THE FUNCTIONAL ANALYSIS APPROACH TO ESTABLISHING THE OCRWM REQUIREMENTS BASELINE

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ABSTRACT

This paper describes the development of the Physical System Requirements (PSR) documents which serve as the functional requirements baseline for the U.S. Department of Energy's Civilian Radioactive Waste Management program. Based on a functional analysis approach, the PSR documents have organized the hundreds of externally generated regulatory requirements according to the functions that must be performed by the Nuclear Waste Management System. The PSR documents also contain results of the functional analysis in the form of boundary diagrams, function hierarchy trees, function description tables containing the allocated requirements, architecture tree and tables, and functional flow diagrams. These documents are being used as a basis for developing more detailed technical requirements documents, design documents and construction drawings. The results of the functional analysis approach provide a framework for ensuring traceability of the requirements derived from regulations, applied during the design process, and specified during construction.

INTRODUCTION

The Nuclear Waste Policy Act (1) (NWPA) of 1982 assigned to the U.S. Department of Energy (DOE) the responsibility for managing the disposal of spent nuclear fuel and high-level radioactive waste and established the Office of Civilian Radioactive Waste Management (OCRWM) for that purpose. Since its inception, OCRWM has always worked to a firm set of technical requirements. Beginning in the early 1980's, there were the National Waste Terminal Storage series of criteria documents. These were followed by the Generic Requirements for a Mined Geologic Disposal System (DOE/RW-090) in 1984 and then the Waste Management System Requirements (WMSR) series of requirements documents. The Secretary of Energy, in his November 1989 (2) report to Congress (DOE/RW-0247), announced three new initiatives for conduct of the OCRWM program. One of these initiatives was to establish an improved management structure and procedures. In response, OCRWM performed a management study and the Director subsequently issued the Management System Improvement Strategy (3) (MSIS) on August 10, 1990, which requires a rigorous implementation of systems engineering principles with special emphasis on functional analysis.

A primary objective of OCRWM's MSIS was to establish a consistent set of program requirements, including:

- Requirements for the physical systems that will ultimately comprise the Nuclear Waste Management System (NWMS),
- Requirements for the management program that must bring this system into being, and
- Requirements for the test facilities that will be used to determine if the selected site and engineered systems will comply with their ultimate requirements.

The physical system functional analysis was conducted to better understand what was needed in order to satisfy OCRWM's overall mission to Manage Waste Disposal in a safe and effective manner while complying with the regulations promulgated by Congress, DOE, NRC and EPA. It has resulted in the establishment of the Functional Requirements Baseline which provided the basis for preparing Conceptual Designs of the various parts of the NWMS (Fig. 1). The Technical Requirements Baseline is still being prepared from this Functional Requirements Baseline and the resultant Conceptual Designs. Title I (preliminary design) and the Design Requirements Baseline will follow and, finally, a Title II (detailed) Design will be prepared prior to building, testing, and operating the system.

APPROACH

The iterative, *step-wise approach* for conducting the functional analysis is shown in Fig. 2. The functional analysis was led by a facilitator who directed a team of technical experts from across the OCRWM Program in accordance with OCRWM's Physical System Requirements/Functional Analysis Management Plan and Quality Assurance procedures. As a first step in the functional analysis, the mission of the NWMS was explicitly stated. Based upon the Nuclear Waste Policy Act, **the mission of the operating waste management system is to manage and dispose of the nation's spent fuel and high-level radioactive waste in a geologic repository in a manner that protects the health and safety of the public and of workers and the quality of the environment.** In order

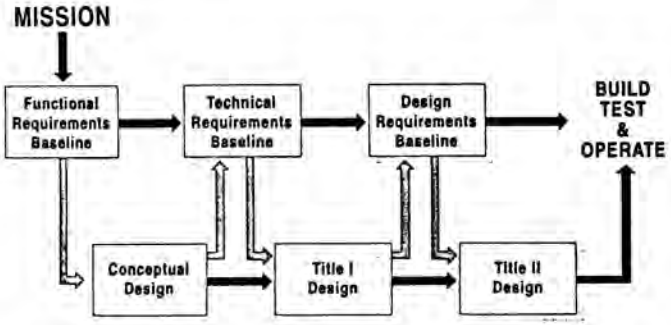

Fig. 1. Implementation of systems engineering during the design process.

to accomplish this mission, DOE is developing a NWMS which will accept, transport, store, and dispose of spent nuclear fuel and high-level radioactive waste in a geologic repository in a timely manner. The mission statement provided the basis to:

- Identify the functions that must be performed by the physical system and each of its elements to fulfill the nuclear waste disposal mission,
- Specify the corresponding requirements imposed on each of the functions, and
- Select the conceptual architecture that will be used to satisfy the requirements.

The functional analysis of the NWMS covered the time period from the initial acceptance of spent fuel or high-level waste through 10,000 years following closure of the repository. Several working sessions were held with the technical experts to define the functions, allocate the requirements, and develop the functional flow diagrams. The Functional Analysis Team was supported by a Requirements Research Team who identified and reviewed requirements from numerous source documents. Table I contains a list of source documents from which the requirements contained in the Physical Systems Requirements documents were extracted. Although additional source documents have been, and will continue to be, reviewed, it was determined that the scope and detail contained in the documents referenced in Table I are sufficient to specify the initial set of requirements for the NWMS.

RESULTS

The specification of requirements for the NWMS is an iterative process. Within the Function- Requirements-Architecture (F-R-A) functional analysis approach, the iterations occur at each level of the function hierarchy. Thus, each level must be completely defined in terms of its function, the corresponding requirements which specify how well the function must be performed, and an architectural concept for satisfying the requirements. On a more macro scale, requirements lead to engineering designs which in turn lead to more detailed requirements and then to more detailed designs (as shown in Fig. 1).

In order to accomplish the "manage waste disposal" mission, DOE is developing a NWMS which will accept, transport, store, and dispose of spent nuclear fuel and high-level waste in a geologic repository. Thus, this portion of the MSIS effort has resulted in the preparation of the following NWMS requirements documents (4-9):

- Physical System Requirements - Overall System
- Physical System Requirements - Accept Waste
- Physical System Requirements - Transport Waste
- Physical System Requirements - Store Waste
- Physical System Requirements - Dispose of Waste
- Physical System Requirements - Exploratory Studies Facility

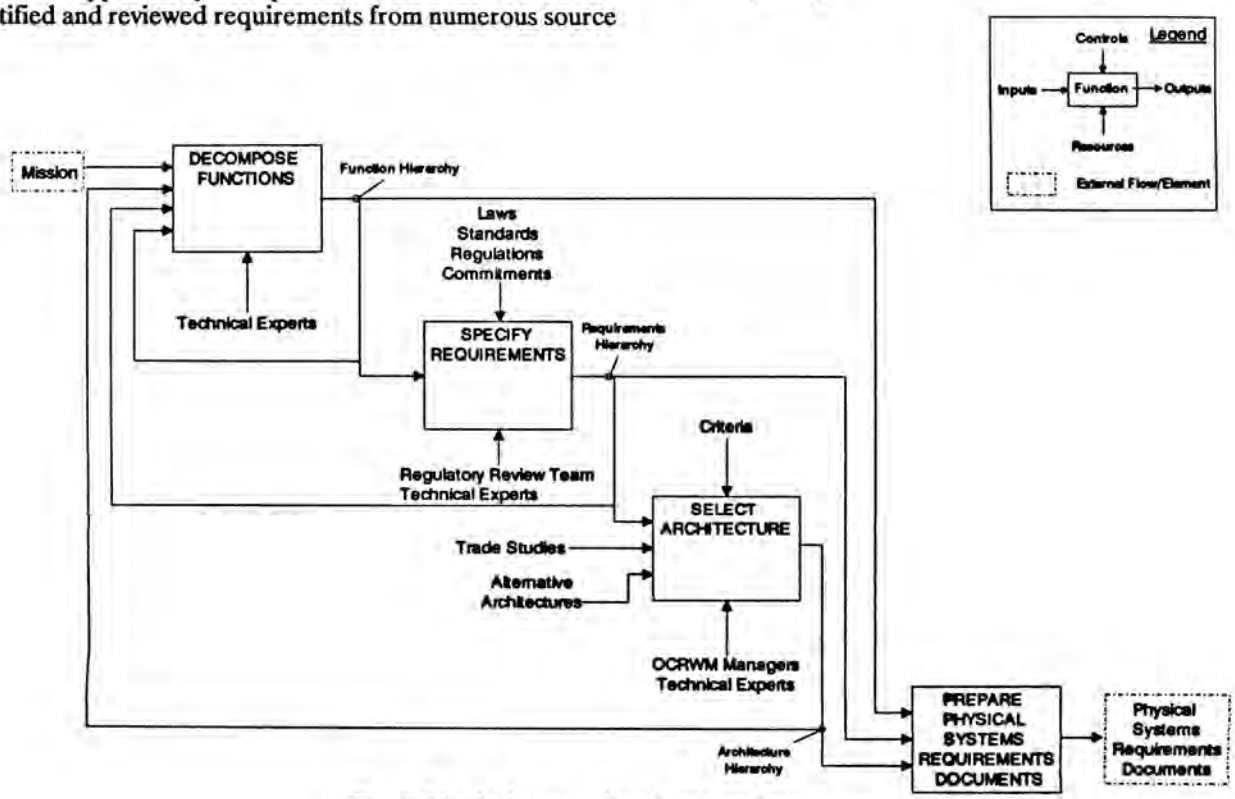

Fig. 2. Physical system functional analysis approach.

Due to the many requirements imposed upon the OCRWM program, they need to be organized into a framework that can be useful for the designers and can serve as a checklist to ensure that all relevant requirements are accounted for at each design step. The PSR documents provide this framework by organizing the myriad of requirements according to the functions that must be performed by the NWMS. The results of applying the F-R-A approach to the "manage waste disposal" mission take many forms; boundary diagrams, function hierarchy trees, function description tables, architecture trees, architecture tables, and functional flow diagrams.

Boundary Diagrams (Fig. 3) are used to explicitly define the boundaries of applicability for both the functions and the physical systems. They are especially useful in identifying where specific requirements are to be applied and who is responsible for them.

The F-R-A approach is based on the premise that, when describing a system, it is better to think in terms of the functions that must be performed than a collection of parts which comprise the system. Function Trees concisely illustrate the hierarchical relationship between parent functions and subfunctions. Figure 4 displays the functions, to the third level, deemed necessary to fulfill the "manage waste disposal" mission. As indicated, the numbering scheme which uniquely identifies function titles is based on using a 1. at the first level, a 1.i at the second level, and a 1.i.j at the third level, etc. This scheme, which permits traceability between functions and subfunctions (and their corresponding requirements) is used throughout the results of the functional analyses.

Function Description Tables were prepared for each function. These tables contain a definition of the function, a list of all inputs to, and outputs from, the function, and a complete specification of all the requirements allocated to the function including its inputs and outputs (Table II).

Even though the F-R-A approach is not intended to yield detailed designs with which to complete each iterative step, it is necessary to identify a preferred system concept that can satisfy the corresponding function and requirements. These concepts for the physical systems and subsystems were placed in a hierarchical order by creating an Architecture Tree. Architecture Tables, containing a list of all the requirements to be satisfied (in part or entirely) by the corresponding piece of the physical system, were also prepared. Each architecture table also contains a justification for the selection of this concept and a brief description of the physical system concept itself.

A primary responsibility of systems engineering is to ensure a well integrated system. In essence, systems integration is simply the management of interfaces. The preparation of Functional Flow diagrams (Fig. 5) is a useful technique to force the participants to thoroughly understand and precisely communicate all the interrelationships between functions. By explicitly showing both the primary internal interfaces between functions and the primary external interfaces between functions and the environment, these flow diagrams also facilitate systems integration.

DISCUSSION

The OCRWM Program consists of two Projects: the Yucca Mountain Project which is investigating the site suitability for a repository and the Waste Acceptance, Transportation and Storage Project. Presently, the OCRWM Interim Technical Baseline is comprised of two distinct parts. As shown on the left side of Fig. 6, the PSR documents currently represent all but the "Dispose of Waste" segment of the

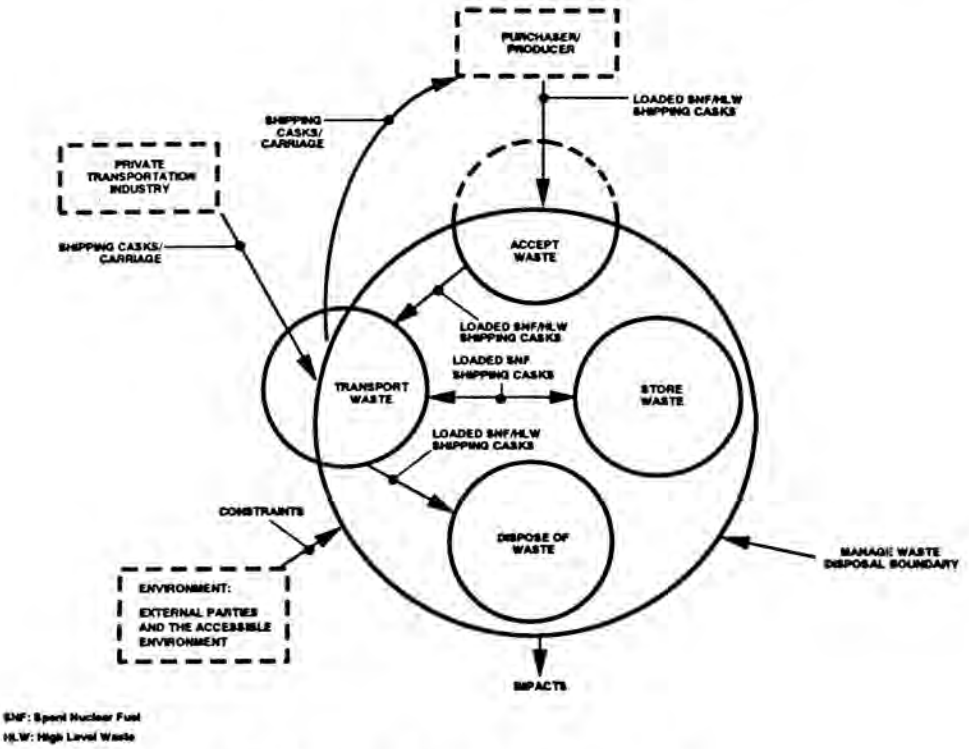

Fig. 3. Manage waste disposal boundaries.

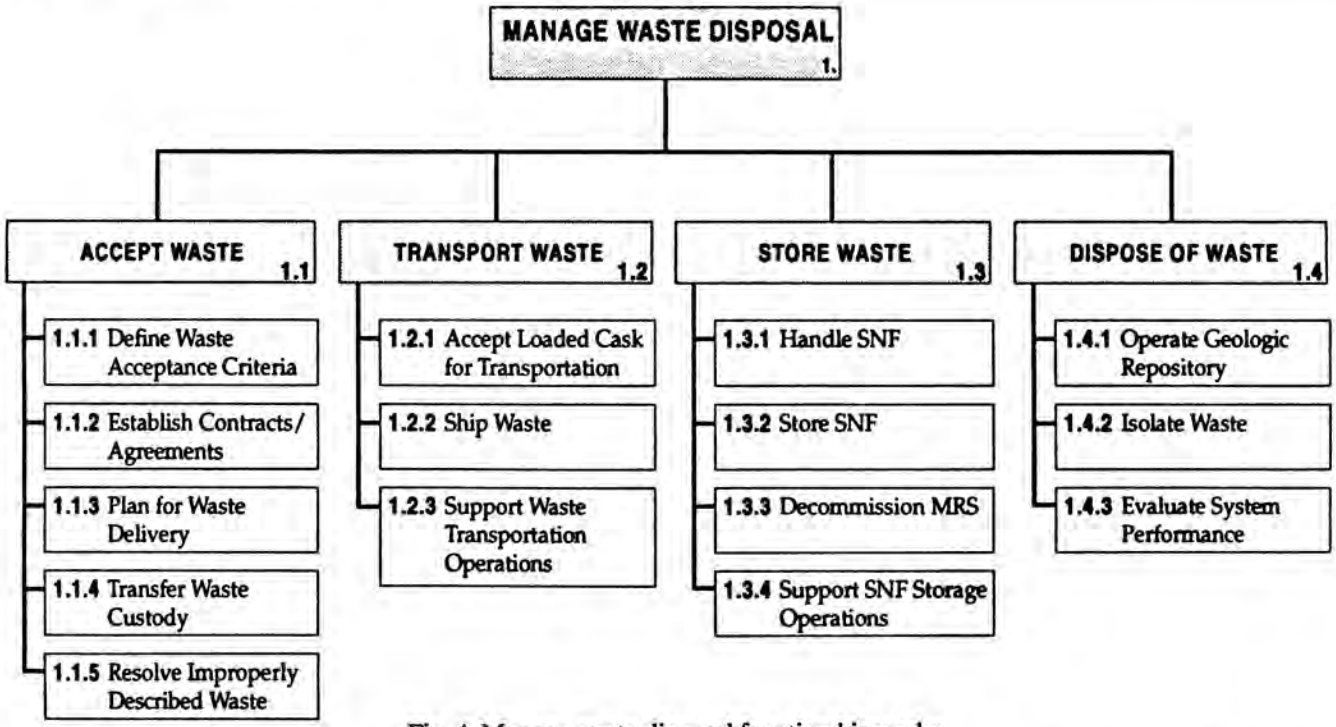

Fig. 4. Manage waste disposal function hierarchy.

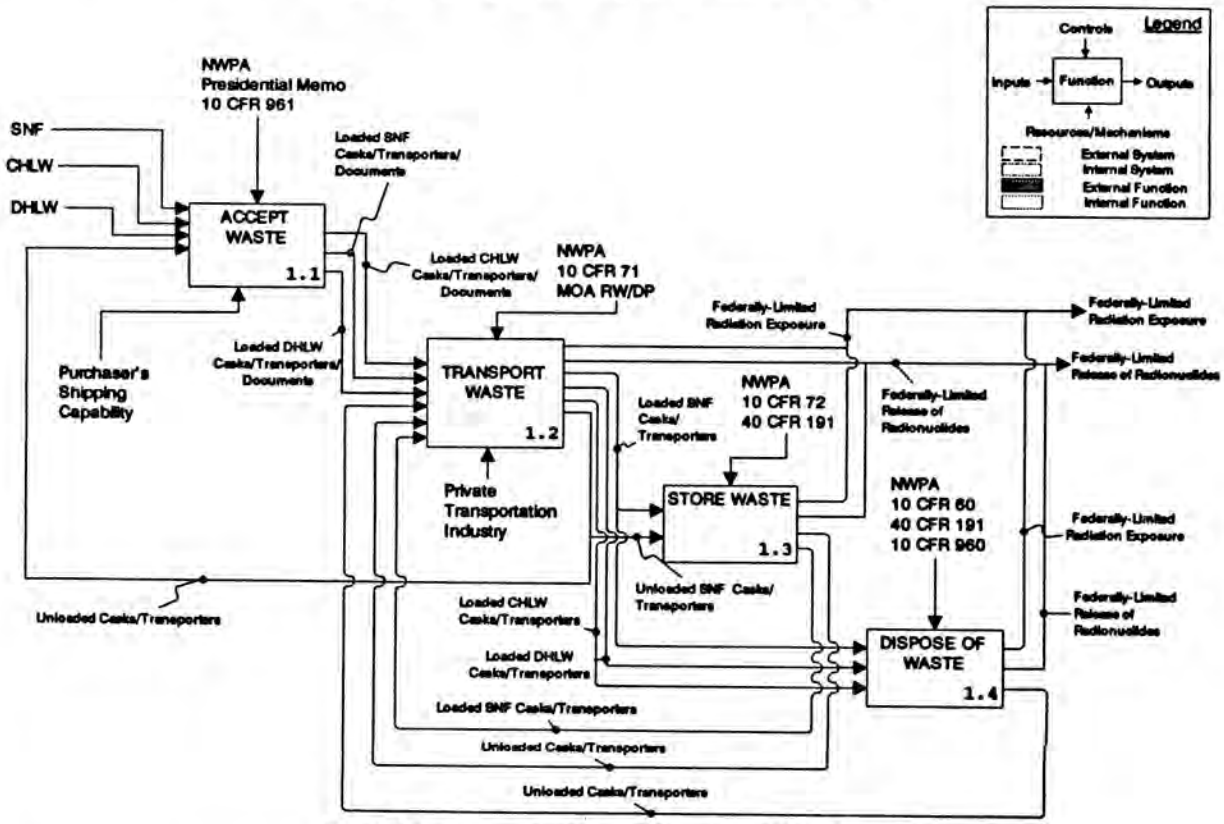

Fig. 5. Manage waste disposal functional flow diagram.

baseline. The repository part of the baseline, and hence the ESF, are still traceable back to the corresponding WMSR baseline documents. The next baseline iteration will establish a technical requirements baseline which is consistent with the new OCRWM Technical Document Hierarchy.

To properly integrate the OCRWM program, the program and project level requirement documents must provide consistent traceability between one another. Each program level requirement must flow down to an appropriate project level requirement and each project level requirement must roll up to a corresponding program level requirement. Flow

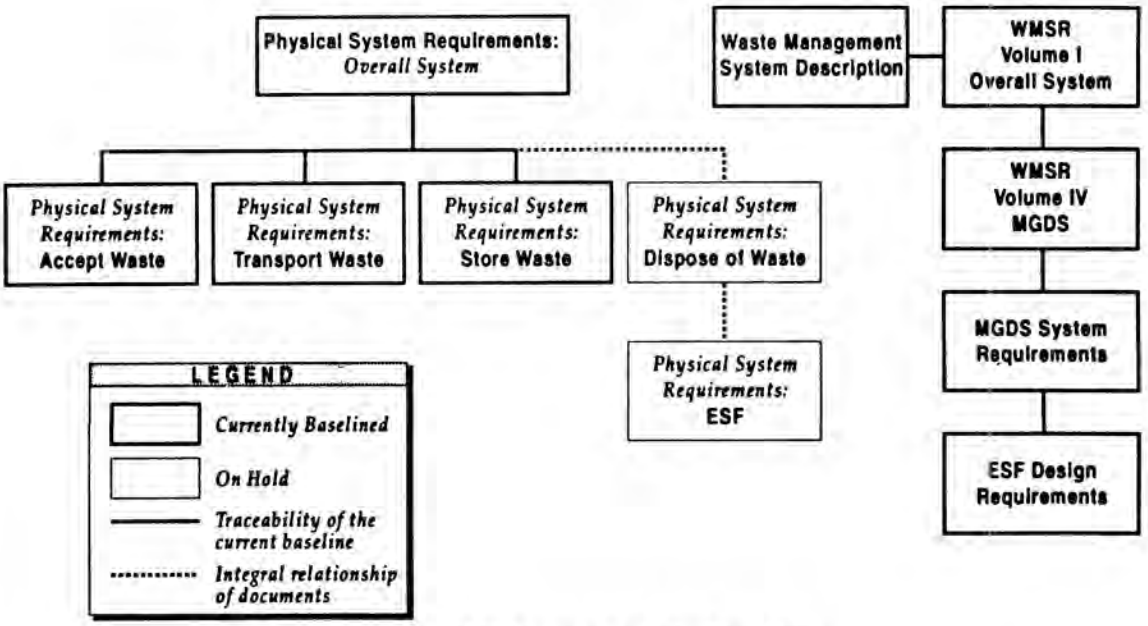

Fig. 6. OCRWM interim technical baseline.

down referencing demonstrates how specific requirements are to be allocated and satisfied by detailed designs: it is necessary for licensing. Roll up referencing verifies the necessity for lower level design requirements and justifies the need for certain design features; it is useful for configuration management and change control. They are both important for effective program management.

CONCLUSIONS

As defined in DOE Order 4700.1, the system engineering process is a sequence of activities that transforms an identified mission need into a description of system performance parameters and a preferred system configuration. A sound requirements baseline must be established to provide the foundation upon which the systems engineering process can be carried out. This application of the F-R-A approach has provided OCRWM with a framework which is especially useful for ensuring the traceability of requirements between the OCRWM program and its individual projects.

REFERENCES

1. NWPA (Nuclear Waste Policy Act), 1983. "Nuclear Waste Policy Act of 1982," Public Law (PL) 97-425, 42 USC 10101-10226, Washington, D.C. This Act includes Amendments PL 100-203 (Dec. 22, 1987) and PL 100-507 (Oct. 18, 1988)
2. DOE (U.S. Department of Energy), 1989. Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program, DOE/RW-0247, Washington, D.C. [DOE/RW-0247].
3. MSIS, "Management Systems Improvement Strategy," Memorandum dated August 10, 1990, from Dr. John W. Bartlett, Director, OCRWM, Washington, D.C.
4. DOE (U.S. Department of Energy), January 1992. Physical System Requirements - Overall System, DOE/RW-0334P, Washington, D.C. [PSR-OS]
5. DOE (U.S. Department of Energy), August 1992. Physical System Requirements - Accept Waste, DOE/RW-0369, Washington, D.C. [PSR-AW]
6. DOE (U.S. Department of Energy), April 1992. Physical System Requirements - Transport Waste, DOE/RW-0352, Washington, D.C. [PSR-TW]
7. DOE (U.S. Department of Energy), November 1992. Physical System Requirements - Store Waste, DOE/RW-0319, Revision 1, Washington, D.C. [PSR-SW]
8. DOE (U.S. Department of Energy), June 1991. Physical System Requirements - Dispose of Waste, Draft Document, Washington, D.C. [PSR-DW]
9. DOE (U.S. Department of Energy), July 1991. Physical System Requirements - Exploratory Studies Facility, Draft Document, Washington, D.C. [PSR-ESF]

TABLE I
Source Documents Containing Requirements in the PSR Documents

Document Identifier	Document Description
29 USC 651 et seq.	Occupational Safety and Health Act
30 USC 801 et seq.	Mine Safety and Health Act
33 USC 1251 et seq.	Clean Water Act
42 USC 300f et seq.	Safe Drinking Water Act
42 USC 4321 et seq.	National Environmental Policy Act
NWPA-42 USC 10101	Nuclear Waste Policy Act
10 CFR 20	Standards for Protection Against Radiation
10 CFR 21	Reporting of Defects and Noncompliance
10 CFR 30	Rules of General Applicability to Domestic Licensing of Byproduct Material
10 CFR 40	Domestic Licensing of Source Material
10 CFR 60	Disposal of High-Level Radioactive Wastes in Geologic Repositories
10 CFR 61	Licensing Requirements for Land Disposal of Radioactive Wastes
10 CFR 70	Domestic Licensing of Special Nuclear Material
10 CFR 71	Packaging and Transportation of Radioactive Material
10 CFR 72	Licensing Requirements for the Independent Storage of Radioactive Wastes
10 CFR 73	Physical Protection of Plants and Materials
10 CFR 74	Material Control and Accounting of Special Nuclear Material
10 CFR 75	Safeguards on Nuclear Material - Implementation of US/IAEA Agreement
10 CFR 960	General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories
10 CFR 961	Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste
10 CFR 1022	Compliance with Floodplain/Wetlands Environmental Review Requirements
30 CFR 57	Safety and Health Standards - Underground Metal and Nonmetal Mines
33 CFR 322	Permits for Structures or Work in or Affecting Navigable Waters of the United States
40 CFR 122	EPA Administered Permit Programs: The National Pollutant Discharge Elimination System
40 CFR 141	National Primary Drinking Water Regulations
40 CFR 191	Environmental Rad. Prot. Standards for Management and Disposal of Radioactive Wastes
40 CFR 262	Standards Applicable to Generators of Hazardous Waste
40 CFR 280	Technical Standards and Corrective Action Requirements for Owners and Operators of USTs
40 CFR 355	Emergency Planning and Notification
49 CFR 171	General Information, Regulations, and Definitions
49 CFR 172	Hazardous Materials Tables and Hazardous Materials Communications Regulations
49 CFR 173	Shippers - General Requirements for Shipments and Packagings
49 CFR 174	Carriage by Rail
49 CFR 176	Carriage by Vessel
49 CFR 177	Carriage by Public Highway
49 CFR 392	Driving of Motor Vehicles
EXEC. ORDER 11988	Floodplain Management
DOE/RW-0035	Monitored Retrievable Storage Submission to Congress
DOE/RW-0214	Quality Assurance Requirements Document
DOE/RW-0235	MRS System Study Summary Report
DOE/RW-0239	The DOE Position on the MRS Facility
DOE/RW-0247	Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program

TABLE I, Cont'd
Source Documents Containing Requirements in the PSR Documents

Document Identifier	Document Description
DOE ORDER 1540.1	Materials Transportation and Traffic Management
DOE ORDER 3790.1A	Federal Employees Occupational Safety and Health Program
DOE ORDER 4700.1	Project Management System
DOE ORDER 5000.3A	Occurrence Reporting and Processing of Operations Information
DOE ORDER 5480.1B	Environment, Safety and Health Program for DOE Operations
DOE ORDER 5480.3	Safety Requirements for the Packaging and Transportation of Hazardous Materials
DOE ORDER 5480.11	Radiation Protection for Occupational Workers
YMP/CM-0011	Site Characterization Program Baseline
MOA RW/DP	Memo of 7/14/86 on Policy for Shipping DHLW to a Civilian Radioactive Waste Repository
MOU DOE/DOL	Memorandum of Understanding Between DOE and DOL
Presidential Memo	Memorandum of 4/30/85 on Disposal of Defense Waste in a Commercial Repository
Bartlett Letter to Sanda	Letter of 2/14/92 on DOE's Obligation to Accept SNF Pursuant to NWPA and 10 CFR 961

TABLE II
Function Description Table for Function 1.4: Dispose of Waste

I. Function ID Number: 1.4
II. Function Title: Dispose of Waste
III. Function Definition:

To emplace spent fuel/high-level radioactive waste in a geologic medium and to isolate such wastes from the accessible environment.

The term disposal means the emplacement in a repository of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste. [NWPA Sec. 2 (9)]

"Disposal System" means any combination of engineered and natural barriers that isolate spent nuclear fuel or radioactive waste after disposal. [40 CFR 191.12(a)]

"Disposal" means the isolation of radioactive wastes from the accessible environment. [10 CFR 60.2]

IV. Interfaces:

A. Inputs:

1.4I1	Loaded SNF Cask/Carriage	**From:**	1.2
1.4I2	Loaded CHLW Cask/Carriage	**From:**	1.2
1.4I3	Loaded DHLW Cask/Carriage	**From:**	1.2

B. Outputs:

1.4O1	Empty Cask/Carriage	To:	1.2
1.4O2	Federally-Permitted Radiation Exposure	To:	Accessible Environment
1.4O3	Federally-Permitted Release of Radionuclides	To:	Accessible Environment

V. Function Requirements:

A. Constraints:

1.4C1 ... repositories that will provide a reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository;

[NWPA Sec. 111 (b)(1)]

.....

1.4C7 Environmental impacts shall be considered by the DOE throughout the site characterization, site selection, and repository development process. The DOE shall mitigate significant adverse environmental impacts, to the extent practicable, during site characterization and repository construction, operation, closure, and decommissioning.

[10 CFR 960.3-4]

B. Performance:

....

1.4P2 ...the start of repository operations is...2010.

[DOE/RW-0247]

C. Interface:

1.4I1 The SNF acceptance rate at the geologic repository will be in accordance with Appendix F of this document.

[TBD, pending DOE/OCRWM decision]

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1.4O2 Management and storage of spent nuclear fuel or high-level or transuranic radioactive wastes at all facilities regulated by the Commission or by Agreement States shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from: (1) Discharges of radioactive material and direct radiation from such management and storage and (2) all operations covered by Part 190; shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other critical organ.

[40 CFR 191.03(a)]

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