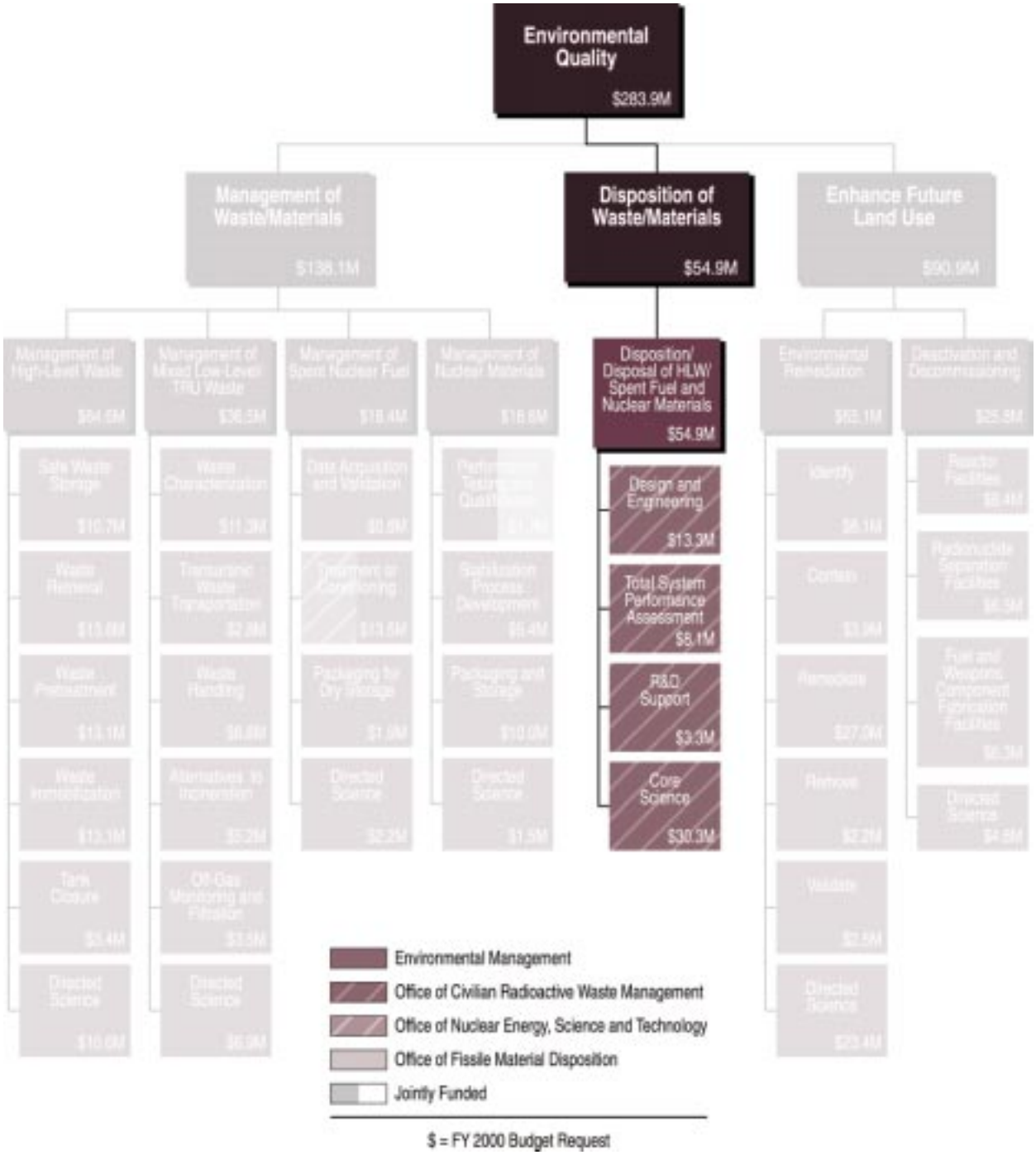
Chapter 7
Disposal



Chapter 7
Disposal

Table of Contents

Page

Overview 161
Definition of Problem Area 161
National Context/Driver and Federal Role 162
Linkage to DOE Strategic Goals and Objectives 163
Problem Area Uncertainties 164
R&D Investment Trends and Rationale 165
Key R&D Accomplishments 165
Key R&D Issues 165

Problem Area R&D Program 167
Program Description 167
Design and Engineering 167
Total System Performance Assessment 170
R&D Support 172
Core Science 172

Budget Summary Table 175

Overview

Definition of Problem Area

The *Nuclear Waste Policy Act of* 1982, Public Law 97-425, established the Department of Energy's (DOE) responsibility to provide for the permanent disposal of the Nation's high-level radioactive waste (HLW) and spent nuclear fuel (SNF), and directed that the owners and generators of these wastes bear the costs of disposal. The Act also established the Office of Civilian Radioactive Waste Management (OCRWM) to carry out a mission to provide for the disposal of SNF and HLW in a geologic repository, in a manner that protects the health and safety of the public and workers, and maintains the quality of the environment. The Civilian Radioactive Waste Management System (CRWMS) is being developed by OCRWM to fulfill that mission.

Since the enactment of the Act, the OCRWM Program has undergone some changes. The *Nuclear Waste Policy Amendments Act of 1987,* Public Law 100-203, designated the Yucca Mountain site in Nevada as the only site to be characterized to determine its suitability for a geologic repository. *The Energy Policy Act of 1992,* Public Law 102-486, directed the Environmental Protection Agency (EPA) to promulgate new health and safety standards for the Yucca Mountain site, based on the findings and recommendations of the National Academy of Sciences. Within one year of their promulgation, the Nuclear Regulatory Commission (NRC) is to revise its technical requirements and criteria for licensing the repository, based on those standards.

The types of waste that will be delivered to the repository for disposal consist of commercial spent fuel (including mixed oxide spent fuel), high-level waste (including immobilized plutonium), and DOE spent fuel (including Naval spent fuel). These wastes vary appreciably in form, radioactive content and condition. Due to age and degradation, some of the DOE spent fuel may require conditioning or stabilization before it can be accepted for disposal in the repository.

Most of the commercial spent fuel consists of fuel assemblies discharged from 78 pressurized water reactors (PWRs) and 40 boiling water reactors (BWRs). This spent fuel is located at 72 nuclear power plant sites and one independent storage site in 33 states. The total amount of spent fuel in inventory as of 1996 is estimated at 34,250 Metric Tons of Heavy Metal (MTHM) in PWR and BWR fuel assemblies. By 2030, the amount of spent fuel in inventory is projected to be 86,700 MTHM. The actual amount of spent fuel to be discharged could exceed the projected amount if reactor life extension programs are authorized by the Nuclear Regulatory Commission and implemented by the utilities. Conversely, the amount of spent fuel could be less than projected if reactors are shut down prematurely.

The high-level waste to be disposed of is immobilized and encased in metal canisters by both commercial and defense waste generators. It is estimated that about 20,000 canisters will be produced through 2035, including canisters that will contain immobilized surplus weapons-usable plutonium. However, there is currently some uncertainty in the exact number of high-level waste canisters that will ultimately be produced. Production of canisters of commercial and defense high-level waste has already begun at the West Valley Demonstration Project in New York and at the Defense Waste Processing Facility at the Savannah River Site,

respectively. Wastes from these two facilities are in the form of borosilicate glass encased in stainless steel canisters. Production of waste canisters is also planned at both the Hanford Site and the Idaho National Engineering and Environmental Laboratory. The reference waste form for these two sites is also a glass form, but final decisions on their characteristics and canister sizes have yet to be made.

DOE spent fuel includes fuel from defense production reactors, naval propulsion reactors, domestic and foreign research reactors, commercial reactors, Fort St. Vrain High Temperature Gas-Cooled Reactor, and debris from the Three Mile Island Unit 2 reactor. The DOE spent fuel inventory projected to the year 2035 totals about 2,502 MTHM, as shown in Figure 7-1.

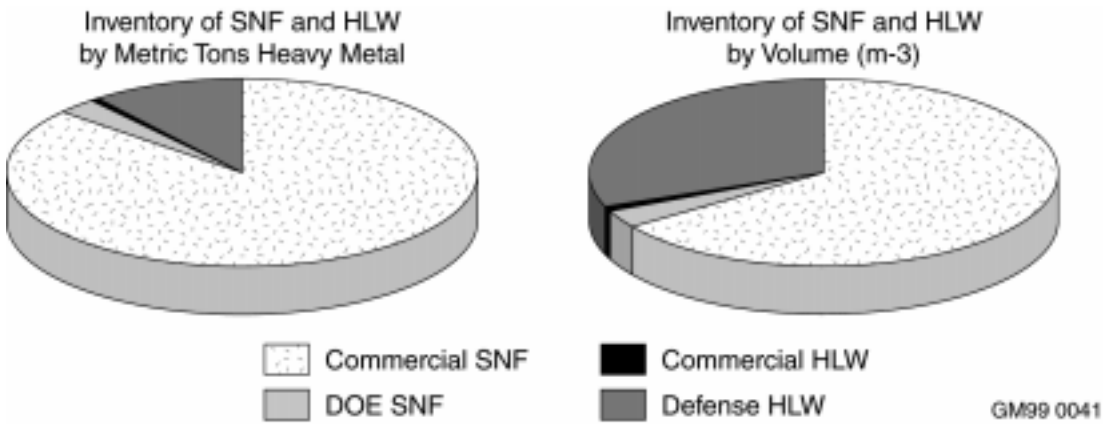


Figure 7-1 Projected inventories of SNF and HLW by Metric Tons Heavy Metal and by Volume.

The current focus of the program is on the remaining work that needs to be done to support a site suitability recommendation in 2001, and if the site is approved by both the President and Congress, preparation and submittal of a license application to the NRC in 2002 for construction authorization for a monitored geologic repository at the Yucca Mountain site. To obtain an NRC license, DOE must demonstrate that a repository can be constructed, operated, monitored, and eventually closed without unreasonable risk to the health and safety of workers and the public. R&D work performed by National Laboratories is designed to support both the Site Recommendation and the license application. The work includes the development of a number of products for license application. These include reference designs for the repository and waste packages; improved models for the engineered and natural barriers and radionuclide transport through them; and evaluation of the probable long-term performance of the repository in its geologic setting.

National Context/Driver and Federal Role

The nuclear waste disposal program is charged with characterizing a site to determine its suitability for development as a repository, recommending to the president that the site be approved for repository development, and obtaining a license from the Nuclear Regulatory Commission to construct and operate the repository. Once licensed, the program is charged with taking title to nuclear wastes at civilian and government storage sites, transporting the wastes to a geologic repository, packaging the wastes in disposal containers, and emplacing the waste packages in underground drifts (tunnels).

Linkage to DOE Strategic Goals and Objectives

The Spent Fuel and High- Level Waste Disposal R&D efforts support the Environmental Quality strategic objectives as indicated in Figure 7-2.

Proof of performance of a monitored geologic repository is without precedent. The repository must isolate SNF and HLW from the human environment for over 10,000 years. To demonstrate that the facility can be safely deployed, DOE has conducted extensive research and evaluation activities that will provide reasonable assurance that the geologic disposal site will contain the wastes. Tests, studies, and analyses aimed at predicting performance of the natural and engineered barriers by simulating repository conditions have been developed. The work occurs in situ at repository depths, on the surface above the repository block, and in the laboratory. The scientific activities have been carefully planned to account for coupled processes affecting repository performance, namely thermal, hydrologic, chemical, and mechanical phenomena, over the range of expected near- and long-term conditions.

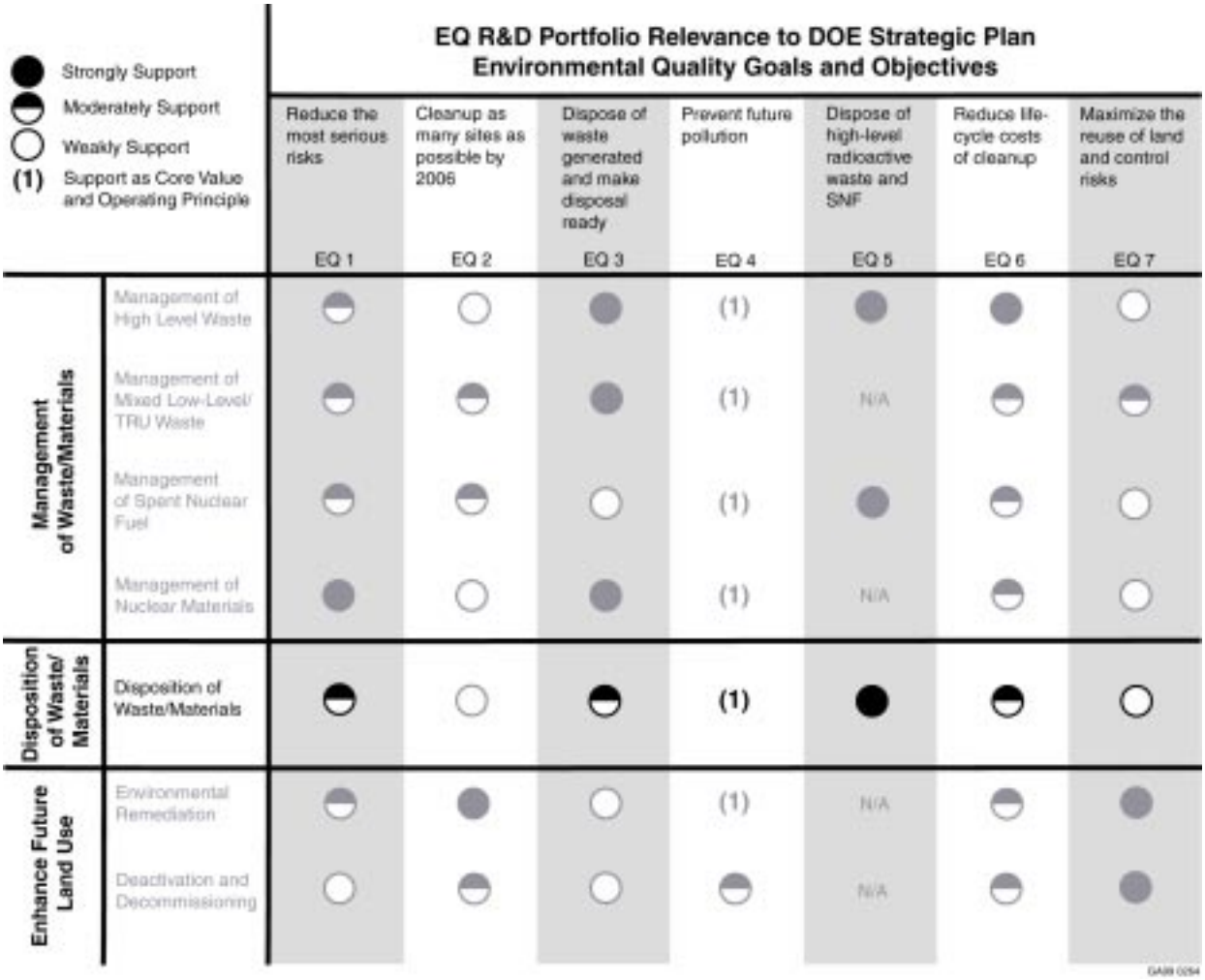


Figure 7-2. Relevance of disposal R&D investments to Environmental Quality goals and objectives.

An objective of this investment area is to identify engineering materials, which will assist the engineered barrier designs to provide long-term containment of SNF and HLW planned for disposal in a geologic repository at Yucca Mountain. The multi-disciplinary R&D efforts focus on developing technological solutions to very complex problems associated with the disposal of the nation's nuclear waste in a safe, environmentally sound, and cost-effective manner, a one-of-a-kind endeavor never before attempted. This information will be considered in any decision to recommend the site for repository development and will provide support for NRC issuance of a license for repository operation.

In addition, this environmental quality objective provides necessary information, in the form of acceptance criteria, which assists in the management, treatment or conditioning if necessary, and interim storage of SNF and HLW. Specifically, assurance that near-term decisions on managing SNF and HLW is compatible with ultimate disposition is a critical part of DOE's integrated role.

Problem Area Uncertainties

The challenge in licensing a geologic repository is demonstrating a reasonable assurance of compliance with safety standards over many thousands of years. To reduce current uncertainties and increase confidence that a repository can contain and isolate waste for thousands of years, DOE is focusing its ongoing efforts on three major areas:

- Increasing the understanding of the key processes that are important to long-term performance of the repository such as the flow of groundwater and radionuclide transport through the engineered and natural barrier systems, including responses of these processes to the heat generated by the disposed waste.

- Improving the design of key engineered components of a repository such as testing and selection of improved waste package materials, waste-package emplacement design to achieve improved management of thermal load, and evaluation of backfill and drift-shield effectiveness.

- Increasing confidence in performance assessment models such as employing the improved process models with reduced uncertainties, using more realistic and reasonable parameters as opposed to highly conservative ones, and enhancing the capability of the Repository Integration Program (RIP) code to incorporate more of the details in the process models.

DOE also faces a challenge in selecting waste container materials (to include structural inserts and engineered criticality controls) that can withstand the range of conditions in the repository to prevent significant corrosion over the long time frames needed to ensure adequate waste containment and isolation. Investments are needed to examine the impact of container structural inserts and engineered criticality controls on the corrosion performance of the SNF forms and waste package.

R&D Investment Trends and Rationale

Figure 7-3 illustrates the current R&D investments for SNF and HLW disposal. Total investment levels are expected to remain relatively constant over the next few years. However, as the total system performance assessment proceeds and support for licensing enters the final stages, the mix is expected to shift. The current approach to the characterization of Yucca Mountain distinguishes between tests required to evaluate site suitability, to support licensing, and to confirm the safety of the repository before closure. This distinction permits phasing of tests to achieve an earlier evaluation of the suitability of Yucca Mountain.

Many near term R&D objectives have been related to development of the Environmental Impact Statement (EIS), scheduled to be issued in draft this year and finalized next year. Investments will then shift in more direct support of licensing. Support to licensing will continue after the license application submittal, scheduled for 2002. These efforts will include performance confirmation activities and updates to ongoing research and modeling in support of licensing hearings.

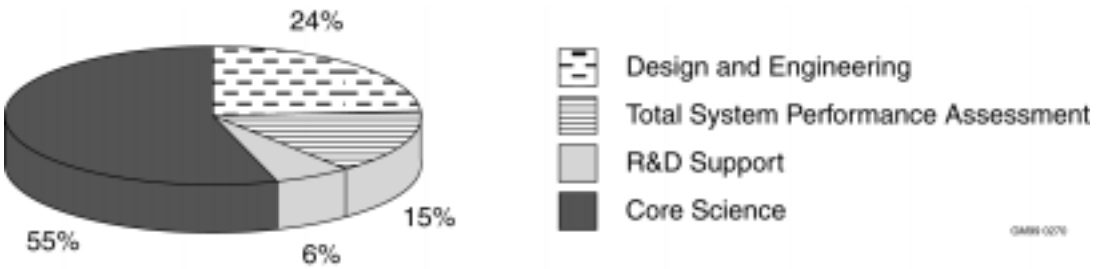


Figure 7-3. Cumulative investment in disposal areas over 3 years (FY 1998–FY 2000).

Key R&D Accomplishments

As directed by Congress in 1997, the Program completed a viability assessment of the Yucca Mountain site in December 1998. The assessment represents a "snapshot" of our knowledge of the candidate site from over 15 years of scientific investigations. Based on the viability assessment, DOE believes that Yucca Mountain remains a promising site for a geologic repository and that work should proceed to support a decision in 2001 on whether to recommend the site to the President for development as a repository.

Key R&D Issues

The repository for SNF and HLW will be the nation's second geologic repository. The nation's transuranic waste repository, the Waste Isolation Pilot Plant (WIPP), was finally opened this year, over a decade behind the original schedule. Based on the experience with WIPP, there will be a continued and possibly increased need for research in support of licensing and to answer legal challenges over the next decade.

Centralized interim storage of SNF and HLW remains a possible alternative while licensing and preparation of the repository proceeds. The capability to accelerate transportation of SNF and HLW to a receiving facility must be maintained, including supporting research and development.

If Yucca Mountain is determined to be suitable for a geological repository, development of the operational infrastructure will be placed on a fast track to support operations after 2010. Research and design of systems already underway as part of the EIS and licensing process will accelerate.

A number of questions remain concerning acceptability of waste forms for nuclear materials dispositioning. The geologic respository is one solution for a portion of these materials, but decisions on which materials will not be finalized for some time. Continuing research and modeling of repository system impacts due to disposition of varying quantities of different materials and waste forms will be necessary.

Problem Area R&D Program

Budget: FY98-$62.1M, FY99-$61.4M, FY00-$54.9M

Program Description

DOE investigations of the Yucca Mountain site have resulted in a substantial understanding of the site, a preliminary reference repository design, and assessments of the performance of the repository system. These work products are of the type needed to support site recommendation and submittal of a license application. However, additional technical work is needed to complete the postclosure safety case, support the preclosure safety case, and support remaining design decisions.

DOE is funding multiyear tests of likely waste package materials under relevant repository conditions. The tests are aimed at identifying any localized corrosion mechanisms and developing models to predict long-term corrosion of waste package materials. Other testing is planned on specific waste forms to understand their corrosion and dissolution properties under relevant repository conditions.

In order to understand how the natural and engineered barrier system would respond to the waste-generated heat, DOE is also funding a multi-year drift-scale heater test and completing analyses of the large block and single-heater tests already completed; and performing several unique flow tests underground at the Yucca Mountain site in order to further define how groundwater flows under the site geologic conditions.

Design and Engineering

Budget: FY98-$15.0M, FY99-$14.8M, FY00-$13.3M

R&D Challenge. DOE faces a challenge in selecting waste container materials (to include structural inserts and engineered criticality controls) that can withstand the range of conditions in the repository to prevent significant corrosion over the long time frames needed to ensure adequate waste containment and isolation. Investments are needed to examine the impact of container structural inserts and engineered criticality on the corrosion performance of the SNF forms and waste package.

Research and development activities in support of design and engineering of the repository; SNF and HLW degradation mechanisms; and waste package material performance are planned over the next several years. The principal factors affecting the postclosure performance of the waste package include:

- Water dripping onto the waste package.
- Humidity and temperature of the waste package environment.
- Chemistry of water on the waste package.
- Integrity of the carbon steel outer barrier of the waste package.
- Integrity of the high-nickel alloy inner barrier of the waste package.

- Integrity of spent nuclear fuel cladding.
- Dissolution of the uranium oxide and glass waste forms.

Spent nuclear fuel and high-level radioactive waste glass will be tested under conditions anticipated in the repository. These tests will provide data on dissolution and release rates for film flow and dripping water conditions. In one test, spent nuclear fuel, both in cladding and crushed in a thin film, will be tested for cladding integrity, bounding alteration, and release rates. In a separate test, colloids that form during the degradation of spent nuclear fuel and glass samples will be analyzed. Another test assesses how dripping solutions interact with potential waste package and emplacement drift materials such as crushed tuff, concrete, and corroded metal products.

Degraded glass-type waste forms will continue to be tested semiannually with actinide-doped material coming from the Defense Waste Processing Facility and the West Valley Demonstration Project. Parametric tests will continue including evaluating surface area, waste chemistry, and temperature. The tests will be adapted to assess interactions between leachates and waste package component materials. The reaction rate for glasses of the Defense Waste Processing Facility type with water vapor will be determined as a function of temperature.

Oxidation will be measured using thermogravimetric analysis techniques, which quantify changes in sample weight as a function of time and temperature. These tests will help in understanding, quantifying, and modeling how uranium dioxide fuel oxidizes (kinetics).

Dissolution rates will be obtained from flow-through dissolution tests on spent fuel samples under controlled chemistry and temperature conditions. The data will be used in developing models and as input for analyzing and interpreting results from the unsaturated drip testing. In addition, the bounds for release rates of highly soluble fission products will be obtained.

Colloids, extremely small particles suspended in water, are important to understanding transport through the unsaturated zone because radionuclides may bind to them. Laboratory studies are planned to address uncertainties about the formation and stability of colloids and their interactions with radionuclides, particularly plutonium.

Testing specimens with the same characteristics as the waste package helps develop understanding of how these materials degrade. The materials to be tested will include high-nickel and titanium-based alloys including crevice corrosion-resistant candidates Alloy 22 (nickel based) and titanium grades 7 and 16 (titanium based with small additions of palladium). Testing will be done in various aqueous solutions and at different temperatures, with samples being removed at planned intervals. Multiple samples will be used for statistical purposes. Candidate materials will be exposed to potential aqueous environments for at least 5 years. Different configurations of specimens will be used to investigate all forms of corrosion behavior. The test solutions of specimens will be analyzed on a continuing basis for evidence of microbial growth and its effects on corrosion. The results from these tests will be used to develop process models. An enhanced phase stability model will be developed for microbiologically influenced corrosion, pitting and crevice corrosion, stress

corrosion, general corrosion and oxidation, and galvanic corrosion. The degradation of the metallic materials comprising the waste packages will be modeled as a function of time. Modeling will progress from a preliminary level to a more advanced stage as relevant test results become available and can be incorporated.

Thermogravimetric analysis studies address materials susceptible to accelerated corrosion in humid conditions. The controlled humidity experiments study the degradation of the susceptible materials at less than 100 percent relative humidity and a constant temperature so that degradation of the waste package can be modeled.

Long-term corrosion tests are underway for the materials that comprise the outer (corrosion allowance) and inner (corrosion resistant) barriers of the waste package. These materials are being tested under a range of representative repository conditions. Specimens are exposed in the vapor phase (humid conditions), at the water line (partially immersed), and fully immersed (underwater). The interaction between the corrosion-resistant and corrosion-allowance materials (barriers) when the waste package is cracked or breached will also be assessed.

The viability of ceramic materials as an alternative or augmentation for the inner or outer barriers of the waste package or for use in drip shield applications may be evaluated. Ceramics would best be used as coatings on metallic material. Tests will be conducted to determine the adhesive strength of the coating and its ability to withstand thermal and handling loads. Critical factors in assessing the effectiveness of ceramic coatings include the ability to maintain an impervious barrier of protection for the material being coated (substrate). The permeability and density of the coatings as a function of the type of ceramic and the way it is applied will also be determined. Samples of various thickness, structure, and composition will be exposed to corrosive conditions to find out how much protection the coatings provide. Of particular importance is how porous or cracked regions of the coating affect the long-term behavior of the substrate metal.

Specific activities supporting design and engineering include:

- Thermogravimetric analysis on corrosion resistant materials, and ceramic and ceramic-coated materials.
- Long duration galvanic specimen testing.
- Critical potential measurements.
- Assessment of potential for microbiologically influenced corrosion (MIC).
- Phase stability microstructural evaluation.
- Ceramic materials testing and modeling.
- EBS materials testing and modeling.

- Testing and modeling of the engineered barrier system (EBS).

Current regulations require that nuclear criticality be prevented or its potential minimized in all phases of repository operations and after permanent closure. Two important aspects of the criticality analysis are securing NRC approval for using burnup credit to demonstrate criticality control, and evaluating the effectiveness of measures to control criticality. Technical work to be completed regarding nuclear criticality includes:

- Completing work to improve methods including determination of the range of parameters to describe the potentially critical configurations, refinement of the method for generating probability distributions of parameters affecting criticality, and estimation of consequences of potential criticalities.

- Completing work to justify the use and estimate the amount of burnup credit. Though the techniques being developed rest on scientific fact and well-understood theory, they do go beyond current practice in NRC licensing proceedings.

Total System Performance Assessment

Budget: FY98-$9.1M, FY99-$9.0M, FY00-$8.1M

Process models are mathematical representations of features, events, and processes that could affect how the repository functions. Taken together, the abstractions of the process models comprise the Total System Performance Assessment model used to evaluate future doses of radiation to persons living near Yucca Mountain for thousands of years into the future. There are process models for the interaction of heat and water in the repository; the near-field geochemical environment; waste package degradation; waste form degradation and the mobilization of radionuclides and other contaminants of concern by water; transport of radionuclides through engineered barriers; unsaturated zone water flow; transport of radionuclides through the unsaturated zone; saturated zone flow and transport; disruptive processes and events; and the movement of radionuclides throughout the biosphere, the region in which flora and fauna are present.

Specific activities supporting Total System Performance Assessment include:

- *Geologic Framework and Disruptive Events:* This work includes improving the characterization of the geologic framework of the site and improving the evaluation of natural processes and events that could change the physical and chemical properties of rock and water at the site. Much of the effort concentrates on incorporating new data into and refining the three-dimensional model that represents the rock formations and geologic structures comprising Yucca Mountain. This work includes studies providing additional site-specific soil and rock property data needed to finalize repository design to account for potential seismic disturbances.

- *Unsaturated Zone Process Testing:* This work addresses changes in climate and their effects, infiltration of water through surface soils and near-surface rocks to rock layers below, and movement of water downward through the unsaturated zone (the rock mass above the water table). The objectives are to continue to monitor and

improve the understanding of how and at what rates water passes through the unsaturated rock and to improve predictions of the conditions under which water may seep into the waste emplacement drifts.

- *Saturated Zone Process Testing:* This work addresses the flow of water in the saturated zone, located below the water table. The results will provide additional information about the features of the rock that allow, enhance, or retard the movement of water. This information will be factored into models that represent the rock layers and the water flowing through them. The way water mixes in the different layers in the saturated zone is of particular interest because it controls the amount by which radioactive elements (radionuclides) in the groundwater will be diluted, which in turn directly affects potential doses to exposed persons.

Accomplishments:

- Computer code for optimal loading of shipping canister.
- Development of the near-field and altered-zone environment models for the site.
- Development of drift seepage model for the site.
- Development of a preliminary model for the thermally driven coupled processes.
- Enhancement of the groundwater flow radionuclide transport models for the natural barrier system.
- Codes for establishing neutron absorption level in waste packages.

As directed by Congress in 1997, the Program has completed a viability assessment of the Yucca Mountain site in 1998. The viability assessment describes the preliminary design concepts for the repository and waste packages; a quantitative assessment of the probable long-term behavior of the repository in its geologic setting; a plan and cost estimate for the remaining work required to complete a license application to the Nuclear Regulatory Commission for construction authorization; and an estimate of the costs to constuct and operate the repository in accordance with its design concept.

Performance assessment analyses of the preliminary waste package and repository designs indicate that:

- For 10,000 years after the repository is closed, people living near Yucca Mountain are expected to receive little or no increase in radiation exposure.
- The maximum radiation exposures from the repository is expected to occur after about 300,000 years. People living approximately 20 kilometers (12 miles) from Yucca Mountain at that time might receive additional radiation exposures equivalent to present day background radiation.

- Based on the viability assessment, DOE believes that Yucca Mountain remains a promising site for a geologic repository and that work should proceed to support a decision in 2001 on whether to recommend the site to the President for development as a repository.

R&D Support

Budget: FY98-$3.7M, FY99-$3.7M, FY00-$3.3M

R&D support includes maintenance of technical databases, sample management, quality control of project activities, external peer reviews of products, and activities associated with project management. R&D support ensures that all R&D efforts are integrated among the various project participants, thereby achieving well-coordinated results and minimizing duplication.

Core Science

Budget: FY98-$34.2M, FY99-$33.8M, FY00-$30.3M

This work studies how the natural environment within the immediate vicinity, or near-field, of the waste packages will be affected by excavation of the waste emplacement drifts and other underground openings, by the heat generated by the waste, or by the introduction of nonnative materials. The work also will address the extent to which heat generated by the waste will create an altered zone of rock away from the waste packages. The studies will address the effects of coupled (or interacting) thermal, mechanical, hydrological, and chemical processes. Finally, core science will help DOE to understand the long-term geologic processes, both anticipated to occur and unlikely but possible to occur, that affect the movement of radionuclides over many thousands of years far from the planned disposal site.

Remaining work includes laboratory tests and modeling to improve simulations of the performance of engineered barrier system design options; compare the performance of different materials that might be used in a repository; improve evaluations of the mechanical stability of ground support materials; refine evaluations of thermohydromechanical coupled effects on engineered barrier system design options and rock stability; refine evaluations of thermohydrochemical coupled effects on seepage into drifts and engineered barrier system performance; improve specification of the near-field chemical environment; and update models of flow and transport through the altered zone.

Specific activities include:

- Production of an integrated 3-D model of the mineral distribution that impact flow and transport.

- Development and application of the UZ site-scale transport numeric and conceptual models.

- Development of a methodology for numerically simulating radionuclide transport, including colloidal-facilitated transport, through the saturated zone (SZ).

- Analysis of hazardous minerals (dust and wall rock samples) within tunnels in the Exploratory Studies Facility (ESF).
- Conduct bomb-pulse Cl-36 and chloride pore water analyses on samples from Yucca Mountain.
- Quantification and 3-D modeling of the effects of repository-induced thermal alterations on the Yucca Mountain mineralogy.
- Evaluation of subsurface design concepts for modification of host rock hydrology.
- Drift seepage threshold testing.
- Continued development and application of the UZ site-scale numeric and conceptual models.
- Continued development of UZ drift-scale model.
- Geologic testing.
- Fracture, matrix, moisture monitoring, and chlorine analyses in the east-west cross drift.
- Electrical resistivity tomography (ERT) measurements.
- Seepage threshold testing in alcoves and niches.
- Field and laboratory transport testing.

Thermal testing studies how the heat produced by deposited waste would affect mechanical, hydrological, and chemical characteristics of the emplacement drifts and surrounding rock. The objectives are to understand how mechanical, hydrological, and chemical processes are affected by heat and how they interact with one another under the influence of heat. The results will be factored into models that represent the rock layers and the heat flowing through them and provide additional information about the features of the rock that allow, enhance, or retard the movement of heat.

Specific activities supporting thermal testing include:

- Large block test. Characterizing the large block of rock at the surface near Yucca Mountain that was heated for more than a year and is now in a cooling phase.
- Drift-scale thermal testing. Conducting a drift scale test that involves heating and monitoring a drift and surrounding rock within the Exploratory Studies Facility, and planning and implementing a field thermal test in the cross drift excavation. In Alcove 5, at the Yucca Mountain Exploratory Studies Facility, a special integrated test facility has been designed and has begun operations to help scientists understand

coupled interactions of mechanical, geochemical, and hydrologic effects due to the thermal effects of high-level waste and spent nuclear fuel on groundwater flow and chemistry. This creative experiment is designed to simulate long-term, environment-specific interactions between key physical and chemical processes to support scientific understanding of rock, water, and waste interactions.

- Single Heater test. Completing the analysis of data from the single heater test, which heated rock within the Exploratory Studies Facility and then allowed the rock to cool.

- Modeling and analysis of thermal-hydrological-mechanical-chemicaI (THMC) processes.

Budget Summary Table

(Dollars in thousands)

Research Area Function	**FY 1998 Appropriated**	**FY 1999 Appropriated**	**FY 2000 Request**
Design and Engineering	14,993	14,807	13,256
Total System Performance Assessment	9,145	9,039	8,093
R&D Support	3,742	3,701	3,313
Core Science	34,228	33,818	30,277
Total	**62,108**	**61,365**	**54,939**