements and provide a documented systems engineering basis for selecting the optimum design. System effectiveness and value engineering analyses will be conducted to ensure that engineering decisions resulting from tradeoff studies of alternative concepts or designs are made only after consideration of overall impact on system effectiveness and program cost and schedule. System studies will be conducted and models will be developed to support these evaluations.

4.1.1.4 System Definition and Design

After the conceptual design is determined, as described above, that design is reflected in the top-level system requirements documents. Not every detail of the conceptual design becomes part of the system requirements, only those that need to be controlled at the program level and that complete the documentation of the System Requirements Document. The focus of the systems engineering process is then directed at defining the optimized system in a series of project-level design requirements documents and design specifications. Design packages resulting from these documents portray the performance, configuration, and arrangement of the chosen system in suitable forms that include schematic diagrams, models, drawings, and manuals. These documents define system and configuration item interfaces, permit requirements traceability, and provide a means for comprehensive change control.

4.1.1.4.1 Requirements Traceability

Requirements traceability is a critical aspect of the documented systems engineering process. Traceability must exist in both directions (top down and bottom up) through all levels of requirements and specifications, and throughout the design and test documentation. Traceability ensures that the impact of changes to requirements at any level can be reviewed for impact on the total system. During synthesis, the system architecture is defined to satisfy the functional performance requirements. After synthesis, all design data are identified by reference to a configuration item (CI) number. Once requirements relationships are established, they are maintained in an automated relational data base management system. Other basic traceability tools include specification matrices, configuration management documents, and similar record documentation systems.

4.1.1.4.2 Interface Management

The CRWMS interfaces are classified as either: (1) Program Interfaces or (2) Project Interfaces. The Program interfaces are defined as any interface whose functions and/or influence extend outside a single CRWMS program element. For example, program interfaces are those interfaces that exist between two or more CRWMS elements (Waste Acceptance, Transportation, Monitored Retrievable Storage, Mined Geologic Disposal System) or between a program element and an external entity. A project interface is defined as any interface whose functions and/or influence are contained solely within a single CRWMS program element. An example of a project interface is the MRS transfer cell to the storage mode (storage cask).

The program level interfaces will be identified and described in one Interface Specification (IFS) document and the associated system element interface requirements will be defined in the appropriate System Requirements Document (SRD). The detail design of interfaces will be developed in specifications, drawings, etc., and documented in Interface Control Documents (ICDs). The ICDs are the implementation of the interface requirements established in the SRDs. The interface process, including ICDs, shall be managed by the Interface Control Working Groups (ICWGs), approved by appropriate BCCBs, (PBCCB for program level documents and POBCCB for project level documents), and controlled in accordance with the Baseline Management Plan. The role, composition, and operation of the ICWG will be established in the ICWG Charter.

Project ICWGs will be established to identify, document, and manage interfaces at the project level. The Project Offices shall develop procedures to implement interface control in accordance with this SEMP and OCRWM implementing procedures.

4.1.2 Licensing

Licensing is the cumulative process of activities to ensure that the licensing requirements are met and that the completed License Application (LA) and the companion Safety Analysis Report (SAR) will satisfy NRC requirements and will result in the issuance of a license. This includes demonstration of compliance with all regulatory requirements, including the Environmental Impact Statement, as part of the submission to the NRC.

The OCRWM-M&O licensing team will develop, in stages, an Annotated Outline (AO) for potential LAs. This will involve the preparation of progressively more detailed drafts (of these AOs) that will be provided to the NRC staff for information and guidance. As issues arise, they will be identified and evaluated in the Annotated Outline/Issue Resolution Initiative process. This process involves iterative interactions between the NRC staff and the OCRWM. It will lead to a shared understanding between OCRWM and the NRC of the requirements and the interpretation of the regulations. The Annotated Outline Initiative will evolve into the completed license application if a suitable site is found.

To successfully accomplish the objectives of the licensing process, that process must be integrated with the systems engineering process. Regulatory requirements must be analyzed and identified for incorporation in the technical requirements baseline. Subsequent compliance with these requirements must be verified and demonstrated to the NRC in the LA.

Development of the licensing documentation is fully integrated with the system engineering process, including coordination of the licensing and systems engineering milestones. Particular emphasis will be placed on the safety engineering program to ensure safety is built into the design, and that the systems safety and hazards analysis effort is responsive to the needs of the Safety Analysis Report. In addition, to provide assurance that the CRWMS does not pose an unacceptable risk to public and environmental health and safety, models will be used to predict system behavior to support the license applications. The use of models is necessary where no direct means exist to assess the behavior of a system of this projected size over the time scales involved in its functional lifetime.

Integrating the systems engineering process with the cumulative licensing process is essential in order to be able to adapt to changes in technical capabilities or in the interpretation or application of regulatory requirements. The potential for negotiated or redefined understandings of regulatory requirements emphasizes the need for strict adherence to a systematic approach to requirements analysis, requirements traceability, and configuration management.

4.1.2.1 Systems Engineering, Acquisition, and Licensing Integration

The traditional systems engineering process of integrated technical reviews and acquisition milestones throughout the design process does not account for licensing considerations. Licensing considerations, however, are of critical importance to this program. Accordingly, licensing activities must be incorporated in the systems engineering process and licensing milestones must be integrated with the design process to ensure their appropriate consideration in the CRWMS development program and to provide the proper support to the licensing effort.

Furthermore, the normal acquisition process, featuring three distinct design phases (conceptual, preliminary or Title I, and detailed or Title II) linked to specified Key Decision milestones, is not completely compatible with the integrated systems engineering-licensing process necessary for successful implementation of the CRWMS development program. Key Decision (KD)2 at the transition from the preliminary or Title I design phase to the detailed or Title II design phase and KD3 at the completion of detailed design and prior to the start of construction are primarily defined as such to ensure that proper Headquarters visibility and ESAAB action are effected prior to all major commitments of resources for a project. But projects requiring NRC licensing do not lend themselves to this traditional sequencing of design phases and decision points for significant expenditures of funds. The License Application (LA) and the Safety Analysis Report (SAR) submitted to the NRC must be based on a detailed design of the structure, systems, and components important to safety. Other parts of the design, however, do not need to be at that degree of detail. Accordingly, for projects subject to licensing, after KD1 the design will be accomplished in two phases different from the normal acquisition process. The first of these two phases will combine the preliminary and detailed designs for the structure, systems, and components important to safety and will be called the License Application Design for the MGDS and the Safety Analysis Report Design for the MRS facility. The second phase will complete the detailed design of all other structure, systems, and components. This final design will be called the Final Procurement and Construction Design (FP&C Design). Thus, KD2 will occur after LA (or SAR) Design and KD3 will occur after FP&C Design.

Figure 4-3 depicts this integration of licensing activities with the systems engineering process and the relationship of these activities to the milestones and design phases in the normal acquisition process. The KD2 point for the MGDS and MRS facility acquisitions is shown as (KD2) on Figure 4-3. The MGDS and MRS system elements have similar design phases albeit different names; both focus on the license application and the key design milestones. However, they are subject to slightly different licensing processes. The MRS involves a one-step licensing process in which the license is to be received prior to the start of construction. The MGDS will be a two-step process. The first licensing milestone after license application will be the issuance of a construction authorization before construction starts. The second step will be the license that will authorize the receipt of waste.

The development programs of the ESF, Transportation, and Waste Acceptance activities shall be conducted in accordance with normal acquisition procedures (depicted in Figure 4-3). The details of how the projects will implement these procedures will be documented in project-level plans. It is recognized that some deviations are necessary to support the unique systems engineering milestones associated with the licensing processes for either the MGDS or the MRS facility development programs.

The technical reviews and other systems engineering activities, shown in Figure 4-3, will be described in Section 4.2.

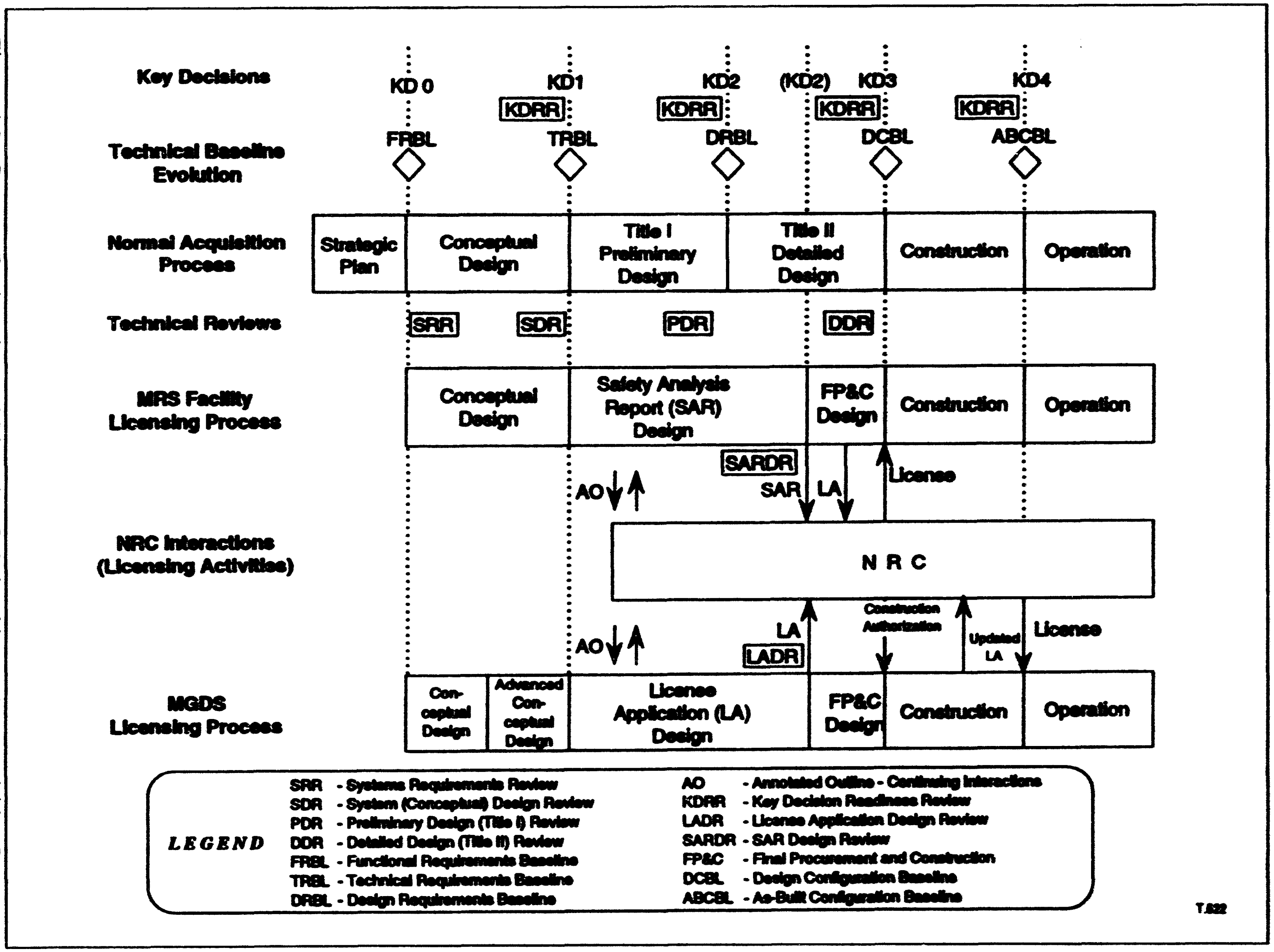

Figure 4-3. Systems Engineering and Licensing Relationships to the Acquisition Process

4.1.3 System Design, Test, Construct, and Operate

After the top-level system requirements documents are approved, the projects evolve the system requirements into design requirements in order to create the preliminary (Title I) design. Design proceeds through the various phases of the acquisition process and Key Decision milestones as illustrated in Figure 4-3. Testing is initiated in accordance with the Test and Evaluation Master Plan as part of the verification process, which is described in detail in Section 4.2.3. After Detailed Design (Title II) is approved, and any required license is issued, construction begins. The next major phase is the operations phase, which follows construction, and issuance of the license to operate. Systems engineering activities continue during all these phases. Construction management, operational testing, configuration audits, and as-built specification development are examples of the types of activities that are on-going throughout this period.

4.2 TECHNICAL BASELINE PLANNING AND CONTROL

This section describes the contents of the technical baseline and the technical planning and control activities for the design, development, test, and evaluation of CRWMS. A summary of the technical baseline hierarchy for each MSA is presented in each Project Plan.

4.2.1 Technical Baseline

All technical requirements for design and site characterization as well as the design specifications and configuration are contained in the technical baseline. The technical baseline is the reference set of technical data and requirements and is controlled, using procedures described in the Baseline Management Plan discussed later in Section 4.2.3.3, by the PBCCB at the program level and the POBCCB at the project level. All documents in the technical baseline related to structures, systems, and components important to safety and waste isolation are quality affecting and will be prepared in accordance with the applicable QA procedures. Figure 4-4 highlights the program technical baseline documents and the top tier of the project documentation as depicted on the OCRWM Document Hierarchy. Each project will develop design requirements and related documentation in increasing levels of detail as the technical baseline evolves, based on specific project needs, to the final design specifications and then to the as built documentation that describes the system at KD4 after construction. The development of the technical baseline is governed by this program SEMP.

The technical baseline consists of five interrelated stages, each with its associated documentation:

1. The functional requirements baseline
2. The technical requirements baseline
3. The design requirements baseline
4. The design configuration baseline
5. The as-built configuration baseline.

The initial technical baseline was the Functional Requirements Baseline. It included the requirements identified from external laws and regulations and derived from the functional

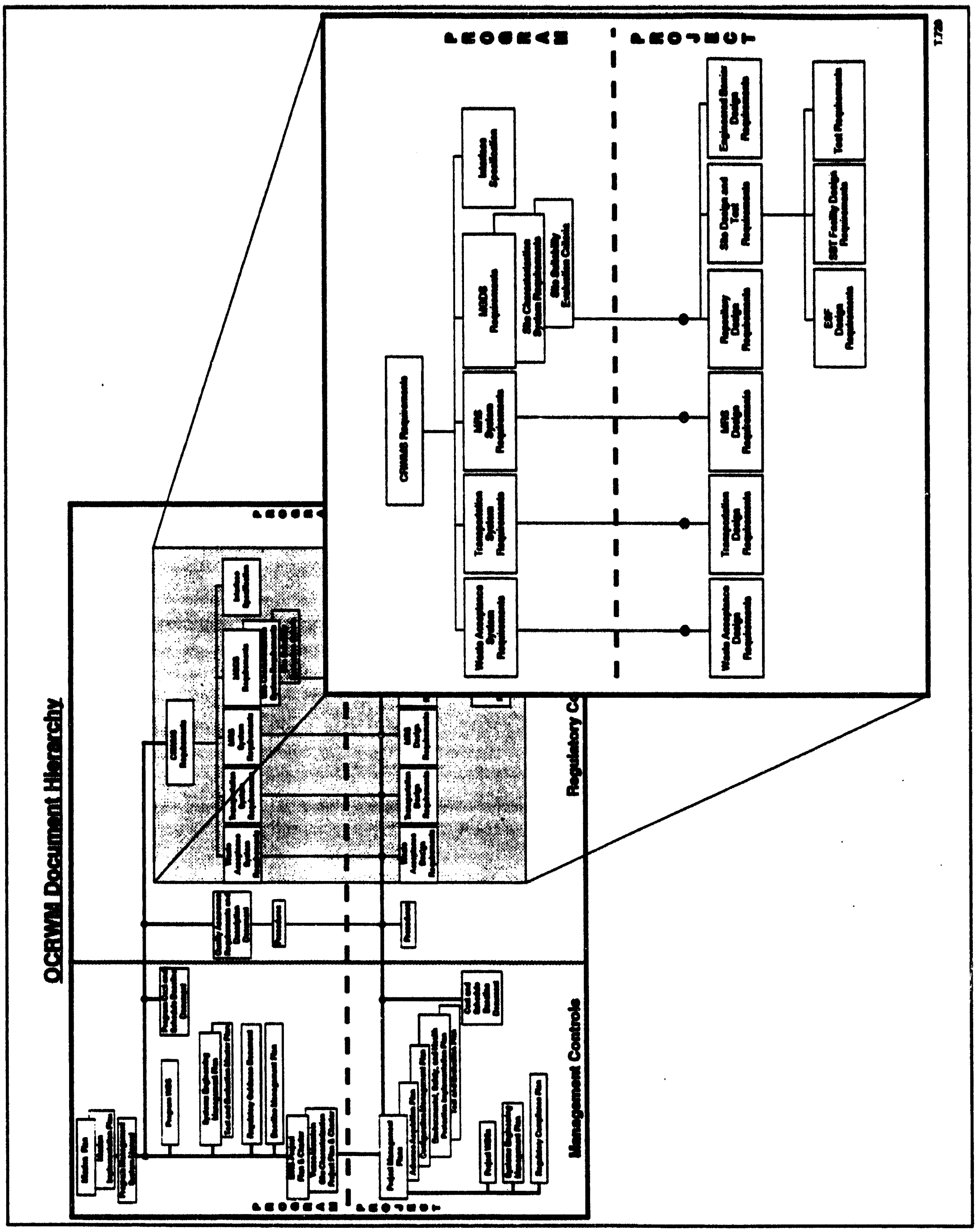

Figure 4-4. Technical Baseline Hierarchy

analysis of the OCRWM mission need. The functional requirements baseline was the key first step in the design process for the two CRWMS Major System Acquisitions in that it provided the necessary basis for the start of conceptual design. The functional requirements baseline consisted of the WMSR Vol I, WMSR Vol IV, and Waste Management System Description documents to support the Yucca Mountain Site Characterization MSA and the Physical System Requirements (PSR) documents (including the PSR-Overall System, PSR-Accept Waste, PSR-Transport Waste, and PSR-Store Waste documents) to support the MRS Project MSA. The functional requirements baseline documents were superseded and archived upon approval by the PBCCB of the System Requirements Documents shown on the OCRWM Document Hierarchy illustrated in Figure 4-4. Requirements traceability will be maintained through the baseline document structure as shown in that Figure. The technical baseline will evolve as depicted in Figure 4-4 and amplified in Figure 4-5.

The **technical requirements baseline**, shown in Figure 4-5, consists of five System Requirements Documents: the CRWMS Requirements Document, Waste Acceptance System Requirements Document, Transportation System Requirements Document, MRS System Requirements Document, MGDS Requirements Document (which includes the Site Characterization System Requirements and the Site Suitability Evaluation Criteria), and the Interface Specification document.

The CRWMS Requirements Document (CRD) is the top-level document in the technical requirements baseline. It identifies the functions required of the system to meet mission objectives, specify performance levels, and identify the controlled interfaces. It also define the system elements and the requirements allocated to each element. The CRD include the ESAAB level-0 scope baseline for each project. The System Requirements Documents (SRDs), which are subordinate to the CRD, define the functions and configuration items to a lower level of detail than the CRD. They state the technical requirements of the particular system element, allocate system-specific requirements to functional areas, document design constraints, and define interfaces between and among functional areas. Additionally, they specify the requirements for the characteristics, logistics, design, verification, and delivery of the system. They also provide a general overview of the system elements that may be required by trainers, support personnel, and other users of the system elements. The technical requirements baseline is the basis for initiating preliminary (Title I) design and subsequent system development.

The Interface Specification (IFS), also part of the technical requirements baseline, identifies and describes the functional and physical interfaces between the system elements. These interfaces are: Waste Acceptance System - Transportation, MRS - Transportation, MGDS - Transportation, MGDS - MRS, Waste Acceptance System - MRS, and Waste Acceptance System - MGDS. For each system element the IFS will describe the interfaces with each other system element in order to properly design, develop, test, evaluate, and operate the system element. The interface requirements associated with each system element are defined in the appropriate SRD described above. The implementation of interface requirements will be developed in specifications, drawings, etc., and documented in Interface Control Documents (ICDs). The ICDs represent the agreement of the interfacing design organizations.

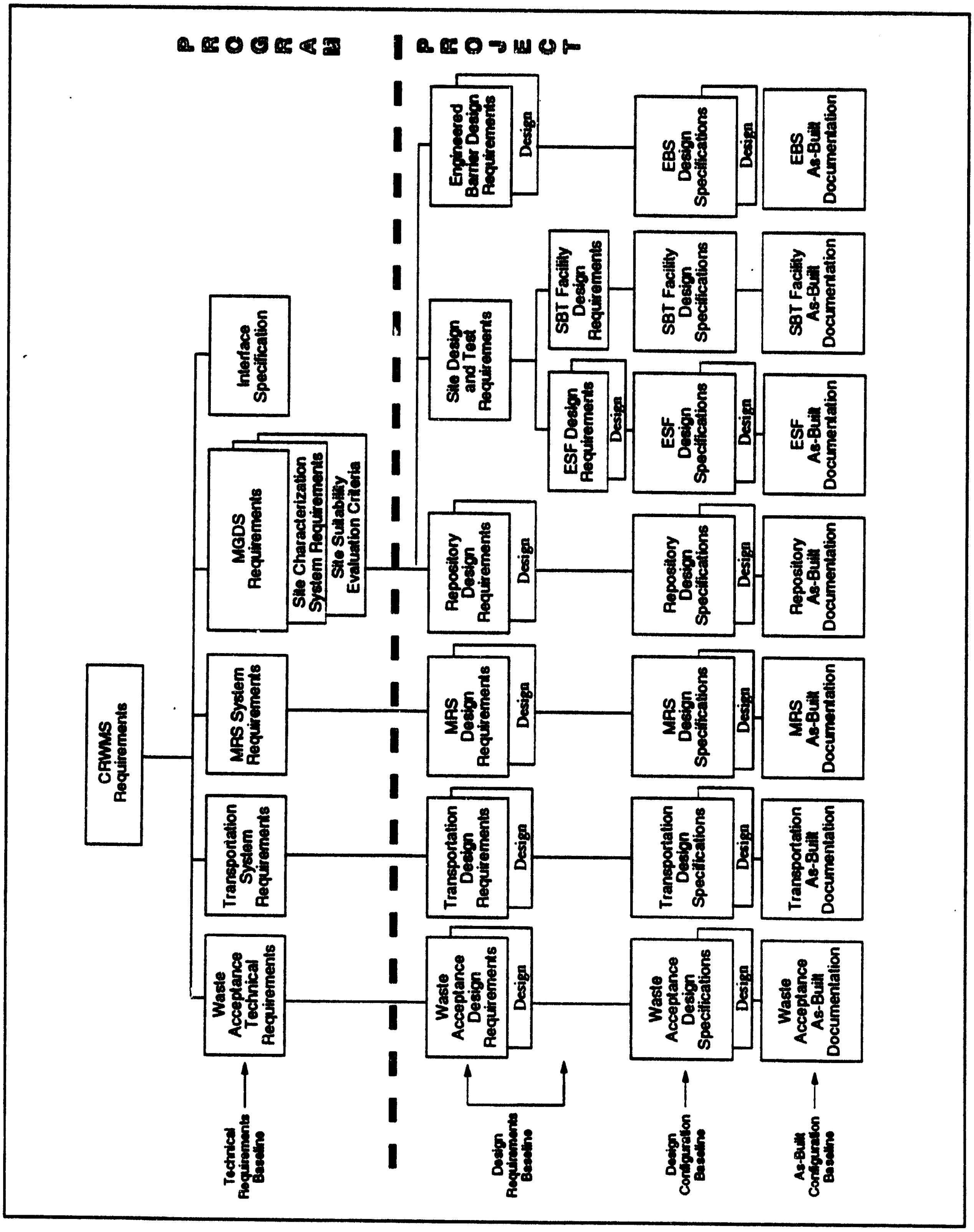

Figure 4-5. Technical Baseline Evolution

Interfaces between system elements will be documented in inter-element ICDs controlled at the program level. Interfaces within a system element are documented as intra-element ICDs and managed at the project level.

The **design requirements baseline** consists of the Design Requirements Documents and the corresponding preliminary (or Title I) design packages. It is established at the completion of preliminary design. A Design Requirements Document (DRD) will be developed at the project level in response to the System Requirements Document for each system element (Waste Acceptance, Transportation, MRS, and MGDS). The design requirements documents will expand on each functional requirement allocated to a particular system element; apportion the requirements to specific components of each element; and delineate additional requirements, performance criteria, and constraints that reflect design decisions concerning system requirements implementation. These design requirements documents will be part of the project-level technical baseline. They will be developed by the cognizant project manager and controlled by the respective Project Office Baseline Change Control Board (POBCCB). Upon approval, the design requirements baseline becomes the basis for detailed design.

The **design configuration baseline**, resulting from completion of detailed design, consists of the Design Specifications and the detailed (Title II or FP&C) design packages. Upon approval, it is the basis for start of construction. The design configuration baseline documents will provide all the details of the design necessary for fabrication, assembly, construction, installation, and testing of the facilities and equipment. They will include specifications and final drawings, quality assurance provisions, test procedures and operations and maintenance manuals. Each design configuration baseline document will demonstrate design specification traceability through the design requirements to those contained in the appropriate higher level requirements document. A design configuration baseline document will be developed for each system element. These documents will be developed by the cognizant project manager, and controlled by the respective POBCCB.

The **as-built configuration baseline** consists of the as-built documentation including the as-built design packages and specifications. Upon approval, it is the technical basis for the start of operation. The as-built configuration baseline documents will be updates of the respective design configuration baseline documents. They will reflect changes to the design configuration resulting from deviations and waivers granted during construction, equipment upgrade or replacement, procedure modifications, and in-situ test data, etc. The as-built configuration baseline will be updated throughout the life of the system to reflect the actual system configuration. The as-built configuration baseline documents will be developed by the cognizant project manager and controlled by the respective POBCCB.

Figure 4-5 portrays the evolution of the technical baseline over the life of the program by illustrating the different stages as they would exist upon approval of a particular system element's requirements and design documentation at the end of a specific design phase. The design documentation in the design requirements baseline is the preliminary (or Title I) design. The detailed design (Title II or the FP&C Design) is part of the design configuration baseline. The technical baseline evolves through the various stages along with the design process. The technical baseline develops so that after it is complete, and all cross checks and reviews have been done, it will consist of a top-down set of requirements and design configuration decisions in which all subsidiary requirements flow down from the requirements above them, and the decisions on the selection of systems or components are necessary and sufficient to meet all the requirements. The technical baseline shall include the functions, requirements, and architecture for the system as a whole, system elements, and subsystems.

The evolution of the technical baseline from one design phase to another reflects the progress of the system development from mission need and concept to final design, construction and subsequent operation. As each stage of the technical baseline is accomplished, it is reviewed, evaluated, and approved in accordance with the appropriate baseline change control procedures. Figure 4-6 presents another illustration of this evolution by depicting the application of the systems engineering process to the acquisition phases. Figure 4-6 shows the functional requirements baseline (FRBL) progressing through the various design phases to the technical requirements baseline (TRBL), the design requirements baseline (DRBL), the design configuration baseline (DCBL), and, finally, the as-built configuration baseline (ABCBL). This figure also shows the relationship of the requirements and design documentation with these technical baseline stages.

Figure 4-7 depicts this evolution of the technical baseline by pictorially describing the development of each stage. The concurrent development and interaction of each design and its related requirements or specifications document is illustrated as the technical baseline is developed over the life of the system.

4.2.2 Systems Engineering Planning

In order to ensure that systems engineering activities are accomplished in a coherent and timely manner responsive to the overall needs of the program, a schedule of systems engineering activities will be developed to track progress in accomplishing systems engineering objectives. These systems engineering activities will be planned and documented, and systems engineering studies will be conducted to help resolve key technical issues.

4.2.2.1 Systems Integration and Compliance Network

The System Integration and Compliance Network will be used to plan and schedule all major systems engineering activities. By so doing, it provides management with a quantitative tool to measure and evaluate progress of technical events and systems engineering milestones. This network will help provide overall visibility into systems engineering tasks. It will be used as the basis for the progressive definition and control of the systems engineering process. It includes a logical sequence of the following systems engineering activities: systems requirements analysis/definition, performance confirmation, technical reviews, and audits. It shall provide technical inputs into engineering and program decision points, demonstrations, reviews, and other identified events. At a minimum, all the milestones shown earlier in Figure 4-3 will be captured. It will be updated at least monthly, and incorporated into quarterly systems engineering management reviews.

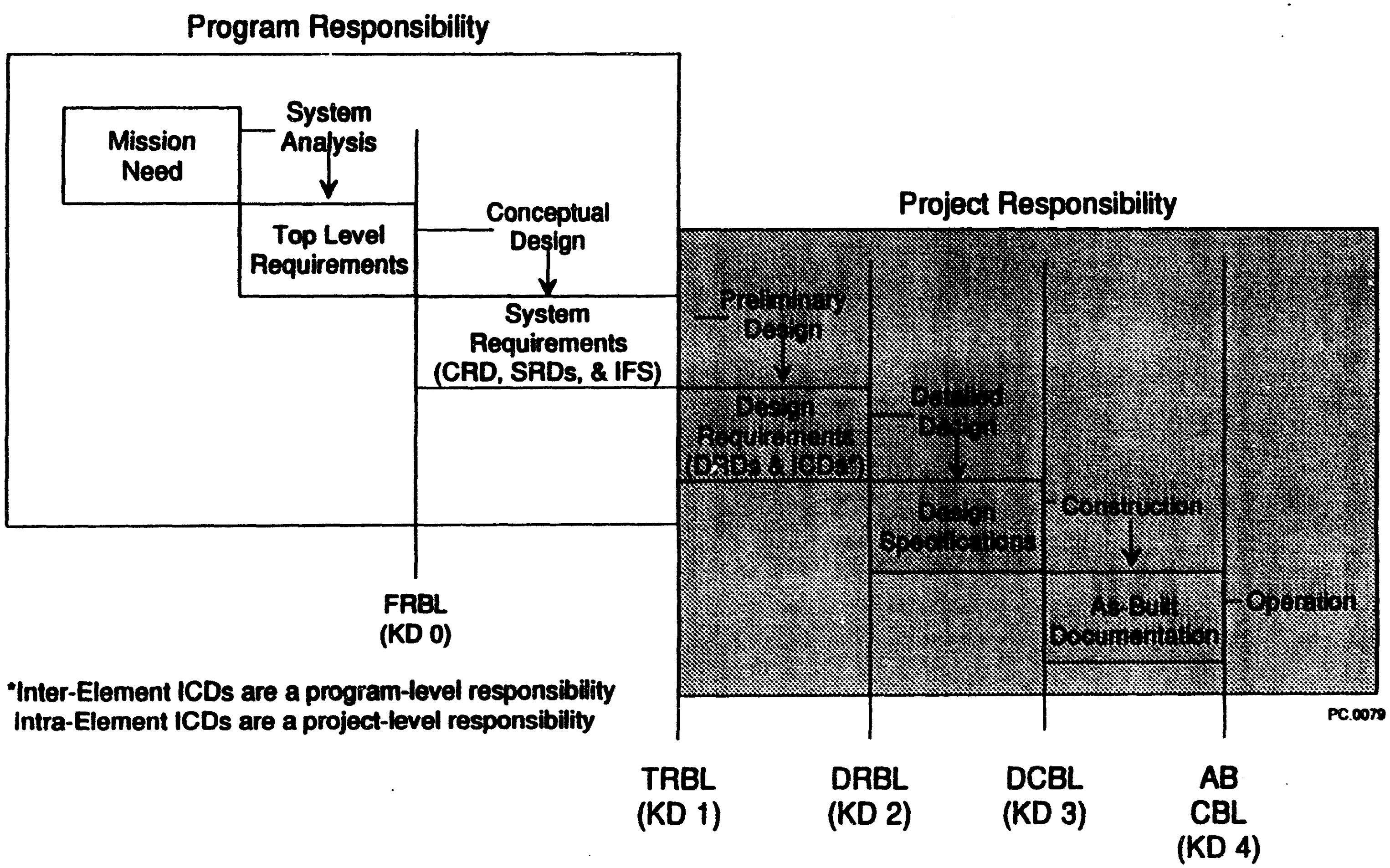

Figure 4-6. Application of Systems Engineering Process to Acquisition Phases

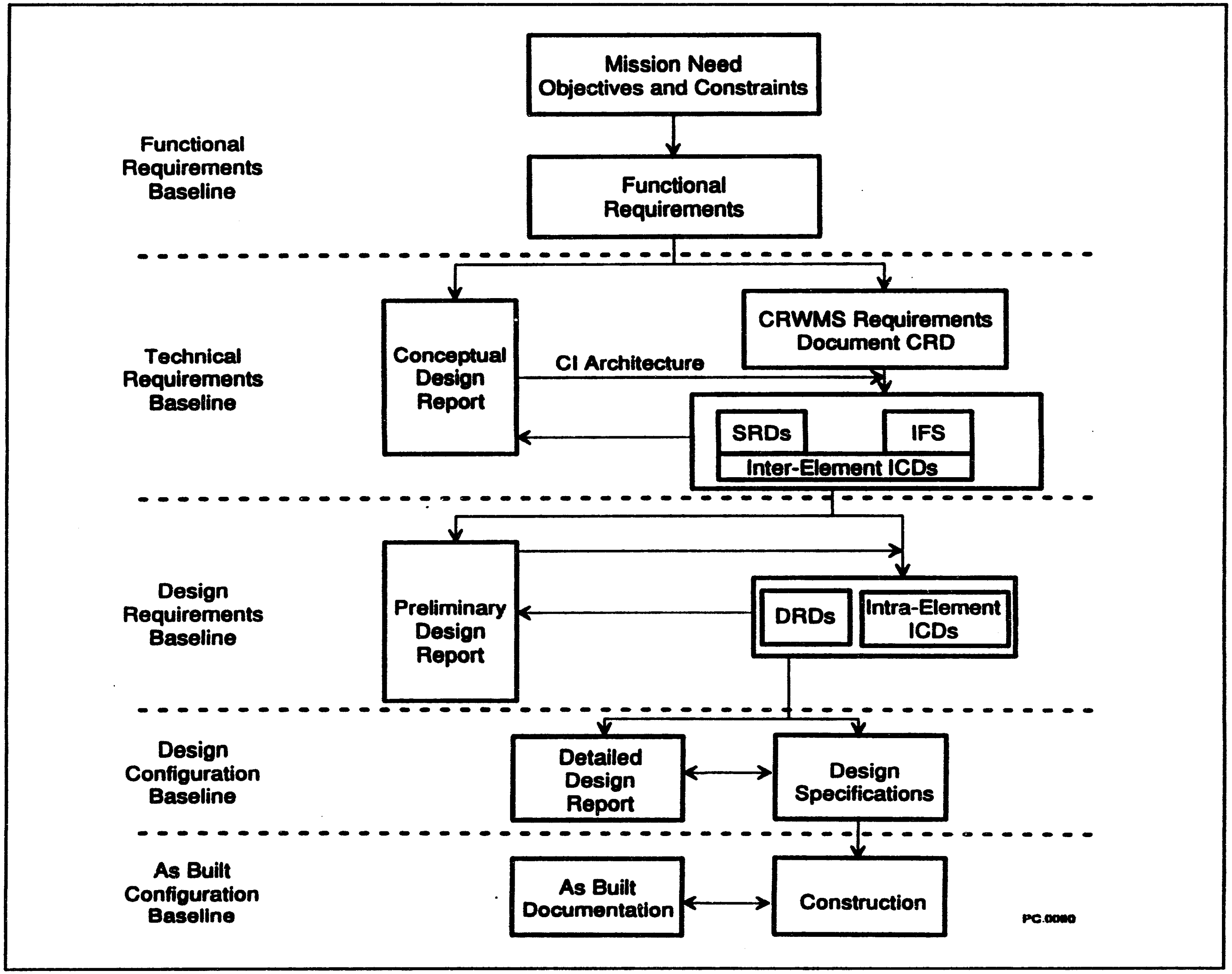

Figure 4-7. Technical Baseline Development

4.2.2.2 Systems Engineering Documentation

The OCRWM SEMP is the top-level systems engineering management document. Each project manager is also responsible for developing a project SEMP. Project SEMPs will be prepared in accordance with DOE Order 4700.1 and this program SEMP, but may be tailored in content, detail, and format consistent with the specific scope, nature, and complexity of the project. Project SEMPs shall be approved by the appropriate POBCCB and reviewed by the ADSC. As a minimum, a project SEMP shall identify the following:

- The approach to be used for implementing systems engineering within the project consistent with program guidance.
- The organizational structure and responsibilities for implementing the systems engineering effort, including the responsibilities of the project office and its contractors
- The approach to risk management, trade studies, and Technical Performance Measurement (TPM)
- The documents that constitute the project technical baseline
- Program and project review to be conducted to ensure adherence to the technical baseline. This will include the scope, frequency, and organizational responsibilities for participation and presentation
- Documentation to be developed and maintained, including organizational responsibility for development, review, approval, and the contents of such documents
- Systems engineering milestones.

In addition to the SEMP and technical baseline documents described in Section 4.2.1, there are a number of other planning documents discussed throughout this plan. These documents are listed in the Table 4-1, with a reference to show where the document is discussed in this SEMP.

4.2.2.3 Systems Studies

Systems studies are conducted at the program and project levels to provide input for the resolution of key issues concerning system configuration, system performance, functional allocations, system interfaces, resource allocation, scoping information or policy decisions.

A system study may be quality-affecting, based on its intended use. System studies used to determine or establish system/design requirements for safety related systems will be subject to the QA procedures that are appropriate for the particular application, in accordance with the Quality Assurance Requirements and Description document (QARD).

Table 4-1. Systems Engineering Planning Documentation

DOCUMENT	SEMP REFERENCE
Project Systems Engineering Management Plan	2.1, 4.2.2.2
Systems Studies Plan	4.2.2.3
Risk Management Plan	4.2.3.2
Baseline Management Plan	4.2.3.3
Test and Evaluation Master Plan	4.2.3.4
Regulatory Guidance Document (RGD)	4.2.3.7, 4.3.2.1
Regulatory Compliance Plan	4.2.3.7, 4.3.2.1
Engineering Specialty Plans (SEMP & RGD appendices)	4.3.1

A Systems Studies Plan will be developed that provides a methodical approach to the definition and implementation of timely systems studies. Results of these studies will provide a sound engineering basis for reaching system decisions. The Systems Studies Plan will include the following information:

- Description of the scope of systems studies
- Identification of the major decisions required to accomplish program objectives and the major pieces of information required to support these decisions
- A schedule showing when studies are required in relation to other program activities
- A record of completed, ongoing, and planned systems studies.

The plan will be updated periodically to ensure that the information needed to support decision making and to resolve technical issues will be available when needed. Each project will develop a Studies Plan that performs the same function as the program Systems Studies Plan for project-level activities.

System study reports will be developed at the program and project levels to document the results of analyses of: system functions and requirements; system design, development, and operation; system alternatives; system costs; risk and impact assessments; and other system related issues as necessary. The contents of a System Study Report may be the result of a specific analysis or may be derived from extracts of working papers, internal memoranda, minutes of meeting, presentation charts, and formal reports.

4.2.3 Conformance Verification Process

Conformance verification is the means by which technical control is implemented in the systems engineering process to ensure conformance with regulatory and technical requirements. Conformance with regulatory, technical, and design requirements must be evaluated and verified. Changes must be evaluated, controlled, and documented. Change control is achieved through adherence to a disciplined change control process, described in a comprehensive Baseline Change Control Procedure. Program progress must be measured and verified with particular emphasis on regulatory compliance to ensure the CRWMS is granted the necessary licenses. Verification is achieved through the following activities: technical reviews, risk management, baseline management, test and evaluation, model validation, software control, integrated regulatory compliance, and performance assessment. These separate activities act synergistically to constitute the verification process. These activities are described in the following paragraphs.

4.2.3.1 Technical Reviews

Technical reviews will be conducted to assess the development of the technical baseline. These reviews are in accordance with the guidance of DOE Order 4700.1, and will verify conformance with system requirements (at the program level) and design requirements or specifications (at the project level).

The first four reviews described below are the principal means by which the OSC manages the systems engineering process at the program level, and provides the verification needed to establish program integrity for the Director, OCRWM. These reviews will be organized by the OSC and involve both program- and project-level participation. The Director, OCRWM, (or his designee) will chair these reviews. The M&O General Manager will participate in these reviews to ensure the consistency and technical adequacy of the M&O involvement.

1) System Requirements Review (SRR). This review is conducted to ascertain progress in defining system requirements and to evaluate the technical adequacy of those requirements. It also assesses the adequacy of mutual understanding across the program about these requirements. Management agreement on the set of system-level functions to be implemented is required prior to initiating the functional analysis and allocation process described in Section 4.1.1.1.

2) System (Conceptual) Design Review (SDR). This program level review is conducted to: (a) evaluate the system requirements for adequacy and risk; (b) ensure a mutual understanding among all program participants of the system requirements and the corresponding conceptual design; (c) assess the engineering process that produced the system requirements; and (d) provide a forum to adjudicate comments.

   The SDR is the focal point of the program-level review of the system requirements and, at the same time, evaluates the conceptual design. The SDR serves as the technical review prerequisite required prior to PBCCB approval of the conceptual design report. After technical document review in accordance with applicable QA procedures, each systems requirements document will be presented at the SDR by the systems engineering personnel responsible for development of the technical requirements. At the same time, the project will present the conceptual design for review and verification of conformance with the system requirements. Thus, the SDR validates the systems requirements documents and the conceptual design. After successful completion of the SDR, the ADSC will submit the SRD to the PBCCB.

3) Key Decision Readiness Reviews (KDRR). These reviews will be conducted at the program level after the applicable project design review (discussed below) and before each key decision point. These reviews will provide the Director, OCRWM, the information and assurance necessary to establish program readiness to satisfactorily meet Energy System Acquisition Advisory Board (ESAAB) and ICE prerequisites. Each KDRR will verify that: (a) these prerequisites and programmatic requirements for the start of the next design phase or acquisition activity have been completed; (b) the current design conforms to specified requirements; (c) applicable QA controls and procedures related to the next phase of work have been developed and reviewed for adequacy and appropriateness; and (d) facilities and other resources will be available on schedule.

4) In-Process Reviews (IPR). In the event there are no key decisions or expanded decision points in any given year for a project, an in-process review shall be performed. This review (also referred to as the Energy System Acquisition Review) will provide the Director, OCRWM, with the current project status and evaluation of project cost, schedule, and technical performance against current baselines.

In addition, other reviews will be conducted at the project level by the Associate Director (AD) responsible for the appropriate system element. These shall include, but are not limited to:

5) Preliminary (Title I) Design Review (PDR). This review is conducted to: (a) verify design conformance with system requirements; (b) document the design requirements that describe the design; (c) evaluate the technical adequacy and risk resolution of the selected design; (d) establish the existence and compatibility of the physical and functional interfaces among facilities, hardware, software, personnel, and procedures; and (e) assess progress to determine project readiness to successfully meet ESAAB review. This review may, at the discretion of the Director, OCRWM, and the appropriate AD, be concurrent with the KDRR described in 3) above. Completion of the PDR and successful POBCCB approval of the design requirements establishes the design requirements baseline and provides the basis for the detailed (Title II) design. Portions of reviews performed for QA design verification may be used in support of this review.

6) License Application/Safety Analysis Report Design Review (LADR/SARDR). This review is only applicable to the design efforts of the MGDS (for the License Application Design) and the MRS Facility (for the Safety Analysis Report Design). It is conducted at the completion of that design phase (detailed design of the structure, systems, and components important to safety) to: (a) verify conformance with the design requirements for those design features pertinent to the license application/safety analysis report; (b) evaluate the adequacy of the detailed design of the structure, systems, and components important to safety; (c) document the design specifications that describe the design; and

(d) assess progress to determine project readiness to successfully meet ESAAB review (Key Decision 2).

7) Detailed (Title II) Design Review (DDR). This review is conducted to: (a) verify design conformance with the design requirements; (b) document the design specifications that describe the design; (c) evaluate the adequacy of the detailed design; (d) assess design producibility and risk areas; and (e) assess progress to determine project readiness to successfully meet ESAAB review. This review may, at the discretion of the Director, OCRWM, and the appropriate AD, be concurrent with the KDRR described in 3) above. Completion of the DDR and successful POBCCB approval of the design specifications establishes the design configuration baseline. Portions of reviews performed for QA design verification may be used in support of this review.

   Note: The Final Procurement and Construction Design for the MGDS and the MRS Facility is equivalent to the Detailed Design in that it completes the detailed design for the MGDS and the MRS Facility by including all the design features not part of the License Application/Safety Analysis Report Design.

8) As-Built (Title III) Design Review. Following completion of facility construction, the Project Manager may choose to conduct a design review of the "as-built system". Currently, DOE Order 4700.1 only requires an inspection and acceptance testing at this phase; however, the as-built system should be reviewed against the final technical baseline to ensure conformance with the NRC licensing considerations and to support the key decision readiness review for facility operation approval.

9) Milestone Review. This review is conducted periodically during the design process, at the project manager's discretion, to ascertain the status of technical progress, cost, schedule, or attainment of project objectives. It would normally be scheduled at some predetermined project milestone or design completion point.

10) Peer Review. These reviews will be conducted to evaluate work when the adequacy of information or the suitability of procedures and methods cannot otherwise be established through testing, calculations, or reference using previously accepted standards and practices. For example, a Peer Review may be called when novel or unprecedented testing, procedures, or analyses will be used. These reviews will be conducted, in accordance with QA procedures, by technically qualified personnel who are independent of those who performed the work but who have technical expertise at least equivalent to those who performed the original work.

4.2.3.2 Risk Management

Risk Management (RM) is the method used to identify, analyze, and mitigate deviations from pre-established technical, cost, and schedule parameters. RM is not executed by itself; it is integrated with established systems engineering management techniques such as test and evaluation, technical performance measurement, and performance assessment (described in subsequent paragraphs). RM includes several related actions:

1) Risk Planning. Risk planning is the process of organizing an approach to eliminating, minimizing, or containing the effects of undesirable occurrences.

2) Risk Assessment. Risk assessment is the process of identifying areas of potential risk, and prioritizing these risks.

3) Risk Analysis. Risk analysis requires conducting an analysis to determine the probability of events and the consequences associated with the potential actions that could affect the program. The purpose of risk analysis is to discover the cause, effects, and magnitude of the risk perceived, and to develop and examine alternative options.

4) Risk Handling. Risk handling includes techniques and methods developed to reduce or control the risk.

Risk Management for CRWMS will begin during the earliest stages of engineering design and continue through program development, test, licensing, operation, closure, and decommissioning.

A program Risk Management Plan will be developed to define the process for planning and managing technical, cost and schedule risks, risks common to more than one project, risks concerned with the interfaces between projects, and all risks with potential consequences that exceed predetermined thresholds.

4.2.3.3 Baseline Management - Configuration Management

Configuration Management (CM) is the component of Baseline Management that ensures that technical requirements are clearly identified and maintained throughout the life cycle of the program. It ensures that all products developed or acquired satisfy the technical and operational requirements. Baseline management procedures are used to control changes to the technical, cost and schedule baselines.

CM is a vital part of the CRWMS systems engineering process since it serves to control the technical baseline and document physical and functional interfaces between and within system elements. The CM process helps ensure that the product acquired or developed satisfies the project's technical and operational requirements, and that these requirements are clearly defined and controlled throughout the development and acquisition process.

The CRWMS CM process is documented in the program Baseline Management Plan (BMP). The BMP will be developed in accordance with DOE Order 4700.1 and approved by the PBCCB. The BMP describes how the CRWMS technical baselines will be managed throughout their life cycles. It will include the CRWMS configuration management policy, assign responsibilities for CM implementation, and provide requirements for configuration identification, configuration management, configuration status accounting, and verification. The BMP will describe the operation of the Program Baseline Change Control Board (PBCCB), and Project Office Baseline Change Control Boards (POBCCBs) as necessary to effect control of the system design, development, operation, maintenance, and closure activities throughout the life cycle of the CRWMS.

Each project will develop a Configuration Management Plan in accordance with DOE Order 4700.1 and the OCRWM BMP. Specific CM activities and responsibilities will be tailored to the requirements of each project.

4.2.3.4 Test and Evaluation

A rigorous Test and Evaluation (T&E) program will be implemented to reduce risk, verify conformance with requirements and specifications, provide continuing estimates of operational effectiveness, and help ensure that licensing and other technical program objectives are achieved. The T&E program will be a life-cycle activity that includes both sequential and concurrent tests involving hardware, software, personnel, procedures, and facilities. The T&E efforts will support and closely track the systems engineering milestones in order to provide critical information regarding system design verification, requirements conformance, and system maintainability. The T&E program will consist of two major phases: Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E).

DT&E supports early system engineering, design development, requirements allocation, and verification of technical performance. Initial efforts will be based upon analytical techniques with limited physical testings. Technical Performance Measurement (TPM) and Performance Assessment information will be combined with T&E results to estimate if technical baseline requirements for each project and the program are being met. As the program and DT&E efforts mature, physical testing will increase and analytical techniques, including TPM and Performance Assessment, will continue in full.

OT&E will be conducted to determine the effectiveness and suitability of the CRWMS systems and components to perform as intended. It will continue until all systems and components identified in each T&E plan have been verified as meeting licensing and technical baseline requirements. During OT&E, the emphasis will be on physical testing of the system and components. Performance assessment efforts, and TPM to a lesser extent, will continue during OT&E to verify that the values of the parameters associated with the subsystems and components undergoing T&E meet specified requirements. OT&E will peak with the completion of construction.

The Test and Evaluation Master Plan (TEMP) is the basic planning document for all CRWMS T&E activities. The TEMP will be approved by the PBCCB. It is the authority for all other T&E planning documents including project-level T&E plans. The TEMP will describe the objectives, responsibilities, resources, and schedules for all planned program level T&E and addresses hardware, software, facilities, personnel and procedures. The initial TEMP will be prepared for the SDR milestone. Subsequently, it will be updated in step with the systems engineering process and formally reviewed at each of the program's engineering milestones. The TEMP will define the plans for testing CRWMS performance in a realistic environment including a rigorous assessment of critical safety, health and environmental requirements and issues.

The TEMP will also describe the system-level tests to be performed, the rationale for those tests, the relationship to other tests in the integrated sequence including the contribution each makes to the verification of the system, and the inter-project T&E requirements. The TEMP will describe the integrated evaluation process to be followed to assure performance compliance and verification of the CRWMS.

The results of tests and evaluations provide the basis for evaluating changes to the system technical baseline, maintaining project interface compatibilities and verifying project compliance with program requirements. The TEMP is also used as a coordination document to outline each organization's role in the T&E program and identify major test facilities and resources. The TEMP must also include the T&E planned to verify the correction of deficiencies and to complete production qualification testing.

At the project level, the detailed planning of test and evaluation efforts will be covered in project T&E plans. Project T&E plans are developed in accordance with DOE Order 4700.1 and the program TEMP.

4.2.3.4.1 Technical Performance Measurement

Technical Performance Measurement (TPM) is a systems engineering management tool that is used to help structure the T&E program. Technical measurement parameters, related to requirements critical to mission objectives or radiological safety, will be identified during the requirements development process. These parameters will be analyzed to help determine what should be verified and when and how it should be accomplished. TPM is described in detail in the PMSM. TPM is used to predict future technical system performance and, as such, it serves to identify what needs to be tested to ensure that TPM objectives are achieved. The T&E program results are similarly used in the TPM process as the critical parameters are measured, critical performance monitored and eventually verified. TPM, by providing visibility of actual versus planned technical performance, either verifies conformance or identifies potential problem areas requiring management attention.

As the T&E program progresses, test results will be reviewed, evaluated, and compared to the established TPM boundaries. Trend analyses will be conducted. Resultant reports shall include performance achievements (verification) or performance deviations (uniform decision analysis initiation). For performance in excess of requirements, opportunities for requirement or resource reallocation shall be evaluated.

4.2.3.5 Model Validation

Models used to assess compliance with regulatory requirements will be validated to demonstrate that a model, as embodied in a computer code, is a correct representation of the process or system for which it is intended. Methods for model validation include comparison of model predictions with laboratory tests, field tests and natural analogues. In cases where such methods produce insufficient data to provide model confidence, then a peer review process may be used to support the validation of the model. This is especially the case for the repository due to its long-term operating life.

4.2.3.6 Software Control

The acquisition, development, maintenance and use of software by the M&O to support the analysis and design of the CRWMS will be controlled in accordance with a series of Quality Administrative Procedures (QAPs) prescribing software management direction and requirements in compliance with the OCRWM QARD. A software management QAP establishes the requirements for software life cycles, baselines, controls, documentation, and use in work subject to the QARD requirements. It is applied in conjunction with other QAPs that contain the specific requirements for software verification and validation, software configuration management, and model validation.

The software management QAP defines the logical and informational elements of a software life cycle process for software development and maintenance. This includes specifying the technical and programmatic information that must be captured and guiding the definition of related documentation, reviews and audits. This procedure does not mandate a specific software life cycle but requires the preparation and approval of a life cycle plan to outline a process appropriate to the size, importance, nature, and complexity of the specific software product. It also contains procedural requirements for the qualification of existing and acquired software.

Affected organizations outside the M&O which use software to support the analysis and design of the CRWMS are required to implement a software QA program which complies with the OCRWM QARD.

4.2.3.6.1 Software Verification and Validation

Software verification and validation (V&V) procedures will ensure that individual software development, maintenance, and acquisition activities are performed according to the direction and requirements established in the software management QAP and the OCRWM QARD. The V&V procedures will ensure that software requirements are well defined and testable, that the requirements are fully traced to the software design, that the software design is correctly implemented in the code and that adequate software testing is planned and successfully executed. The V&V procedures will ensure that appropriate documentation is developed for each stage of the software life cycle. The V&V procedures will permit tailoring of complete life cycle activities, according to controls required by the software management QAP and specified in the approved life cycle plan. Each organization using software in quality affecting activities will implement V&V procedures that comply with the OCRWM QARD.

4.2.3.6.2 Software Configuration Management

Software configuration management procedures describe the methods, techniques and controls for software configuration identification, configuration change control, configuration status accounting and reporting, and configuration audits and reviews. Software configuration management procedures also describe controls for software problem reporting and corrective action. The procedures also include methods for source and executable code control, including physical media controls for access authorization and protection from damage or alteration. Each organization using software in quality affecting activities is required to implement software configuration management procedures that comply with the OCRWM QARD.

4.2.3.7 Regulatory Compliance

The Regulatory Compliance verification effort will ensure that all regulatory requirements are traceable and achieved. This effort will be accomplished in accordance with the policies and guidance contained in the Regulatory Guidance Document (RGD). Regulatory compliance is managed at the program level and encompasses the activities described earlier in the Licensing section (4.1.2).

Implementation at the project level will be in accordance with a Regulatory Compliance Plan prepared by each project to describe how that project will comply with the applicable regulatory requirements. The plan will include an integrated program to verify compliance with those requirements. The Regulatory Compliance Plan will be based on the regulatory compliance policies and project-specific requirements and guidance contained in the RGD. These activities, and how they will be integrated with the systems engineering process are described in more detail in Section 4.3.2.1.

4.2.3.8 Performance Assessment

Performance Assessments (PA) are the technical analyses that help demonstrate compliance with regulatory requirements designed to protect the health and safety of the workers and the public. Applicable federal and state regulations set the criteria for performance of the CRWMS. Evaluations are conducted to ensure that the site and designs comply with these regulatory criteria. An important element of the Safety Analysis Report and the Environmental Impact Statement is the analytical qualification of the uncertainty associated with the predicted performance of each of the physical systems. This uncertainty is the result of uncertainty in the accidents or the scenarios potentially impacting the performance, the physical or chemical processes affecting the performance, and the models and parameters used to predict the performance.

The regulatory definitions of performance requirements are presented in 40 CFR 191, 10 CFR 60, and other related statutes. Verification of compliance with these requirements is accomplished through performance assessment, which includes analysis with computer models, studies of natural analogs, confirmatory tests, and expert judgments.

As part of compliance verification, PA will be used to:

1) Evaluate and integrate site characterization data
2) Evaluate waste package and repository design performance
3) Evaluate storage and transportation design performance
4) Evaluate MGDS system performance
5) Evaluate pre-closure radiological safety.

These assessments are important quantitative components of the technical performance measurement. This is especially the case for the repository, due to its long-term operating life. Performance assessments will be used during all phases of the repository development process including site characterization, environmental impact analysis, safety analysis, license application, repository operation, performance confirmation, and post-closure monitoring.

4.2.4 Quality Assurance

The OCRWM Quality Assurance Program is outlined in the Quality Assurance Requirements and Description document (QARD). NQA-1 is the basic document for the OCRWM QA program. The QARD incorporates and supplements the applicable quality assurance program requirements from 10 CFR 60; 10 CFR 71; 10 CFR 72; 10 CFR 50, Appendix B; and NQA-1. Similarly, the M&O Quality Assurance Program is in compliance with the QARD and these same federal regulatory requirements.

The quality assurance program provides for both the achievement of quality and the verification of that achievement. The line organization has responsibility for the achievement of quality. The quality assurance organization has the responsibility to provide assurance to senior line management of the line organization's achievement and verification of that quality. This is accomplished through the conduct of overview activities such as audits, surveillances, and reviews.

Audits include objective evaluation of work areas, quality affecting activities, processes, procedures, and instructions to determine the effectiveness of the QA program and the technical adequacy of work being performed. Surveillances include observation of activities or review of documentation to evaluate compliance with approved procedures. Milestone reviews are conducted in accordance with the respective procedures to ensure that performance complies with requirements.

Quality assurance procedures are prepared and implemented for quality affecting activities that are performed by headquarters and the project offices. Typically, headquarters and the project offices work to the same procedures. However, the project offices will develop and implement quality assurance procedures that are specific to their scope of work, where necessary. These procedures will be consistent with the QARD, and delineate the specific administrative and quality assurance control means used to meet the requirements established in upper-level program documents.

When working to the OCRWM QA program, applicable OCRWM procedures will apply; when working to the M&O QA program, applicable M&O procedures will apply. For OCRWM, the QARD is implemented through the use of controlled procedures. For the M&O, the QARD is implemented through M&O controlled procedures. M&O Quality Administrative Procedures (QAPs) are used to control quality affecting activities and are written to implement specific administrative and quality assurance management controls as required by the QARD. M&O Implementing Line Procedures (ILPs) provide detailed implementing instructions for performance of quality affecting work unique to line organizations. They include the technical, management, and operating instructions to ensure implementation of functional requirements.

Both OCRWM and the M&O have adopted a quality assurance approach in which the extent of quality assurance and procedural control is graded to items and activities, according to the relative importance of the item or activity to safety, waste isolation, or Program objectives. The extent to which quality assurance and procedural control will be applied depends upon fundamental considerations such as the consequence of item failure, importance of data, complexity of design and fabrication, degree to which item functional control can be demonstrated by inspection or test, quality history, and economic considerations.

4.3 ENGINEERING AND PROGRAMMATIC SPECIALTY INTEGRATION

The complexity of the CRWMS program and its systems engineering effort requires substantial input from engineering specialties to ensure the development of a complete technical baseline. In addition, the rigorous legal and regulatory environment in which the program must operate creates other specialty considerations that will play a significant role in the successful execution of the overall program. Specialty engineering considerations impact the functional requirements analysis and programmatic constraints imposed by regulatory agencies in the licensing process affect program requirements and system specifications as well. This section describes how these engineering (e.g., logistics) and programmatic (e.g., environmental) specialties are integrated into the systems engineering process to ensure their inclusion in both the requirements definition and conformance verification functions. The project SEMPs will similarly include these engineering and programmatic specialties to ensure their appropriate inclusion in the design and development of the CRWMS.

4.3.1 Specialty Engineering Integration

Like the traditional engineering disciplines, specialty engineering disciplines must be integrated during the design stages of the system development effort, as well as whenever changes are proposed to the designs. Specialty engineers will participate in all design, review, and evaluation activities as an integral part of the system engineering process.

Specialty engineering disciplines required for the CRWMS development program include the following:

- Integrated Logistics Support (ILS)
- Reliability, Availability, and Maintainability (RAM)
- Life-Cycle Cost (LCC)
- Human Factors Engineering
- Safeguards and Security
- System Safety.

Plans will be prepared addressing the activities required to manage and integrate these specialty engineering disciplines into the CRWMS development program. These plans will describe the objectives and identify responsibilities at the program level and provide specialty engineering guidance to the projects. These plans will be coordinated with the projects to ensure interaction with project implementation activities. The ILS, RAM, Human Factors Engineering, and System

Safety Program Plans will be issued as appendices to this OCRWM SEMP. The Safeguards and Security Plan will be prepared as an appendix to the RGD.

4.3.1.1 Integrated Logistics Support

The main objectives of the Integrated Logistics Support (ILS) program are to ensure that required support and readiness characteristics are designed into the CRWMS and that resources necessary for program readiness are identified and available when required. To achieve these objectives, reliability, maintainability, supportability and readiness requirements must be defined early in the systems engineering process, included in system and subsystem specifications, and considered in the formal review process prior to key decisions. Attainable supportability characteristics are developed throughout the design process using design tradeoff efforts involving all applicable logistic disciplines. The logistic disciplines include: maintenance planning, personnel, training, supply support, technical documentation, support equipment, computer resources support, facilities, packaging, handling, storage, and transportation. The ILS Program Plan will be issued as Appendix E to this OCRWM SEMP.

4.3.1.2 Reliability, Availability, and Maintainability

A Reliability, Availability, and Maintainability (RAM) program is critical to support the development of design criteria and the design decision making process in the CRWMS. The program will address the development, allocation, review, revision and monitoring of RAM goals/parameters to ensure the attainment of system and project availability requirements. The goals/parameters will be identified in a comprehensive RAM Program Plan to be issued as Appendix F of this OCRWM SEMP. It will provide policy, objectives, methodologies, requirements, and minimum levels of tasks to be performed during various acquisition stages. It will also address the required verification and validation standards that must be complied with to ensure system availability.

4.3.1.3 System Life-Cycle Cost

System life-cycle cost (LCC) represents the system cost over the entire life cycle through decommissioning of the facilities. It is well established that for a major system acquisition most of the LCC is essentially "fixed" by the time that preliminary or Title I design has been completed. Hence, design considerations will include cost parameters that achieve a desirable balance among performance, reliability, supportability, schedule, and cost attributes while complying with safety and licensing requirements. LCC estimates will be made using systems engineering cost analyses and coordinated with formal Total System Life Cycle Cost (TSLCC) estimates used to help determine the adequacy of fees paid into the Nuclear Waste Fund.

4.3.1.4 Human Factors Engineering

Human Factors Engineering (HFE) objectives are to ensure that applicable requirements are incorporated into the technical baseline, and that decisions and actions affecting the waste management system do not adversely affect the health and safety of the public and workers or the quality of the environment. HFE will reduce the potential for human error in system operation and promote system safety, operational efficiency, ease of maintainability, and reliability. The HFE effort involves: examining regulations and codes to identify those with HFE implications; deriving requirements and specifications that take into account human physical and cognitive capabilities and limitations as applied to system design; allocating the functional requirements to humans and/or machines; ensuring that HFE considerations are adequately reflected in project training programs; and participating as an integral part of all audit and design and technical reviews. HFE will address subsystem design and the relationship of system elements to each other and how they can be optimized. HFE will also be addressed in the design process by incorporating operational considerations in the design to achieve the objectives of system safety, operational efficiency, and RAM. Tradeoff studies will be made to accomplish this optimization. HFE is described in the HFE Program Plan (Appendix G). Responsibility for HFE implementation rests with the system engineering activity at each project with coordination and guidance provided at the program level.

4.3.1.5 Safeguards and Security

A CRWMS Safeguards and Security program will be developed at the program level to establish and maintain adequate safeguards, including physical security, to protect nuclear materials, program facilities, and essential program records (e.g., site characterization data, test results, licensing documentation, etc.). The OCRWM Safeguards and Security Plan will be prepared as an appendix to the RGD. It will provide guidance to be implemented at the project level. Safeguards and Security issues affecting the development of the technical baseline will be identified in both the OCRWM Safeguards and Security Plan and the project documentation to ensure that appropriate systems engineering actions may be accomplished during system development. This will include identifying the need for requirements and specifications and suggested methods for verifying conformance with those requirements.

4.3.1.6 System Safety

A comprehensive system safety program will be established so that system safety is integrated into all phases of the systems engineering process and that safety is made an integral part of the CRWMS program. Its main objectives are to ensure that potential hazards are systematically identified, potential consequences are analyzed, and reasonable efforts to eliminate, control, or mitigate the hazards have been taken. The system safety program will interface with the regulatory compliance program, which addresses compliance to environmental, safety and health regulations. This interface will ensure that all aspects of safety are addressed, particularly the provision for engineering support for the preparation of the Safety Analysis Report (SAR), which accompanies the NRC license application. The system safety program will be described in the System Safety Program Plan (Appendix H).

The System Safety Program Plan will describe how safety engineering requirements will be incorporated in the engineering process and included in the verification activities. It also will describe how the system safety program will be implemented at the project level including:

- Each project will plan and document a System Safety effort that implements the direction given in the System Safety Program Plan.

- Hazard analyses will be performed during all life-cycle design phases
- System safety reviews will be conducted as an integral part of all design and technical reviews.

4.3.2 Programmatic Specialty Integration

Numerous laws and regulations governing public safety and the environment are imposed upon the siting, design, construction, operation, and decommissioning (where applicable) of the CRWMS segments. Programmatic constraints imposed by the regulatory agencies must be integrated into the systems engineering process so that they can be evaluated, defined, imposed, tracked, and verified in the same way that the functional performance requirements are. Moreover, the involvement of concerned and affected institutions and public groups will help identify emerging public issues and formulate appropriate alternatives for problem resolution. One of the tasks before the systems engineering organization is to ensure that regulatory requirements, institutional constraints, and issues related to public acceptability are translated into architecture and engineering terms and hard requirements with verifiable performance measures. To help accomplish these objectives, these programmatic specialty activities will be integrated into the systems engineering process.

4.3.2.1 Regulatory Compliance Program

The regulatory compliance program will facilitate coordination with NRC to ensure that the license application fully addresses the required data in the detail that will provide the license to construct and operate the nuclear waste disposal facilities. The licensing process will be in accordance with the framework established by the Regulatory Guidance Document (RGD). The RGD will establish a uniform and consistent methodology and program to demonstrate compliance with the mandates of the Nuclear Waste Policy Act, as amended, with federal environmental laws and regulations, with regulatory requirements of the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA) for waste management and disposal, with federal health and safety regulations, with applicable DOE orders, and with applicable state and local regulations. This will include a sequencing of major design and program milestones, definition of required data sets, and identification of what needs to be done, when, and by whom. The systems engineering and design milestones will be managed in conjunction with the licensing milestones. These efforts will be incorporated in the project-level Regulatory Compliance Plan to describe how compliance will be achieved, to provide interpretation of the applicability of the regulatory requirement on the project, to identify what technologies or models will be used, how data and analyses will be verified, and to depict the flow of data and analyses into the licensing documentation.

4.3.2.2 Environmental, Socioeconomic, and Institutional Program

The environmental and socioeconomic program activities must facilitate the timely compliance with applicable Federal, state, and local environmental requirements - including those specified in environmental laws, regulations and standards - to ensure that siting, construction, and operation occur on schedule. Environmental requirements are generally quantifiable and objective, and must be treated as program constraints. Socioeconomic and institutional considerations are generally not easily quantified, and will be applied in design as applicable.

OCRWM policy and guidance regarding environmental, socioeconomic, and institutional activities will be applied to ensure consistency of approach across the program. The OCRWM Socioeconomic Policy Management Directive (SPMD) is the program level policy document that will guide the conduct of all socioeconomic activities. Project level socioeconomic activities will be planned and conducted in accordance with the guidance provided in the SPMD. The implementation of the considerations set forth in this document will ensure that issues are handled adequately, that data and resources are integrated, and that risks and liabilities are properly addressed.

5. APPLICATION OF SYSTEMS ENGINEERING TO CRWMS DEVELOPMENT

This section describes how the systems engineering process, described in Section 4, will be implemented in the development of the Civilian Radioactive Waste Management System. Both program-level and project-level activities are described within each element of the CRWMS. The CRWMS Program currently includes two formally designated projects, each of which is designated as a Major System Acquisition (MSA). They are the Yucca Mountain Site Characterization Project (YMP), and the Monitored Retrievable Storage (MRS) Project, which includes the MRS Facility, Waste Acceptance System, and Transportation System. The systems engineering interface between the Program and projects is described in Section 3.

5.1 Development of the Waste Acceptance System

5.1.1 Waste Acceptance System Description

The mission of Waste Acceptance is to manage the acceptance of Spent Nuclear Fuel (SNF) and High Level Waste (HLW) from the Purchasers/Producers of said waste into the CRWMS. Waste Acceptance is a system element within the CRWMS technical baseline but it is not a physical system. It administers the transfer of waste title from the Purchasers/Producers into the CRWMS. Figure 5-1 pictorially depicts the Waste Acceptance function in the operation of the CRWMS.

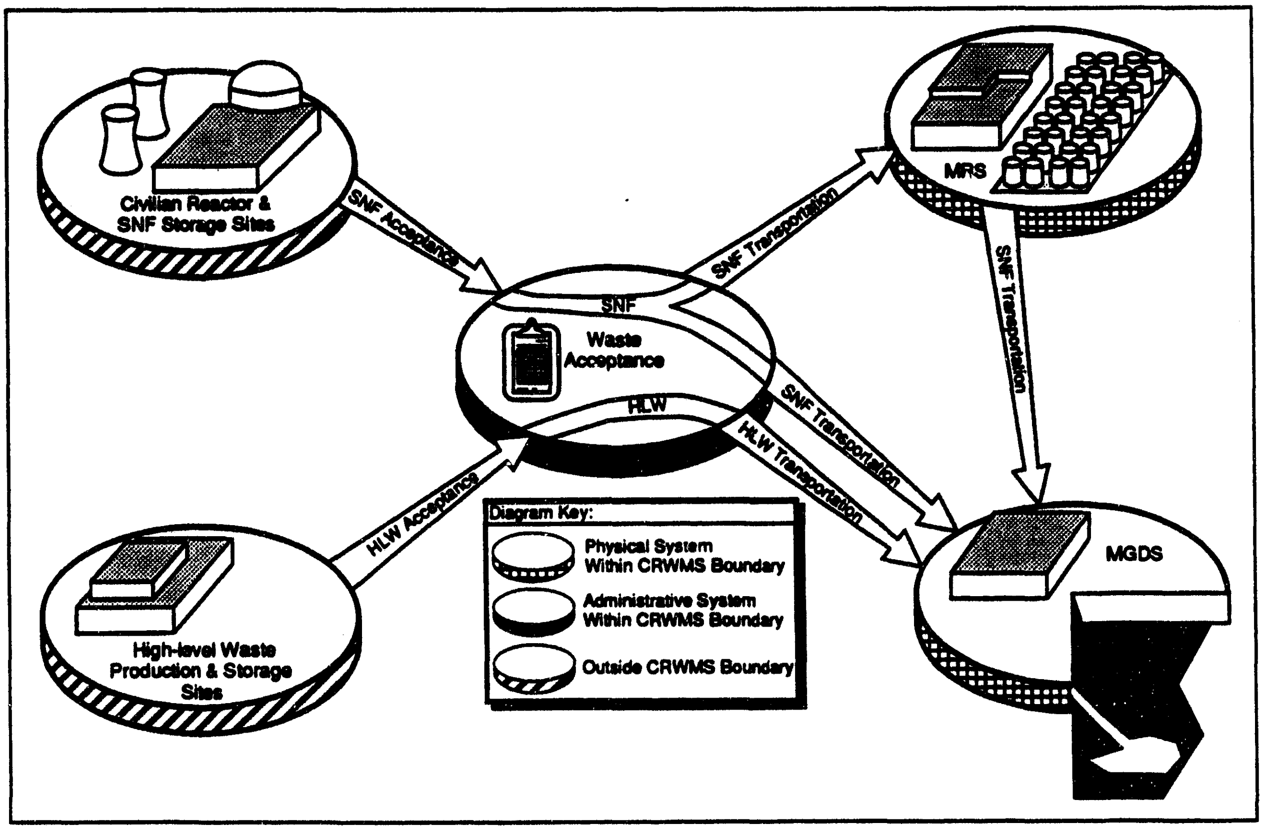

Figure 5-1. Civilian Radioactive Waste Management System

Waste Acceptance will administer the CRWMS interactions with the Purchasers (owners or generators of SNF from civilian reactors) and the Producers (generators of HLW). The Waste Acceptance System will maintain records of the waste locations and characteristics, maintain records for waste acceptance capacity, and verify that the waste has been properly described. In addition, Waste Acceptance will manage the contract/agreement process with the Purchasers/Producers, develop schedules for waste acceptance, ensure that the waste is in proper form for transport and storage, and accept title to the waste from the Purchasers/Producers.

Requirements for the Waste Acceptance System will be developed in accordance with the systems engineering process described in Section 4 and documented in the program-level Waste Acceptance System Requirements Document (SRD).

5.1.2 Management Responsibilities for the Waste Acceptance System

The Associate Director for Storage and Transportation (ADST) is responsible for the management and development of the Waste Acceptance System. Project level documentation and the project portion of the technical baseline will be developed in accordance with the systems engineering process described in Section 4.

5.1.3 Waste Acceptance Process

The Nuclear Waste Policy Act of 1982 requires that all owners and generators of SNF and generators of HLW enter into contracts with OCRWM for the disposal of their SNF and HLW. In exchange for these services, the Purchasers of the SNF pay a fee of 1 mill per kilowatt hour electricity generated and sold for SNF generated after April 7, 1983 (SNF generated before 4/7/83 is subject to a one-time fee). Civilian and Defense HLW Producers are expected to pay an amount equivalent to the fees paid by the Purchasers of spent fuel. (The method for calculating the Defense HLW fee was published in the *Federal Register*, Vol. 52, No. 161, August 20, 1987.)

The waste acceptance process begins with Purchasers providing OCRWM with information concerning the quantities and characteristics of the waste currently in inventory. These characteristics include the date on which the SNF was permanently discharged. Purchasers also provide OCRWM with projections of the waste that will be generated during future operations,

In accordance with the *Standard Contract for the Disposal of Spent Nuclear Fuel and/or High Level Waste* (10 CFR Part 961), an annual Acceptance Priority Ranking (APR) report and an Annual Capacity Report (ACR) are issued. The APR establishes the order in which projected SNF acceptance capacity is allocated. As required by the standard contract, the priority ranking is based on the date the SNF was permanently discharged, with the owners of the oldest SNF, on an industry-wide basis, given the highest priority.

The 1991 APR is the basis for allocating SNF acceptance capacity to each owner in the 1991 ACR. The ACR applies a ten-year projected waste acceptance rate to the APR, resulting in individual capacity allocations. An allocation is a specified acceptance capacity (measured in metric tons of uranium) in a particular year for an individual Purchaser.

The allocations in the 1991 ACR are the basis for Delivery Commitment Schedule (DCS) submittals, which represent the next step in the SNF acceptance process outlined in the Standard Contract. The DCS provides the Purchasers with the opportunity to inform the Department of Energy of their plans for utilizing their allocations of projected SNF acceptance capacity. This information will assist OCRWM in meeting its contractual waste acceptance responsibilities and in developing the waste management system.

The Standard Contract states that, beginning January 1, 1992, Purchasers may begin submitting DCSs, for DOE approval, that identify all SNF the Purchasers plan to deliver to DOE beginning 63 months thereafter. A DCS is submitted for only one designated delivery site and only one fuel type (BWR, PWR, or Other). Both the Purchaser's and Department's ability to commit to a specific delivery date over 63 months in the future is limited. Therefore, only the year of delivery is designated on the DCS. The DCS also includes information concerning the proposed transport mode and the range of permanent discharge dates for the fuel to be delivered.

After a DCS has been approved, Purchasers may either use the DCS as the reference document for submittal of the Final Delivery Schedule (FDS), which is required 12 months prior to delivery, or use the DCS as the basis for exchanges with other Purchasers. The FDS provides further specificity with regard to the SNF to be delivered. The actual date of delivery will be proposed by the Purchasers in their FDS submittal.

5.2 DEVELOPMENT OF THE TRANSPORTATION SYSTEM

5.2.1 Transportation System Description

The Civilian Radioactive Waste Management System must have the capability to transport spent fuel from commercial nuclear reactors to the MRS facility and from the MRS facility to the repository, and to transport high-level radioactive waste from generator sites to the repository. OCRWM is developing a Transportation System that will perform these functions.

The Transportation System consists of two physical elements: (1) the cask system and (2) the transportation support system. The cask system includes transportation casks, transporters, and ancillary equipment and special tools designed for use in the Transportation System. The transportation support system consists of facilities, systems, equipment, and services for managing the Transportation System operations, for training waste purchaser/producer and Transportation System personnel, for procurement of equipment and services, and for inspecting, testing, and maintaining equipment in compliance with requirements. A cask maintenance facility will be designed and constructed as part of the MRS facility.

5.2.2 Management Responsibilities for the Transportation System

The Associate Director for Storage and Transportation (ADST) is responsible for the cask systems technology development and procurement, support system development, operations, and institutional activities. The cask systems development and procurement include developing and procuring transportation cask systems including cask-handling equipment, specialized test equipment and associated hardware. Support system activities focus on the development of the

Transportation System including facility design, operations, maintenance, and field services development, specification development, and service contractor acquisition. Operations focuses on the execution of activities necessary for operating the Transportation System. The institutional activities include public information, outreach to the general public, policy and regulatory analysis, and interaction with local, regional, tribal, and federal government organizations.

The Transportation System, as part of the MRS Project, will be addressed in the MRS Project SEMP. Special emphasis will be given to system studies to optimize the transportation system for safety and efficiency.

5.2.3 Development and Acquisition of the Cask Systems

5.2.3.1 Development of the Cask Systems

Transportation cask systems may be designed as single purpose (a cask licensed for transportation only), dual purpose (a cask licensed for transportation and storage), or universal (a cask licensed for transportation, storage, and disposal). At the present time, the OCRWM is focusing on development of single purpose cask systems.

OCRWM is planning four initiatives for cask system development: (1) from-reactor cask systems suitable for shipping spent fuel either to the MRS facility or the repository, (2) cask systems for shipping from the MRS facility to the repository, (3) cask systems for shipping nonstandard spent fuel and nonfuel-bearing components, and (4) cask systems for shipping high-level waste.

Initial emphasis is on the development of from-reactor cask systems (Initiative 1) suitable for shipping most of the spent fuel to either an MRS facility or a repository. To ensure the availability of a fleet of cask systems at startup of the MRS facility in 1998, the OCRWM is acquiring a fleet of from-reactor truck and rail/barge spent fuel transportation casks designed using proven technology already certified by the NRC. This fleet may consist of existing transportation casks, modified existing transportation casks, new design casks using proven technology, or any combination thereof.

In addition, another category of from-reactor cask systems will be developed using innovative technology. The DOE's Idaho Operations Office has been assigned the responsibility for this innovative technology design effort. Cask design technology being developed to support this design effort consists of five activities: 1) the use of credit for fissile material burn up in cask design, 2) the use of the source-term approach in demonstrating the containment capability of the cask, 3) the benchmarking of computer codes for certain structural and thermal calculations, 4) the evaluation of innovative materials and components, and 5) the development of methods for controlling radioactive contamination on the surfaces of casks. The results of these technology development efforts will be factored into the cask system designs. A rail/barge cask system and two truck cask system designs are nearing completion.

As required by the Nuclear Waste Policy Amendments Act, the Transportation System will use only casks that have been certified by the NRC for the shipment of SNF and/or HLW. The process to obtain NRC certification of shipping casks is outlined in 10 CFR 71. It will be the responsibility of the cask designer/owner to obtain a Certificate of Compliance from the NRC for each type of cask (i.e., Design Model having a unique Certificate of Compliance Number) being developed before the cask is accepted by OCRWM. To support the designers' certification efforts, broad technical issues that arise during the design and certification process may be addressed by the DOE under its Memorandum of Understanding with the NRC and through applied technology tasks sponsored by OCRWM. Cask design activities are monitored by DOE and their support contractors. The monitoring activity includes regular reporting and formal design review meetings.

5.2.3.2 Acquisition of the Cask Systems

The cask system acquisition process consists of certain system engineering activities performed prior to procurement and during the design and development activities. These system engineering activities include the following:

1) Definition of Transportation System requirements and interfaces at the program level

2) Development of Transportation System design requirements, initial specifications, and interface requirements at the project level

3) Incorporation of Transportation System design requirements into the development contract (RFP).

4) Definition of responsibilities for cask design and engineering development

5) Definition of test requirements and prototype development

6) Definition of cask certification requirements.

In addition, extensive system engineering studies and tradeoff analyses will be conducted to evaluate different design concepts and development alternatives.

Systems engineering activities during design and development include design reviews, readiness reviews, defining product specifications and interface requirements, defining and monitoring acceptance testing, defining and executing operational testing, and monitoring the cask certification process. The design reviews shall be conducted in accordance with the guidelines described in Section 4.2.3.1. Provisions and requirements for these activities, including the reviews, shall be included in the appropriate RFPs for the cask development procurement. These reviews will be conducted at the conclusion of the preliminary design and the detailed design to evaluate the design and verify conformance with requirements prior to proceeding to the next step in the acquisition process. The ADST shall ensure systems requirements are assessed against the cask procurement and design packages. The OCRWM will organize and conduct these reviews. Project representatives, supported by the cask development contractor, will present and justify the design and development support planning. Additionally, a Key Decision Readiness Review (KDRR) will be required prior to initiating cask system procurement.

Upon completion of the design reviews, the approved designs will be documented and controlled in the technical baseline. System engineering activities during procurement will include documenting the as-built configuration baseline, continued testing, and other tasks defined in the KDRR.

5.2.4 Development and Acquisition of the Transportation Support System

5.2.4.1 Development of the Transportation Support System

The Transportation Support System consists of facilities and services, such as an operations control center, transporter service facility, carrier services, training services, operations services, emergency services, and security services. The design and development of the support system will proceed in parallel with the cask systems development. System requirements and specifications will be developed based on cask system support needs, regulatory requirements, and operational needs including both utility and MRS support requirements. The system design will proceed in conformance with the baseline requirements and in accordance with the systems engineering process described in Section 4.

5.2.4.2 Acquisition of the Transportation Support System

There are several options for the acquisition of support facilities, equipment, and services including procurement of a completed facility, construction of a facility by a prime contractor, and service contracts. In addition to the various service facilities and carrier operating services, the Transportation System will need security, training, emergency, and operations support services. Requirements for these services will be defined in the design requirements documents. Once service requirements have been determined, plans will be developed to acquire or provide the services. These plans will guide the procurement process and the acquisition, management and performance of the support services during Transportation System operations.

5.3 DEVELOPMENT OF THE MRS FACILITY

5.3.1 MRS Facility Description

The MRS facility will provide temporary storage for a limited amount of Spent Nuclear Fuel (SNF) awaiting disposal in a geologic repository. The primary activities associated with this facility include the following:

1) Receiving, repackaging, and placing into storage SNF from civilian nuclear reactors

2) Monitoring and managing SNF while in storage

3) Removing SNF from storage and preparing it for shipment to the geologic repository.

The MRS System, in its role as a temporary storage facility for SNF, serves two major purposes: it will accept waste for storage prior to the availability of the geologic repository, and it will serve as a storage and staging facility to assist in management of the waste delivery schedule to the repository when the repository is operational.

5.3.2 Management Responsibilities for the MRS Facility

The Associate Director for Storage and Transportation (ADST) is responsible for all aspects of the development of the MRS facility, including the preliminary planning, siting, design, construction, pre-operational testing, and operation activities. There are, however, some significant functions affecting siting and design considerations that are assigned to the Nuclear Waste Negotiator, including interactions with any potential host. These functions could impact the ADST responsibilities and influence the development of the MRS Facility. Accordingly, interactions between the Office of the Nuclear Waste Negotiator (ONWN) and OCRWM will occur throughout the term of the Negotiator.

Prerequisites for accomplishing the design and development process for the MRS facility are the preparation of a project SEMP and the establishment of an approved QA program with procedures in place for all participants in design activities. Specifically, as a prerequisite to start SAR design, an MRS Project Plan, an MRS Project Management Plan, and an approved SAR Design Plan must be in place. Prerequisites to start Final Procurement and Construction (FP&C) Design include an approved FP&C Design Plan, a designated MRS Site, and a QA Program and procedures for all project participants in design activities. This provides the basis for the preparation of FP&C Design and meeting the quality assurance commitment to the NRC.

5.3.3 Design and Development Process

The initial MRS design process is based on DOE 4700.1 directives, which were modified to accommodate licensing considerations. The MRS phased design process includes Conceptual Design, SAR Design, and Final Procurement and Construction Design. This process, its milestones and relationships to other design, acquisition, and licensing processes is discussed in Section 4.1.2.1.

5.3.3.1 Conceptual Design

The MRS Facility conceptual design was based on the functional requirements contained in the Physical System Requirements - Store Waste (PSR-SW) document. It was initiated after ESAAB approval for KD 0. The PSR-SW document was replaced by the MRS System Requirements Document, which incorporated the conceptual design and became part of the Technical Requirements Baseline portion of the overall technical baseline, as described in Section 4.2.1.

A Conceptual Design Report was prepared and submitted for technical document review. It will be subject to the System Design Review, as described in Section 4.2.3.1, before initiating the MRS Facility SAR design phase. The design architecture, as reflected in the Conceptual Design Report, has been captured in the System Requirements Document to constitute the technical requirements baseline. This baseline is to be the basis for the MRS Project cost and schedule baseline, the Key Decision 1 Readiness Review, ESAAB approval of KD-1, and the start of the SAR design phase.

5.3.3.2 SAR Design

The SAR Design continues the development of the MRS Facility based on the approved conceptual design and the SRD. Prerequisites for initiating the SAR Design are ESAAB approval of KD-1 and the issuance of the MRS System Requirements. During the initial phase of this effort an initial design will be developed to provide sufficient technical and licensing information to conduct studies and analyses of alternative designs, develop preliminary cost and schedule estimates, consider available environmental data and potential host considerations, and to support OCRWM policy decisions on the configuration of the MRS Facility. The MRS Design Requirements Document will be initiated by the MRS Project.

When the equivalent Title I or preliminary design is complete, a Milestone Review, as described in Section 4.2.3.1, will be conducted by the project to verify and evaluate the design and document the design requirements. Upon approval by the POBCCB, this initial design and the Design Requirements Document that describes it constitute the Design Requirements Baseline and become the basis for the start of the final phase of the SAR Design.

Since the SAR Design must be site specific and in accordance with any host-DOE agreement, site selection is an additional prerequisite for initiating this final phase of the SAR Design. During this phase, the MRS Design Specifications will be developed for those design features pertinent to the Safety Analysis Report. The SAR Design will constitute the final, detailed design for all structures, systems, and components subject to NRC evaluation in the SAR submitted as part of the license application. The SAR Design will be reviewed at a SAR Design Review (SARDR) as described in Section 4.2.3.1. After SARDR and approval by the POBCCB, the Design Specifications and the SAR Design will be captured in a SAR Design Report and integrated into the technical baseline as the Design Configuration Baseline for those configuration items represented in the SAR submission. This is the basis for the KD-2 Readiness Review and ESAAB approval of KD-2 prior to the start of the FP&C Design.

5.3.3.3 Final Procurement and Construction Design

The FP&C Design represents completion of the detailed design. FP&C Design includes any revisions required by the NRC of the SAR Design; completion of all remaining design specifications; preparation of final working drawings, specifications, bidding documents, cost estimates, and coordination with all parties that might affect the project; development of firm construction and procurement schedules; and assistance in analyzing proposals or bids. In addition, equipment analyses will be performed based on failure modes and effects analysis and reliability, availability, and maintainability analysis.

The FP&C Design will be reviewed at a Detailed Design Review (DDR) as described in Section 4.2.3.1. After the DDR, all MRS design specifications and the approved FP&C Design will be integrated into the technical baseline as the completed MRS Design Configuration Baseline. Upon POBCCB approval of the FP&C Design and the Design Specifications, this design configuration baseline becomes the basis for the KD-3 Readiness Review and ESAAB approval of KD-3 prior to the start of MRS facility construction.

5.3.3.4 Construction, Testing, Operation, and Decommissioning

MRS facility construction will begin after receipt of the license from the NRC and approval of Key Decision 3 by the ESAAB. Construction will be in accordance with the FP&C Design and in conformance to the MRS product specifications.

Once construction of the MRS facility is completed, it will be tested to demonstrate operational readiness. Title III inspection will be performed at turn over or completion of acceptance testing. At this time, the MRS configuration baseline document will be updated to reflect any deviations or waivers granted during construction, equipment upgrade or replacement, procedure modifications, etc, and will be approved by the MRS project change control board. This updated document will become the MRS as-built configuration baseline. MRS facility operation will begin after the KD-4 Readiness Review and ESAAB approval of KD-4.

The term of the license issued by the NRC under 10 CFR 72 will not exceed 40 years from the date of issue. Extension of the license beyond the issued term will require re-application to the NRC for a license extension. When it has been determined that the function of the MRS facility is no longer needed, the facility will be decommissioned. The OCRWM will submit to the NRC an application for termination of license and decommissioning of the facility. This application must be made within two years following permanent cessation of operations, and in no case later than one year prior to expiration of license. The application for termination must be accompanied, or preceded, by a proposed final decommissioning plan.

5.4 DEVELOPMENT OF THE MINED GEOLOGIC DISPOSAL SYSTEM

The Mined Geologic Disposal System (MGDS) is made up of three principal development activities: site characterization, repository development, and engineered barrier system (EBS) development. These activities are all under the direction of the Associate Director of Geologic Disposal (ADGD). The Yucca Mountain Site Characterization Project is responsible for characterizing the candidate site at Yucca Mountain, Nevada, to determine its suitability for development as a permanent geologic repository and for developing the repository and EBS ACD and LAD. The First Repository Project will be responsible for the FP&C Design and construction of the geologic repository. The repository life cycle involves the design, construction, operation, and decommissioning of a geologic repository. The development of the EBS involves the design and acquisition of a suitable system to contain the waste within the repository.

The accomplishment of these three activities will be coordinated and integrated, including design and interface management considerations, by the ADGD. Program guidance related to the integration of design considerations is provided in the following sections. Specific project management actions to be implemented to effect this integration will be described in the Project SEMP.

5.4.1 Site Characterization

5.4.1.1 Site Characterization System Description

Site Characterization is being conducted through the implementation of the Site Characterization Plan, which includes the Exploratory Studies Facility (ESF), and the Surface-Based Testing Activities. The Site Characterization Plan is being implemented at the Yucca Mountain site to conduct various tests and experiments needed for site characterization, suitability evaluations, and performance assessment. If the Yucca Mountain site is approved for repository development, parts of the ESF may be used during the construction and operation of the repository. Therefore, the ESF will be designed with the potential for integration into the repository using an iterative design process, which complements the design activities of the repository and allows for a continuous interaction of designs. This includes repository interfaces and openings to ensure that the ESF does not compromise the waste isolation capabilities of the site.

5.4.1.2 Yucca Mountain Site Characterization Management Responsibilities

The determination of test and design requirements leading to development of the technical baseline for the MGDS are being carried out by the Yucca Mountain Site Characterization Project (YMP). The YMP has been designated as a DOE Major System Acquisition, and a Yucca Mountain Site Characterization Project Office (YMPO) has been established. The YMPO is responsible to the Associate Director Geologic Disposal for all Yucca Mountain site characterization functions as well as all other MGDS design and development activities leading to the establishment of the technical baseline for the MGDS. For start of ESF Title II design, an approved ESF Title II design plan and an approved QA program and procedures must be in place for all project participants in design activities to provide the basis for the preparation of the Title II design and to meet the quality assurance commitment to the NRC. Testing activities in the ESF and for surface-based testing must follow approved QA procedures.

5.4.1.3 Site Characterization System Requirements

The Site Characterization System Requirements documentation is shown in Figure 4-4, Technical Baseline Documentation. The top-level requirements document for the MGDS is the Mined Geologic Disposal System Requirements Document, including the Site Characterization System Requirements and the Site Suitability Evaluation Criteria. The top-level MGDS Requirements documents shown on Figure 4-4, along with the Interface Specification, provide the program-level systems requirements that constitute the basis for the design activities at the project level.

5.4.1.4 Site Characterization System Design and Development Process

The Site Characterization System design and development process is a phased acquisition process. After the conceptual design are the Title I and Title II designs, followed by construction and operation. Licensing is not a requirement for Site Characterization development, however, it will be a significant consideration since portions of this system might be incorporated within the potential repository. Therefore, the ESF must be designed so as not to adversely affect the repository license application.

5.4.1.4.1 ESF Title I Design

The ESF Title I design was based on the WMSR Vols. I & IV and the related ESF Design Requirements. The ESF Design Requirements were subsequently modified based on the system requirements baseline, as reflected in the design requirements baseline in Figure 4-4. The ESF design will incorporate those design features needed to optimize the system and best ensure its compatibility, if necessary, with repository development and the associated license application.

5.4.1.4.2 ESF Title II Design

The ESF Title II design is being developed based on the design requirements baseline and will reflect the best judgements of what is required to characterize the proposed Yucca Mountain site for suitability as a geologic repository, while retaining compatibility with repository design requirements for licensing. The ESF Title II design is being completed in up to 12 design packages. ESF construction will be phased based on completed design packages that have undergone appropriate design reviews, construction readiness reviews, and approvals by the Project Manager and the Director, OCRWM. At the completion of Title II design for each design package, a Detailed Design Review (DDR) will be conducted to verify conformance with design requirements, validate the design specifications, and evaluate the adequacy of the detailed design. These reviews will provide a basis for the construction readiness review for each package. The Project Manager may choose to combine the reviews for several design packages, in order to reduce the number of necessary reviews prior to construction. Prerequisites for completing ESF Title II design include an approved Mined Geologic Disposal System Requirements baseline and approved ESF and surface-based testing design requirements baselines.

With ESAAB approval, construction has begun based on the design specifications and phased Title II design contained in the Design Configuration Baseline. During and upon completion of construction, the baseline will be updated to reflect all approved modifications. The resultant documentation will constitute the as-built configuration baseline.

5.4.1.4.3 Operations

Site characterization operations (testing) will be conducted throughout ESF construction and operations. Site characterization consists of the field studies, experimentation, and modeling that will determine if the site is suitable for repository development and that will provide data to support licensing a suitable site. Site characterization activities are conducted in accordance with the Site Characterization Plan being implemented by the YMPO. If the site is approved as a repository, selected portions of the ESF could be incorporated into the geologic repository operations area (GROA). If it is disqualified, site characterization activities will cease and the site will be restored.

5.4.1.5 Surface-Based Testing

Surface-based testing will be conducted throughout the site and surrounding areas as part of site characterization. These data, in conjunction with the underground test data, will be used for suitability evaluations and performance assessment. Data from both surface-based and underground tests will be used to aid repository design and to support licensing a suitable site.

5.4.2 Development of the Repository

5.4.2.1 Repository Development Management Responsibilities and Requirements

Repository development is the responsibility of the Yucca Mountain Site Characterization Project Office (YMPO). The YMPO is responsible to the Associate Director Geologic Disposal for repository design as well as all other MGDS development activities pertaining to the establishment of the design requirements, configuration, and as-built baselines for the MGDS. The top-level requirements document for the repository is the Mined Geologic Disposal System Requirements document, which is shown as the technical requirements baseline in Figure 4-5. The Repository Design Requirements will establish the project-level design requirements baseline.

The MGDS development process will be managed and the design activities conducted in accordance with the Project Management Plan and the project SEMP. These documents will provide detailed plans for conducting NRC-license design phases (ACD, LAD, FP&C). In addition, a QA program and procedures must be in place for all project participants in design activities to provide basis for the preparation of the Title II design and to meet the quality assurance commitment to the NRC.

5.4.2.2 Repository Development Process

The development of the repository is closely related to the site characterization effort. The MGDS conceptual design, in conjunction with other early site characterization documentation (e.g., site characterization plan) under project change control, is a first step in the design process for the repository. The Site Characterization effort will be structured to provide the site and system performance information needed to develop the repository construction and operation. The development of the MGDS will be based on design phases similar to Title I and Title II design under DOE Order 4700.1. However, in order to comply with unique requirements established by the NRC on licensees, additional considerations are necessary. In order to accommodate the NRC requirements, Advanced Conceptual Design (ACD) will complete conceptual design and begin the initial engineering trade studies to support License Application Design (LAD). Before the completion of ACD, the Project Manager shall ensure that the design is consistent with the approved CRWMS and MGDS System Requirements Documents. LAD will encompass the intent of Title I design and also the Title II design for all structures, systems, and components important to safety and waste isolation. FP&C design will complete the Title II design for all other MGDS subsystems and incorporate specific design changes resulting from NRC review of the LAD. The specific details of the design phases shall be documented in the Project SEMP. The design phases are followed by construction, operation, and decommissioning.

5.4.2.2.1 Advanced Conceptual Design

The primary purpose of the ACD phase is to develop the necessary information to begin the license application design. The following defines the products of the ACD:

- **Design approaches for the License Application Design**: All tradeoff engineering studies will be completed during the ACD to allow specification of the preferred design approach for the LAD. The ACD will evaluate design alternatives and provide justification for the selection of the preferred alternative.

- **Detailed design requirements for the License Application Design** : The ACD effort will help to refine and elaborate design requirements for the LAD; these requirements will reflect a full understanding of the repository subsystem and its functions. Included in these design requirements will be initial quantitative performance criteria. The design requirements will consider all applicable Federal, State, and local codes and specify how they apply to the LAD. In addition, the requirements will specify the design requirements for the structures, systems, and components important to safety and the engineered barriers important to waste isolation. Data gathered during site characterization will be factored into the LAD requirements.

- **Items important to safety and waste isolation**: During the ACD, all structures, systems, and components that are important to safety and the engineered barriers that are important to waste isolation will be identified. Conceptual designs for these structures, systems, components, and barriers will be completed during the ACD.

- **Definition of interfaces**: During the ACD, interfaces among subsystems of the MGDS will be adequately defined or clarified. The plans for integrating the exploratory studies facility into the repository subsystem will be clearly defined, including the requirements that such integration imposes on both subsystems. In addition, the waste characteristics that are important to repository design will be identified and fully established.

- **Licensing issues**: All licensing issues pertinent to the repository will be identified during the ACD. Approaches for the resolution of issues that have been discussed with the NRC will be developed during the ACD in order to allow timely resolution of these issues.

- **Life-cycle cost estimates**: A life-cycle cost estimate adequate to support budget authorization for the LAD and the fee-adequacy evaluation will be developed. The cost estimate will be reported according to the WBS. Cost-estimating and budget-validation guidance, which will include uncertainty and contingency goals for the cost estimate, will also be provided. The cost estimate will be consistent with the physical subsystem structure.

- **Preliminary schedule**: The ACD effort will produce a preliminary schedule for repository design and development including critical paths, major procurement, construction schedule, and adequate contingency provisions.

The ACD documentation will describe the reference design in a level of detail appropriate to the ACD phase. In addition, it will document the design alternatives that were considered and will describe how the reference design was selected in sufficient detail for use in preparing the environmental impact statement. The ACD documentation will identify the fixed design concepts that will be carried forward into the next phase of design. Also, it will identify the uncertainties associated with the reference design and their potential impacts on licensing. Identified uncertainties will be accompanied by discussion of the need for additional development work, additional data and analyses, or contingency measures (e.g., backup design features), if necessary.

On completion of the ACD phase, the YMPO will submit the ACD documentation to the ADGD. A System Design Review (SDR), as described in Section 4.2.3.1, will be conducted to review the ACD. After SDR, the system requirements and the ACD are integrated into the technical requirements portion of the MGDS technical baseline. When the ACD is approved at the conclusion of this review process, it becomes the basis for the KD-1 Readiness Review, ESAAB approval of KD-1, and the start of the LAD.

5.4.2.2.2 License Application Design

The License Application Design continues the development of the repository design based on the approved advanced conceptual design. The repository design specifications will be developed for those design features subject to NRC evaluation in the Safety Analysis Report (SAR) that accompanies the license application. The LAD represents the design upon which the SAR and Environmental Impact Statement (EIS) are based. The LAD will constitute the final, detailed design for all structures, subsystems, and components subject to NRC evaluation in the license application review process. The LAD will be reviewed at a License Application Design Review (LADR) as described in Section 4.2.3.1. After LADR, the final repository design and applicable design specifications and the LAD will be integrated into the MGDS technical baseline as the design configuration baseline for those items represented in the license application submission. After submittal of the LA, the KD-2 Readiness Review, and ESAAB approval of KD-2, the FP&C Design will be initiated.

5.4.2.2.3 Final Procurement and Construction Design

The FP&C Design represents completion of the detailed design. FP&C Design includes any revisions required by the NRC of the LAD, the development of final construction bid packages for all systems, and the completion of all design specifications for procurement and construction.

The FP&C Design will be reviewed at a Detailed Design Review (DDR) as described in Section 4.2.3.1. After the DDR, all repository design specifications and the approved FP&C Design are integrated into the technical baseline as the MGDS design configuration baseline. When the FP&C Design is approved at the conclusion of this review, it becomes the basis for the KD-3 Readiness Review and ESAAB approval of KD-3 which precede the start of repository construction.

5.4.2.2.4 Construction and Testing

Repository construction will begin after receipt of the license to construct from the NRC and approval of Key Decision 3 by the ESAAB. Construction will be in accordance with the FPCD and in conformance to the repository product specifications.

During construction, the repository will be tested to demonstrate operational readiness. Testing of both surface and subsurface facilities will be performed before initial waste emplacement operational readiness is established. At that time, the repository design configuration baseline will be updated to reflect any deviations or waivers granted during construction. If any design changes are made during this phase, the MGDS technical baseline will be updated. This updated document will become the MGDS as-built configuration baseline. At this time, the Key Decision 4 Readiness Review will be conducted to establish that all prerequisites for repository operation have been accomplished.

5.4.2.2.5 Operations and Decommissioning

After the NRC license to operate has been received and ESAAB approval of KD-4, the repository operation will begin. The DOE will apply to the NRC for authorization to permanently close the underground facilities and decommission the surface facilities after completion of repository operations and verification of satisfactory performance. When closure is completed, the DOE will apply for a license termination.

5.4.3 Development of the Engineered Barrier System

The Engineered Barrier System (EBS), as defined in 10 CFR 60.2, "means the waste packages and the underground facility" where the underground facility is defined as "the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals." The EBS boundary is considered as everything inside an underground emplacement area, including the "Waste Package", with the rock wall as the boundary. If the "Waste Package" is positioned in an emplacement borehole, then the EBS would include everything inside the walls of that emplacement borehole.

The Waste Package, as defined in 10 CFR 60.2, includes "the waste form, and any containers,shielding, packing and other absorbent materials immediately surrounding an individual waste container." There is no physical boundary between the waste package and the engineered barrier system because the waste packages are an integral part of the EBS.

The waste package program, as part of the EBS development effort, will develop the waste package design and the scientific basis for waste package performance, if the site is found suitable, for the license application. The underground repository design (discussed earlier in Section 5.4.2) will be developed in parallel and with coordination and interface with the waste package development program. The materials and components of the EBS that affect waste package performance will be specified by the waste package development program. The combined waste package and underground repository facility design will constitute the engineered barrier system.

5.4.3.1 EBS Development Management Responsibilities and Requirements

EBS development is the responsibility of the YMPO. The YMPO is responsible to the Associate Director for Geologic Disposal for EBS design and development. An approved QA program and procedures must be in place for all project participants in design activities. The top-level requirements document for the EBS is the Mined Geologic Disposal System Requirements Document. Whereas these documents provide the technical requirements baseline, the EBS Design Requirements establishes the project-level design requirements baseline.

5.4.3.2 EBS Development Process

A conceptual design for the Waste Package was previously completed as part of the Site Characterization Plan development and is now under project change control. The remaining phases in the development process yet to be completed are the advanced conceptual design, the license application design, the final procurement and fabrication design, and fabrication of the waste package.

5.4.3.2.1 Advanced Conceptual Design

After validation of the conceptual design and review and approval of the MGDS requirements, the YMPO will conduct a project Readiness Review to verify that all prerequisites have been completed for the start of the advanced conceptual design (ACD) phase. The primary purpose of the ACD phase is to develop the necessary information to begin the license application design. During the ACD, design alternatives will be evaluated, a preferred concept identified, design criteria refined, life-cycle costs estimated, and a preliminary schedule developed.

The Waste Package design will be closely integrated with the repository design to ensure a coordinated design approach. On completion of the ACD phase, the YMPO will prepare ACD documentation for the ADGD. This will include a preliminary performance assessment for the prototype waste package. A System Design Review (SDR), as described in Section 4.2.3.1, will be conducted to review the ACD. After SDR, the ACD is integrated into the MGDS technical baseline. When the ACD is approved at the conclusion of the review process, it becomes the basis for the Key Decision Readiness Review and the start of the LAD phase. As outlined above, this data will also be an input for the repository LAD.

5.4.3.2.2 License Application Design

The LAD continues the development of the Waste Package design based on the approved ACD. The design specifications will be developed for those design features subject to NRC evaluation in the Safety Analysis Report, which accompanies the license application for the repository. The LAD represents the design upon which the SAR and the EIS are based. The LAD will constitute the final, detailed design for structure, subsystems, and components subject to NRC evaluation in the repository license application review process. The LAD will be reviewed at a License Application Design Review (LADR) as described in Section 4.2.3.1. After LADR, the waste package design specifications and the LAD will be integrated into the MGDS technical baseline as the design configuration baseline for those configuration items represented in the license application submission. After submission of the license application, the final procurement and fabrication design will be developed for all items not represented in the LAD.

5.4.3.2.3 Final Procurement and Fabrication Design

The final procurement and fabrication design represents completion of the detailed design and includes any revisions required by the NRC of the LAD. It completes all design specifications for procurement and fabrication of the Waste Package. This final, detailed design will be reviewed at a Detailed Design Review (DDR) as described in Section 4.2.3.1. After DDR, the design specifications and the approved design are integrated into the technical baseline as the MGDS design configuration baseline. The approved design becomes the basis for the Key Decision 3 Readiness Review, which precedes the start of waste package fabrication.

5.4.3.2.4 Fabrication

Waste Package fabrication will be in accordance with the final procurement and fabrication design, and in conformance with the design specifications. Once fabrication is complete, the design configuration will be updated to reflect any changes made. This updated documentation will become part of the MGDS as-built configuration baseline.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A

"RESERVED"

APPENDIX B

ACRONYMS

ACRONYMS

ABCBL	As-Built Configuration Baseline
ACD	Advanced Conceptual Design
ACR	Annual Capacity Report
AD	Associate Director
ADGD	Associate Director for Geologic Disposal
ADSC	Associate Director for Systems and Compliance
ADST	Associate Director for Storage and Transportation
AO	Annotated Outline
AP	Administrative Procedure
APR	Acceptance Priority Ranking
ARMS	Automated Requirements Management System
BMP	Baseline Management Plan
BCCB	Baseline Change Control Board
BWR	Boiling-Water Reactor
CFR	Code of Federal Regulations
CM	Configuration Management
CMB	Configuration Management Branch
CMP	Configuration Management Plan
CRD	CRWMS Requirements Document
CRWMS	Civilian Radioactive Waste Management System
DCBL	Design Configuration Baseline
DCS	Delivery Commitment Schedule
DDR	Detailed Design Review
DOE	Department of Energy
DRBL	Design Requirements Baseline
DRD	Design Requirement Document
DT&E	Developmental Test and Evaluation
EBS	Engineered Barrier System
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESAAB	Energy System Acquisition Advisory Board
ESF	Exploratory Studies Facility
ESF-DR	Exploratory Studies Facility-Design Requirement
FDS	Final Delivery Schedule
FFBD	Functional Flow Block Diagram
FP&C	Final Procurement and Construction
FRBL	Functional Requirements Baseline
GROA	Geologic Repository Operations Area

HFE	Human Factors Engineering
HFEPP	Human Factors Engineering Program Plan
HLW	High Level Waste
ICD	Interface Control Document
ICE	Independent Cost Estimate
ICWG	Interface Control Working Group
IFS	Interface Specification
ILP	Implementing Line Procedure (M&O)
ILS	Integrated Logistics Support
IPR	In-Process Review
KD	Key Decision
KDRR	Key Decision Readiness Review
LA	License Application
LAD	License Application Design
LADR	License Application Design Review
LCC	Life-Cycle Cost
M&O	Management and Operating
MGDS	Mined Geologic Disposal System
MRS	Monitored Retrievable Storage
MSA	Major Systems Acquisition
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
OGD	Office of Geologic Disposal
ONWN	Office of the Nuclear Waste Negotiator
OSC	Office of Systems and Compliance
OT&E	Operational Test and Evaluation
PA	Performance Assessment
PBCCB	Program Baseline Change Control Board
PCAD	Program Controls and Administration Division
PDR	Preliminary Design Review
PMSM	Program Management System Manual
POBCCB	Project Office Baseline Change Control Board
PSR	Physical System Requirement
PSR-SW	Physical System Requirement-Store Waste
PWR	Pressurized Water Reactor
QA	Quality Assurance
QAP	Quality Administrative Procedure (M&O)
QARD	Quality Assurance Requirements and Description

QIE	Quarterly Information Exchange
RAM	Reliability, Availability, and Maintainability
RFP	Request For Proposal
RGD	Regulatory Guidance Document
RM	Risk Management
SAR	Safety Analysis Report
SARDR	Safety Analysis Report Design Review
SDR	System Design Review
SEB	Systems Engineering Branch
SEMP	Systems Engineering Management Plan
SEPID	Systems Engineering and Program Integration Division
SNF	Spent Nuclear Fuel
SPIB	Systems Planning and Integration Branch
SPMD	Socioeconomic Policy Management Directive
SRD	System Requirements Document
SRR	System Requirements Review
T&E	Test and Evaluation
TEMP	Test and Evaluation Master Plan
TPM	Technical Performance Measurement
TRBL	Technical Requirements Baseline
TSLCC	Total System Life Cycle Cost
V&V	Verification and Validation
WAS	Work Authorization System
WMSR	Waste Management System Requirements
YMP	Yucca Mountain Site Characterization Project
YMPO	Yucca Mountain Site Characterization Project Office

THIS PAGE INTENTIONALLY LEFT BLANK.

APPENDIX C

GLOSSARY

GLOSSARY

AS-BUILT (TITLE III) DESIGN - Constitutes the design of the as-built system. Confirms the design drawings and final working drawings, design calculations, design specifications, costs and schedules. Assures that the system is constructed in accordance with the approved specifications and that the quality of materials and workmanship meets system requirements.

BASELINE - A quantitative expression of projected costs, schedule, or technical progress to serve as a base or standard for measurement during the performance of an effort; the established plan against which the status of resources and the progress of a project can be measured.

BASELINE CHANGE CONTROL BOARD (BCCB) - A board composed of technical and administrative representatives who recommend approval or disapproval to the BCCB Chairperson of proposed technical and cost and schedule changes to an approved baseline.

BASELINE CHANGE PROPOSAL (BCP) - A proposed engineering change and the documentation by which the change is described, justified, and submitted to the reviewing activity for approval or disapproval.

BASELINE MANAGEMENT PLAN (BMP) - Defines the implementation (including policies and methods) of Baseline Management on a particular program/project.

CONCEPTUAL DESIGN - Develop a system scope that will satisfy program needs. Assure system feasibility and attainable performance levels. Develop reliable cost estimates and realistic schedules in order to provide a system description for Program level review. Develop system criteria and design parameters for all functional and programmatic requirements, specialty engineering requirements, and any other features or requirements necessary to describe the system.

CONFIGURATION - The functional and physical characteristics of hardware, firmware, software, or any other items as set forth in technical documentation and achieved in a product.

CONFIGURATION ITEM (CI) - An aggregation of hardware, software, or any of its discrete portions that satisfies an end use function and is designated for Configuration Management. CIs may vary widely in complexity, size, and type. During development, manufacture, construction, and installation, CIs are those items whose performance parameters and physical characteristics are separately defined to achieve the overall end use function and performance.

CONFIGURATION MANAGEMENT - A discipline applying technical and administrative direction and surveillance to:

- Identify and document the functional and physical characteristics of CIs
- Audit the CIs to verify conformance to specifications, interface control documents, and other contract requirements
- Control changes to CIs and their related documentation

- Record and report information needed to manage CIs effectively, including the status of approved changes.

Configuration Management is the systematic evaluation, coordination, approval (or disapproval), documentation, implementation, and audit of all approved changes in the configuration of a product after formal establishment of its configuration identification.

Note: As used for computer software, Configuration Management is a system for orderly control of software, including methods used for labeling, changing, and storing software and its associated documentation; and the systematic evaluation, coordination, approval or disapproval, and implementation of all approved changes in an item of software after establishment of its configuration.

COST AND SCHEDULE BASELINE - Quantitative expressions of projected cost and schedule objectives/targets to serve as a base or standard for measurement of progress during the performance of an effort; the established costs and milestones against which the status of expenditures and progress of the Program/project can be measured.

DETAILED (TITLE II) DESIGN - Continues the development of the system and completes the design based on the approved preliminary design (Title I) and the design requirements. Detailed design includes any revisions required of the preliminary (Title I) effort; preparation of final working drawings, specifications, bidding documents, cost estimates, and coordination with all parties which might affect the development of the system. Detailed design results in the design specifications and is the basis for construction.

FINAL PROCUREMENT & CONSTRUCTION DESIGN - The design that will develop the final (working) drawings and specifications for procurement and construction. This design phase will complete the detailed design of all structure, systems, and components not part of the LA or SAR Design and will also include any final revisions to the LA or SAR Designs as required to conform with NRC directions regarding the license application.

LICENSE APPLICATION DESIGN / SAFETY ANALYSIS REPORT DESIGN - The design phase that completes the resolution of the design and licensing issues identified and assessed in earlier design phases and develops the preliminary and detailed design of the structure, systems, and components important to safety. The License Application (LA) Design (MGDS) and the Safety Analysis Report (SAR) Design (MRS Facility) are accomplished after the conceptual design (and the advanced conceptual design if applicable) and are followed by the Final Procurement and Construction Design.

LIFE CYCLE COSTS - The sum total of the direct, indirect, non-recurring, recurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, acquisition, test and evaluation, acceptance, licensing, operation, maintenance, and decommissioning of a major system. Where system or project planning anticipates use of existing sites or facilities, restoration and refurbishment costs should be included.

MILESTONE - An important or critical event and/or activity that must occur in the development cycle in order to achieve the project objectives.

PRELIMINARY (TITLE I) DESIGN - Initiates the system design effort based on the conceptual design and the system requirements. Preliminary design determines the requirements and criteria which will define the detailed design. Tasks include preparation of preliminary planning and engineering studies, preliminary drawings and outline specifications, life-cycle cost analysis, preliminary cost estimates, and scheduling for project completion. Preliminary design provides identification of long lead procurement items and analysis of risks associated with continued project development. Preliminary design results in the design requirements and is the basis for the detailed design.

PROJECT - A project is a unique major effort within the CRWMS Program which has firmly scheduled beginning, intermediate, and ending date milestones; prescribed performance requirements, prescribed costs; and close management, planning, and control. A project is a basic building block in relation to the program which is individually planned, approved, and managed. Project level refers to that level responsible for accomplishing the specific activities of that segment of the program.

TECHNICAL BASELINE - A configuration identification document or set of such documents formally designated and approved at a specific time. Technical baselines, plus approved changes to these baselines, constitute the current configuration identification. As used in this program, the "technical baseline" is composed of, and evolves through, the functional and technical requirements baseline that is presented in the System Requirements Documents, the design requirements baseline, the design configuration baseline, and the "as-built" configuration baseline.

THIS PAGE INTENTIONALLY LEFT BLANK.

APPENDIX D

REFERENCE DOCUMENTS

REFERENCE DOCUMENTS

1. U.S. Department of Energy, *OCRWM Program Management System Manual*, Revision 5, DOE/RW-0043REV5, January 1993.

2. U.S. Department of Energy, *Project Management System*, Change 1, DOE Order 4700.1, Washington D.C., June 2, 1992.

3. U.S. Department of Energy, *Major System Acquisition and Major Projects*, DOE Order 4240.1K, Washington D.C., June 23, 1992.

4. U.S. Congress, *Nuclear Waste Policy Act of 1982*, PL 97-425, January 7, 1983.

5. U.S. Congress, *Nuclear Waste Policy Amendments Act of 1987*, Title V, Subtitle A, PL 100-203, December 22, 1987.

6. U.S. Department of Energy, *Mission Plan Amendment*, OCRWM, DOE/RW-0128, June 1987.

7. U.S. Department of Energy, *Waste Management System Description Document*, Revision 1, OCRWM, DOE/RW-0270P, February 1992. (Superseded--see Reference 14)

8. U.S. Department of Energy, *Waste Management System Requirements Document, Volume I-General*, Revision 2, OCRWM, DOE/RW-0264, February 1992. (Superseded--See Reference 14)

9. U.S. Department of Energy, *Waste Management System Requirements Document, Volume IV-Mined Geologic Disposal System*, Revision 2, OCRWM, DOE/RW-0268P, February 1992. (Superseded--see Reference 16)

10. U.S. Department of Energy, *Physical System Requirements - Overall System*, OCRWM, DOE/RW-0334P, January 1992. (Superseded--see Reference 14)

11. U.S. Department of Energy, *Physical System Requirements - Store Waste*, OCRWM, DOE/RW-0319, January 1992. (Superseded--see Reference 17)

12. U.S. Department of Energy, *Physical System Requirements - Transport Waste*, OCRWM, DOE/RW-0352, April 1992. (Superseded--see Reference 18)

13. U.S. Department of Energy, *Physical System Requirements - Accept Waste*, OCRWM, DOE/RW-0369, August 1992. (Superseded--see Reference 15)

14. U.S. Department of Energy, *Civilian Radioactive Waste Management Requirements Document*, Revision 1, DOE/RW-0406P, March 1994.

15. U.S. Department of Energy, *Waste Acceptance System Requirements Document*, Revision 1, DOE/RW-0351P, March 1994.

16. U.S. Department of Energy, *Mined Geologic Disposal System Requirements Document*, Revision 1, DOE/RW-0404P, March 1994.

17. U.S. Department of Energy, *Monitored Retrievable Storage System Requirements Document*, Revision 1, DOE/RW-0420, March 1994.

18. U.S. Department of Energy, *Transportation System Requirements Document*, Revision 1, DOE/RW-0425, March 1994.

19. U.S. Department of Energy, *Quality Assurance Requirements and Description*, Revision 0, OCRWM, DOE/RW-0333P, December, 1992.

20. 40 CFR Part 191, *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, Code of Federal Regulations.

21. 10 CFR Part 60, *Disposal of High-Level Radioactive Wastes in Geologic Repositories*, Code of Federal Regulations, Revision January 1, 1990.

22. 10 CFR Part 72, *Licensing Requirements for Independent Spent Fuel Storage Facilities*, Code of Federal Regulations.

23. American National Standard Institute/The American Society of Mechanical Engineers, ANSI/ASME NQA-1 - 1989 Edition, *Quality Assurance Program Requirements for Nuclear Facilities*, September 15, 1989.

24. U.S. Department of Energy, *Socioeconomic Policy Management Directive*, OCRWM, August 5, 1992.

25. U.S. Department of Energy, *General Design Criteria*, DOE Order 6430.1A, Washington D.C., April 6, 1989.

26. U.S. Department of Defense, *Human Engineering Requirements for Military Systems, Equipment and Facilities*, MIL-H-46855B, January 1979.

27. U.S. Nuclear Regulatory Commission, *Guidelines for Control Room Design Reviews*, NUREG 0700, September 1981.

APPENDIX E

INTEGRATED LOGISTICS SUPPORT PROGRAM PLAN
<TBD>

Note: Designation of this appendix as <TBD>
indicates that inclusion of the appendix is
"To Be Developed" in a future change to the SEMP.

APPENDIX F

RELIABILITY, AVAILABILITY, AND MAINTAINABILITY PROGRAM PLAN <TBD>

Note: Designation of this appendix as <TBD>
indicates that inclusion of the appendix is
"To Be Developed" in a future change to the SEMP.

APPENDIX G

HUMAN FACTORS ENGINEERING PROGRAM PLAN

HUMAN FACTORS ENGINEERING PROGRAM PLAN

G.1 INTRODUCTION

G.1.1 Purpose

The Systems Engineering Management Plan (SEMP) specifies the requirement for an Office of Civilian Radioactive Waste Management (OCRWM) Human Factors Engineering Program Plan (HFEPP). The HFEPP addresses human factors engineering (HFE) issues as mandated by Sections 0101-4, 0110, 1300-12 and 1300-13 of DOE Order 6430.1A, *General Design Criteria* and UCRL-AR-108791, *Human Factors Engineering Design Criteria: Volume 1, General Criteria*. The Human Factors Engineering Program Plan (HFEPP) establishes policy, defines objectives, and provides guidance to the projects. The project-level System Engineering Management Plan will further define the HFE activities. The Civilian Radioactive Waste Management System (CRWMS) Requirements Document (CRD) and System Requirements Documents (SRDs) incorporate specific HFE requirements. The projects shall implement these requirements.

G.1.2 Policy

CRWMS shall incorporate the HFE discipline and principles in the requirements development, analysis, design, construction, operation, and decommissioning of the system to promote safety, minimize operator error, maximize overall efficiency, and support maintainability. A Systems Engineering approach shall be used to ensure coordination of the engineering specialties, including HFE, and their integration with the design and review process. Design and review teams shall include or have resource support available from persons that are HFE qualified by training and experience to perform HFE functions.

G.1.3 Objective

The objective of the HFE program is to improve human, and thus, CRWMS system performance. Improved performance results from reducing human error, increasing productivity, decreasing equipment and property damage, and improving the safe operation and maintenance of DOE facilities and systems.

Specific objectives include:

- Satisfying system requirements by appropriate use of the human component
- Meeting system performance goals through proper design of equipment, software, and environment
- Eliminating or minimizing those design features that constitute a hazard to personnel
- Selecting tradeoff points between automated versus manual operations for peak system efficiency within appropriate cost limits

AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

2 of 2

- Facilitating maintenance through equipment design and equipment/facility layout
- Developing procedures for efficient, reliable, and safe operation and maintenance of equipment
- Eliminating potential error-inducing equipment design features
- Ensuring efficient communication and use through the proper design of the facility layout and equipment arrangement
- Designing CRWMS to minimize training requirements
- Minimizing handling time through proper design of equipment.

G.1.4 Scope

The HFEPP requires the application of HFE criteria, principles, and practices during requirements development, analysis, design, construction, test, operation, and decommissioning of CRWMS. This plan identifies the HFE activities and defines the organizational responsibilities to accomplish Program objectives.

G.1.5 Approach

This Plan integrates the HFE discipline and principles into the systems engineering process to ensure the development of a complete, effective and licensable CRWMS in accordance with the Program Management Systems Manual (PMSM). Implementation of the HFE Program shall comply with the criteria of DOE Order 6430.1A, *General Design Criteria.* Guidance documents including MIL-H-46855B, *Human Engineering Requirements for Military Systems, Equipment and Facilities*, and NUREG 0700, *Guidelines for Control Room Design Reviews* will be used as appropriate.

G.2 HFE PROGRAM AND PROJECT RESPONSIBILITIES

G.2.1 HFE Program Responsibilities

The Office of Systems and Compliance has HFE Program-level responsibilities that includes:

- Establishing HFE policy and objectives
- Identifying and allocating HFE system requirements through SRDs
- Identifying and facilitating the resolution of HFE issues that cross project boundaries
- Monitoring compliance with this Appendix includes participation in reviews and audits.

G.2.2 HFE Project Responsibilities

HFE project-level responsibilities include:

- Developing HFE plans
- Implementing the HFE Program as defined by HFE plans and procedures
- Supporting HFE activities that cross system-element boundaries.

Each project shall develop an HFE plan. This plan shall have the same program-level review and concurrence as the project Systems Engineering Management Plan (SEMP) as specified in Section 4.2 and Appendix F of the PMSM.

G.3 HFE PROCESS IN THE LIFE CYCLE OF THE CRWMS

G.3.1 HFE Overview

DOE Order 6430.1A prescribes the integration of HFE into the system development process through four phases: planning, requirements analysis, system design, and test and evaluation (T&E). For planning, project plans describe the integration of HFE into the design process and identify the types of analyses and evaluations needed to incorporate HFE considerations into the design. The requirements analysis identifies the needs and requirements of the system user, and HFE personnel ensure their incorporation in the technical baseline. During this process, the system functions are allocated to humans, machines, or human/machine combinations. Analyses, such as, task analyses are performed on those functions allocated to humans and human/machine combinations. During system design, HFE criteria are applied to the design or selection of equipment operated and maintained by personnel, layout of facilities, and the development of procedures. T&E verifies the HFE requirements and determines whether the system can be operated and maintained by the intended user personnel under conditions for which it was designed. The HFE project plans shall describe these four phases and the related HFE activities in accordance with paragraph 1300-12.3.2 of DOE Order 6430.1A.

Table G-1 summarizes the HFE activities for Storage and Transportation and MGDS by CRWMS life-cycle phases. The MGDS includes the ESF. These activities are described in Sections 3.2 through 3.7. Planning and requirements analysis are defined in the Conceptual Design Phase. Preliminary system design occurs in the Safety Analysis Report (SAR) and License Application (LA) Design Phase. Final system design for the MRS and MGDS is performed in the Final Procurement and Construction (FP&C) Design Phase. For cask development and other transportation elements, the sequence of events differs from the above phases. After Conceptual Design, a detailed design is developed and a SAR completed. An application is then submitted to NRC for certification. After receipt of the certificate of compliance, fabrication is initiated. T&E begins in the Conceptual Phase and peaks during the Construction Phase. Operational analyses are conducted during operation. Decommissioning tasks are yet to be determined.

Table G-1. HFE in CRWMS Life-Cycle Phases

Normal Acquisition Process:	Conceptual Phase	Title I	Title II	Construction	Operation	Decommissioning
Storage and Transportation Phases:	Conceptual Design	SAR Design	FP&C Design or Licensing	Construction	Operation	Decommissioning
MGDS Phases:	Conceptual Design	LA Design	FP&C Design	Construction	Operation	Decommissioning
HFE Involvement/ Supporting Activities:	•Operational concept •Functional allocation •Scenario development •Task analysis	•Facility layout design •Equipment design •User/computer interface definition •Mockup evaluation •Job design •Work environment design •Conceptual design phase task updates	•SAR/LA task updates •Procedure development	•Test and evaluation •Failure analysis •Operating and support hazard analysis	•Operational analysis •Occurrence investigations	• TBD

G.3.2 HFE in Conceptual Design Phase

G.3.2.1 HFE Planning

Planning includes developing the project HFE plan and defining the integration of HFE into the project systems engineering process and design efforts, HFE analyses and evaluations required for system design in the different life-cycle phases, HFE project objectives, and HFE requirements.

G.3.2.2 HFE Requirements Analysis

The requirements analysis includes an assessment of the CRWMS functions, and a study of the mission need, program objectives, and regulatory constraints. From this analysis, personnel and operator- and maintainer-machine interface requirements are identified and included in the CRWMS Requirements Baseline.

The requirements analysis determines the functions to achieve the project's mission need and program objectives, the tasks needed to accomplish the functions, and the allocation of tasks to humans, machines, or human-machine combinations. For those tasks allocated to humans and human-machine combinations, task analyses identify the personnel, operator, and maintainer needs. During the early stages of the project effort, a gross analysis of tasks occurs. This analysis determines whether performance requirements can be met by a combination of proposed equipment, software, and personnel. Task analyses results include estimates of the number, type of staff, and workload at each position; system information flow; and the environmental conditions for optimal human performance. The iteration of task analyses results in more detail as the design matures.

The requirements analysis continues through the design phases with increasing convergence on the role of humans and machines, optimum information flow among humans and machines, design of the workspace layout, and design of the operator- and maintainer-machine interfaces.

G.3.2.2.1 Operational Concept

An operational concept is developed during the early phases of CRWMS. The development of this concept ensures a coherent and feasible set of operations to accomplish the CRWMS mission. The operational concept is reviewed for the appropriateness of the roles and tasks assigned to humans or human-machine combinations. Also, the environmental conditions under which humans are expected to work are reviewed. Any task beyond human capabilities and any unacceptable working environmental condition results in recommendations to change the operational concept. Rationale for concept changes is documented. Refinements to the operational concept continue through operations.

The review of similar operations occurs simultaneously with providing input to the operational concept. This review increases the understanding of the complexities associated with the proposed CRWMS operations and facilitates the development of alternative or refined operational concepts. Similar operations include transportation of hazardous materials, material handling facilities, tunnel boring projects, and other repositories, such as the Waste Isolation Pilot Plant.

G.3.2.2.2 Functional Allocation

Analyses are conducted to determine the information flows and needed processing to accomplish the project objectives. Analyses and tradeoff studies are conducted to allocate system functions to humans, machines, or human/machine combinations. The functional allocation process is documented.

G.3.2.2.3 Scenarios

Based on the operational concept, scenarios provide a basis for development of ways for operators and maintainers to accomplish their tasks. Scenarios for normal and critical off-normal conditions are developed. The inter- and intra-project interface scenarios are analyzed to ensure that no operational design incompatibilities exist, off-normal situations are identified and provisions made for their control, and efficiency and safety are not compromised.

G.3.2.2.4 Task Analysis

Task analyses are performed on those functions allocated to humans and human/machine combinations. The results of the task analyses identify information needed for equipment design and procedures; preliminary staffing levels; and skill, training, and communication requirements. The results of these analyses are documented in a Task and Skill Analysis Report during the Conceptual Design Phase. This report is updated in greater detail in each succeeding design phase.

Critical tasks require further analysis. Critical tasks are tasks that, if not accomplished in accordance with pre-defined requirements, may have significant effects on safety, system reliability, efficiency, effectiveness, or cost. Design decisions about equipment operated or maintained by personnel result from these critical task analyses. These decisions increase operating efficiency and/or decrease human exposure to unsafe conditions. These detailed task analyses identify information and information flow required to perform tasks; operator and maintainer decision-making and actions; workspace envelope required by action taken; work environment; frequency, precision, and required time of needed actions; available feedback from actions taken; required tools and equipment; number of personnel required to perform each task; required job aids; type of communication required; special hazards; team interaction; and the operational limits of personnel, equipment, and software. Results of the critical task analyses are documented.

After completion of the task analyses, workload analyses determine work overload or underload at each position. Further analyses determine if different job loading configurations eliminate the overload and underload work conditions. Results of the workload analyses are documented.

G.3.3 HFE in SAR/LA Design Phase

The HFE requirements identified in the previous phase are converted into design inputs in the SAR/LA Design Phase. Activities initiated in the Conceptual Design Phase are updated in this design phase: the operational concept is refined, the functional allocation of tasks to humans and machines is substantially completed, detailed scenarios are developed, and task analyses are conducted. The results from these tasks are used to make design decisions. Other tasks in this phase include:

- Providing inputs into the facility layout design
- Providing inputs into the design or selection of equipment to be operated or maintained by system personnel
- Providing user/computer inputs into the design of custom software
- Performing trade-off studies
- Evaluating mock-ups/prototypes/dynamic simulations
- Reviewing detailed design drawings
- Providing inputs to the job designs
- Determining adequacy of the work environment and facility design with regard to safety and efficiency of operations.

G.3.3.1 Facility Layout Design

Studies performed for the purpose of increasing safety and efficiency of operation provide facility layout design inputs. Efficiency of operation includes minimizing travel distance, travel time, handling steps, and handling time.

Facility layout studies are conducted to increase the efficiency of operation. The documentation for these studies includes assumptions and a description of methods, results, and recommendations.

G.3.3.2 Equipment Selection or Design

The features of designed or selected equipment are based on criteria derived from the task analysis in the previous phase. The equipment design takes into account human anthropometric data, the sequence of control and display use, and the normal and emergency tasks performed with the equipment. The equipment is designed to achieve required operator and maintainer performance levels; minimize training time; achieve reliable persor.nel equipment performance; and ensure safe operation, maintenance, and control. Equipment design could influence facility design.

G.3.3.3 User/Computer Interface Design

For custom software involving a user/computer interface, the commands (their purpose and effect), command hierarchy, the command language, and the command concept are developed by HFE personnel. The command concept is the arrangement, order, and presentation of the visual information resulting from invoking the command. The Help and Error Message systems associated with the commands are also developed. For off-the-shelf software, recommendations for software selection are based on evaluation of the software package and its ability to satisfy end-user needs.

For custom software systems involving a user/computer interface, documentation is developed to describe the work station configuration including consoles and input/output devices, commands (their purpose and effects), command language and hierarchy, graphics, information layout, error messages, and help system.

G.3.3.4 Trade-off Studies

Trade-off studies are conducted to determine the adequacy of job designs, decision-making aids, and equipment design alternatives. Selection of an alternative is based on the ease, accuracy, and timeliness with which humans can perform their tasks. The cost-effectiveness of the alternatives is also considered. The results of these studies are documented in appropriate project reports.

G.3.3.5 Mockups/Prototypes/Dynamic Simulations

For critical portions of the system elements, mockups and dynamic simulations are developed and evaluated for ease of operation and maintenance. Commercial-off-the-shelf items are also evaluated for ease of operation and maintenance. The evaluations include determining the adequacy of the access, workspace design, layout design, control/display integration, control selection and placement, positioning of visual and auditory displays, access to communications, actuation of warning devices, and other applicable requirements.

For custom software development, prototypes are developed early and shown to the end-user or to the anticipated type of end-user. These demonstrations are held to elicit feedback from the end-user to improve the ease of use of the computer system. The level of complexity for use of the computer system matches the skills of the projected end-user.

Mockups, simulations, or prototypes are developed for equipment involving critical human performance. Recommendations for changes are documented.

G.3.3.6 Detailed Design Drawings

Drawings are reviewed to ensure the system meets HFE requirements and can be operated and maintained efficiently, reliably, and safely.

G.3.3.7 Job Design

Tasks are reviewed to determine what collection of tasks comprise a job and the job's duties and responsibilities. If shift work and shift rotation are required, a job rotation schedule will be developed that minimizes human error due to changes in the circadian rhythm. Job documentation will describe the rationale for the grouped tasks, the job's duties and responsibilities, the shift rotation schedule, and how the rotation schedule will minimize human error.

G.3.3.8 Work Environment and Facilities Design

The adequacy of the work environment and facilities design is evaluated for both normal and off-normal conditions. The work environment includes lighting, noise, temperature, vibration, humidity, and ventilation.

For those jobs anticipated to be executed under extreme operating conditions, the tasks and equipment used are analyzed to ensure all possibilities are considered, determine whether operational incompatibilities exist in equipment, identify all off-normal situations and provide for control, and ensure efficiency and safety are not compromised. Documentation demonstrates studies are performed to achieve the safety objectives. Recommendations are documented.

G.3.4 HFE in FP&C Design Phase

The same activities are conducted in this phase as in the SAR and LA Design Phase but at a more detailed design level. By the end of this phase, equipment selection is completed, fabricated equipment is designed, the needed skills and actions for crew and individual positions are defined, procedures are developed, the work environment meets the requirements, the information flow among humans and machines and the needed information processing capability are finalized, needed job performance aids and tools are identified and designed, and the operations and maintainability concepts are defined. At the completion of this phase, reviews determine whether the final CRWMS design will be efficiently, reliably, and safely operated and maintained. Documentation from the previous phase is updated in this phase.

G.3.5 HFE in Construction

T&E activities peak during construction. In T&E, tests verify whether the system can be operated and maintained by the intended user personnel under the conditions for which it was designed. Providing test plan inputs, participating in tests, and analyzing data for the test report are HFE activities in this phase. When possible, data are collected under actual operational environmental conditions. Tests occur under normal and off-normal conditions. Discrepancies between requirements and observed system performance are documented and changes to the design are recommended. Analyses of failures determine whether failure was due to human error, poor human-machine interface design, or equipment alone. As appropriate, recommendations for changes in design, training, or procedures are made.

The Operating and Support Hazard Analysis determines whether undesirable or unsafe design or procedural features were introduced. Any residual operational hazard to the operator or maintainer is documented.

G.3.6 HFE in Operation

During operation, operational data is collected and analyzed to increase system efficiency. When applicable, occurrence investigations determine if the design or procedures contributed to human error. Where appropriate, a Baseline Change Proposal is submitted to modify the system design and those procedures and training under Change Control Board authority to increase system efficiency or reduce probability of human error.

G.3.7 HFE in Decommissioning

Activities are phased out and functions curtailed during decommissioning so the facility can be closed down with the least impact on the surrounding environment or community. HFE activities are unknown at this time, and will most likely be determined during operations. Affected project documentation is revised accordingly.

G.3.8 Monitoring Process

This section describes the various methods used to monitor project HFE compliance. These methods include those cited in Section 4.2.3, Conformance Verification Process, of the SEMP, and those discussed in this section.

G.3.8.1 Quarterly Information Exchange

The Quarterly Information Exchange (QIE) disseminates technical information among the system elements and identifies issues. HFE studies, tradeoffs, findings, and design decisions are disseminated through the QIE forum.

G.3.8.2 Interface Control Working Group

The Interface Control Working Group (ICWG) identifies, documents, reviews, manages, and controls Program interfaces. In addition, the ICWG resolves interface issues raised by members of the ICWG. The resolution of HFE issues that cross project boundaries is facilitated through the ICWG.

G.3.8.3 Review and Concurrence

The Program reviews project HFE plans to determine conformance to the HFEPP. The Office of Systems and Compliance has review and concurrence authority on these documents.

G.3.8.4 Occurrence Investigations

During construction, T&E, and operation, occurrence investigations determine whether the design, procedures, or training contributed to human error. Where appropriate, a Baseline Change Proposal is submitted to modify the facility design, equipment design, and those procedures and training under Change Control Board authority.

G.3.8.5 Requirements Traceability

Development and approval of system-level and project-level requirements require a top-down and bottom-up requirements traceability process. This process delineates the requirements traceability path from the higher- to lower-level documents and the requirements traceability path from the lower- to higher-level documents. This traceability process and the Automated Requirements Management System (ARMS) traceability tool monitor HFE requirements conformance.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX H

SYSTEM SAFETY PROGRAM PLAN
<TBD>

Note: Designation of this appendix as <TBD>
indicates that inclusion of the appendix is
"To Be Developed" in a future change to the SEMP.

DATE
FILMED
8/22/94

END