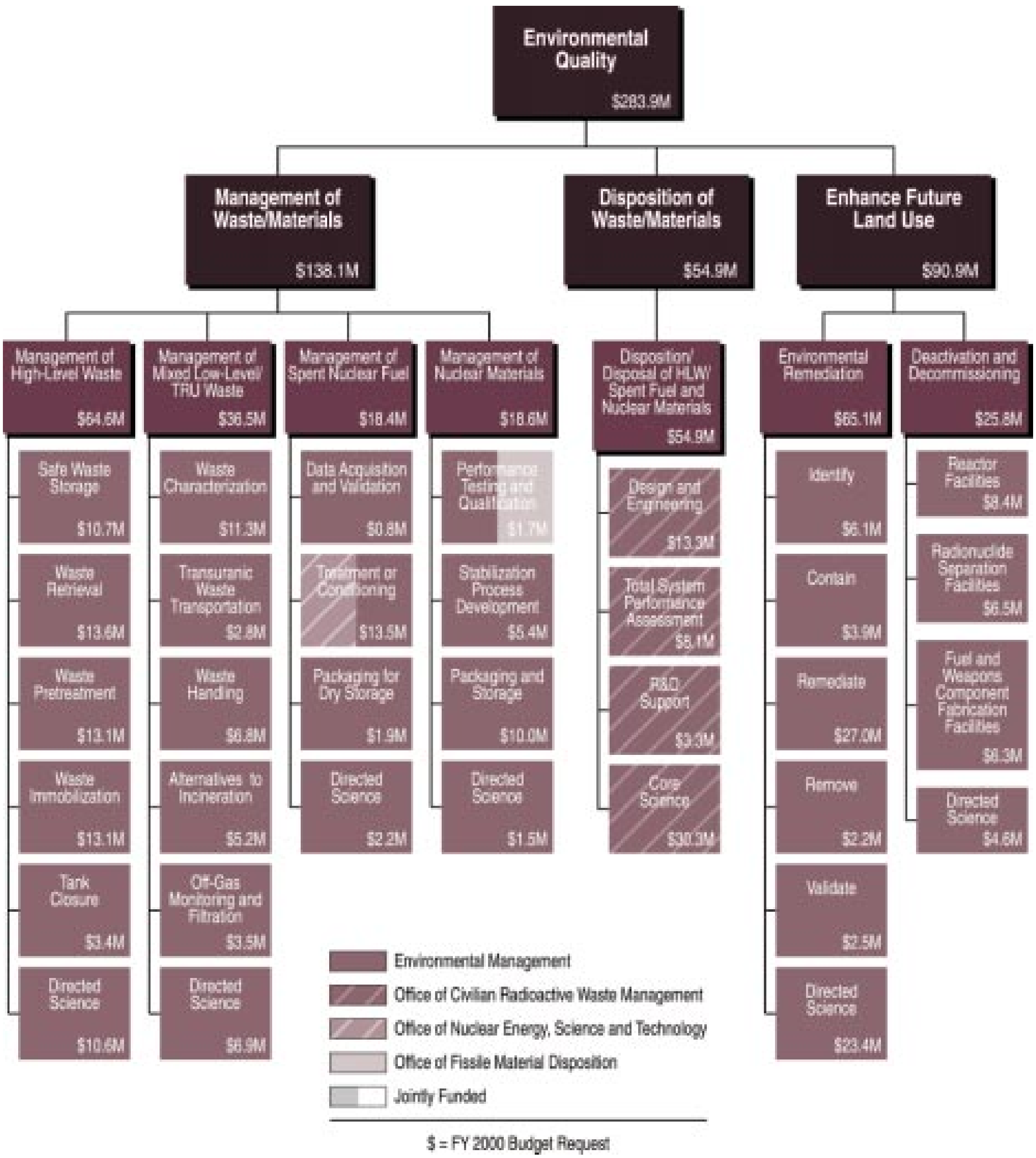
Chapter 1
Introduction



Chapter 1

Introduction

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Background and Purpose

The Department of Energy is one of the lead agencies with responsibility to help create and maintain the scientific and technological infrastructure that supports the nation's security and environmental integrity. Today it is one of the nation's largest sponsors of basic and applied research and development. In September 1997, the Department published the *U.S. Department of Energy Strategic Plan.* The plan was built on the four business lines—National Security, Energy Resources, Environmental Quality, and Science. The Department has initiated a comprehensive effort to improve the planning and management of the large, complex research and development enterprise that supports the business line missions. This approach is based upon developing and managing business line research and development portfolios.

The Department's five-volume R&D Portfolio provides, for the first time, a complete and comprehensive picture of the Department's research and development investment. The relative size and relationship of the four portfolios is illustrated in Figure 1-1. Historically the Department's research and development planning and management was conducted at the program or lower level. This approach resulted in overlaps, missed opportunities for collaboration and integration, and difficulty in identifying research gaps. The portfolio approach provides a comprehensive look at the entire research and development investment, in the context of the Department's missions and strategic objectives. This comprehensive picture provides the basis for analyzing, planning, and budgeting the research that will be needed in the future.

This volume is the first step in Environmental Quality (EQ) portfolio planning and management. It provides a baseline description of Fiscal Year 1998-2000 investments and combines selected R&D activities from four separate programs into an integrated investment portfolio. The portfolio is not organized by program, nor is it a comprehensive accounting of every program's activities. The portfolio does provide an accurate picture of the Department's investment in Environmental Quality R&D and is consistent with the President's budget.

Though it will help identify some of the major issues and challenges of the future, this portfolio is not intended to be a planning document; it provides only a limited discussion of future investment plans. The longer-term view of the EQ portfolio will be developed in the next phase of the process. A more complete discussion of the portfolio approach and management process is described in Volume I of this set of DOE Research and Development Portfolios.

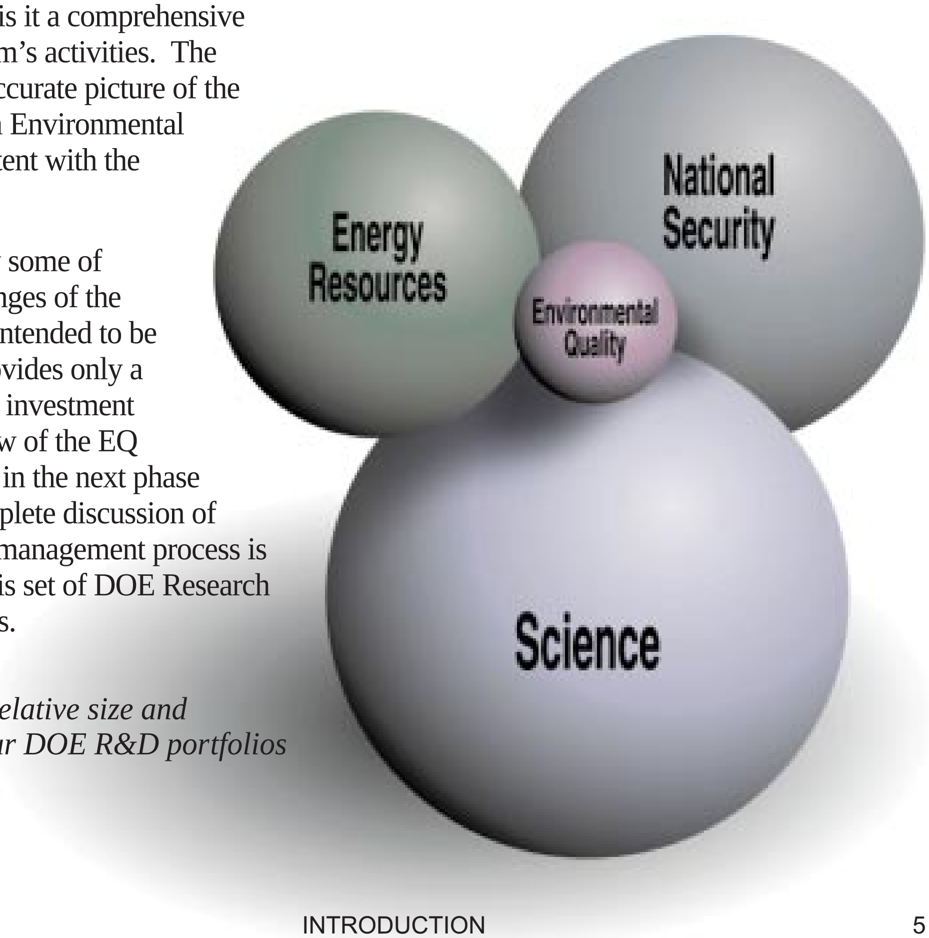


Figure 1-1 Relative size and relationship of the four DOE R&D portfolios

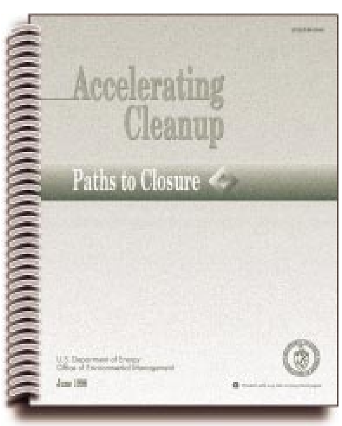
Figure 1-2 Environmental Quality primary areas of responsibility

Overview

The Environmental Quality business line encompasses the three primary areas of responsibility, illustrated in Figure 1-2.

- Reduce the environmental, safety and health risks and threats from the Department's facilities and materials.
- Safely and permanently dispose of civilian spent nuclear fuel and defense related radioactive waste.
- Provide the technologies and institutions to solve domestic and international environmental problems.

The Department of Energy has the responsibility to clean up the 50-year environmental legacy created by the nation's production of nuclear weapons and nuclear energy research and development. These activities generated large quantities of radioactive waste, contaminated large volumes of soil and water and many facilities, and created special nuclear materials that pose special health and safety hazards. The resulting environmental remediation and waste management program is the largest in the world. The magnitude of the cleanup task is defined in *Accelerating Cleanup: Paths to Closure*[1].



The Department's commitment to complete as much of the cleanup as possible by 2006 is based on very aggressive budget and planning scenarios, and in many instances assumes that scientific and technological advances will be made that provide significant cost savings and performance gains over current practices. In addition, cleanup activities must meet regulatory requirements and constraints associated with hazardous materials, radioactive material management and disposition, environmental protection (land, air and water), pollution prevention, resource recovery, and stewardship. In many instances these requirements and constraints are neither uniform nor consistent from one site to another.

[1] Accelerating Cleanup: Paths to Closure, DOE/EM-0362, June 1998.

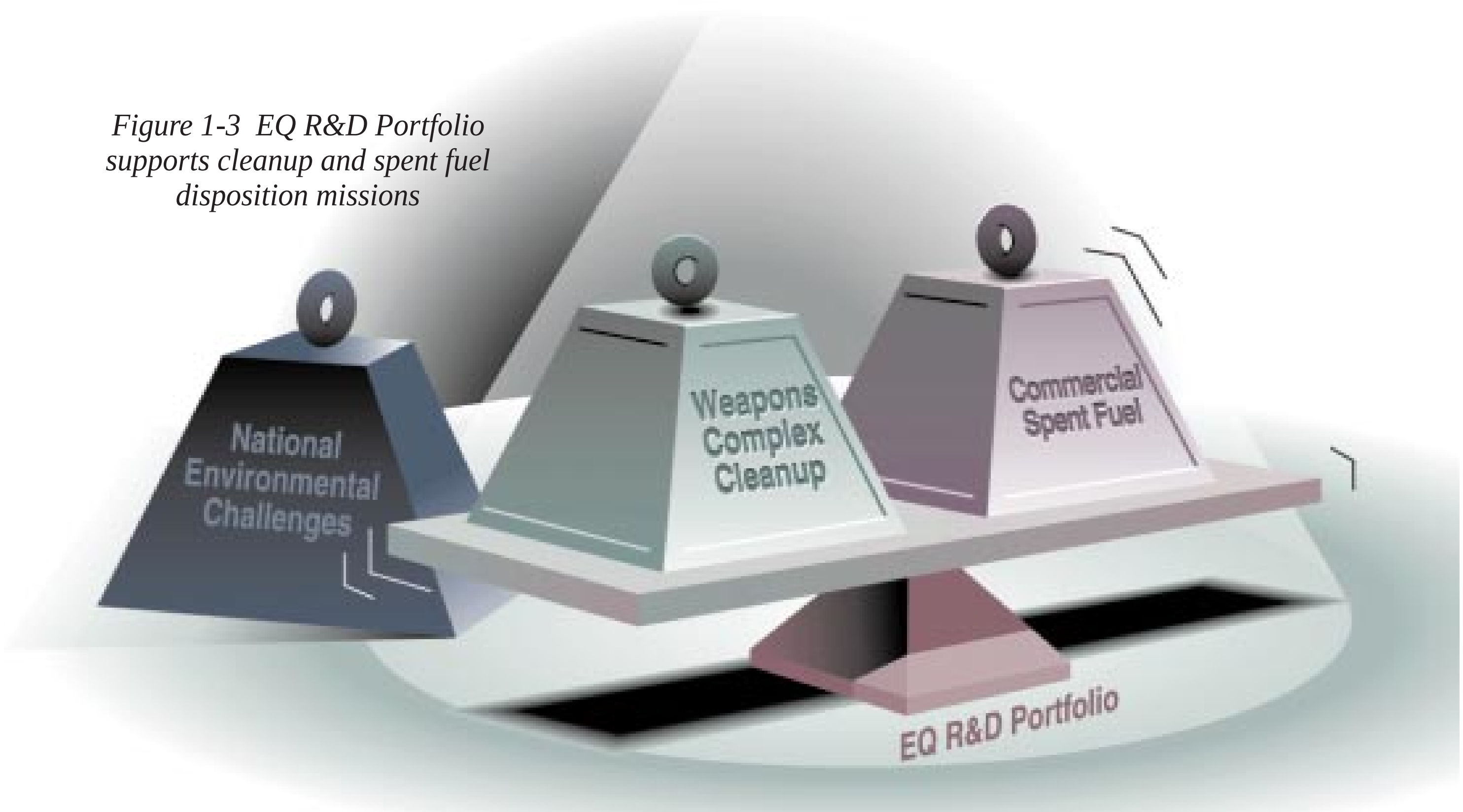
In addition to its cleanup activities, DOE is also responsible for the safe disposal of commercial spent nuclear fuel, which is currently stored in facilities across the United States. The Nuclear Waste Policy Act (NWPA) describes the major regulations and policy relative to disposition of spent nuclear fuel. Long-term, deep geologic disposal has been determined to be the best method to provide long-term isolation of long-lived, hazardous radioactive materials. However, there is no precedent or experience in this area and much knowledge must be gained and technologies developed to ensure the successful performance of this repository.

The *Nuclear Waste Policy Act* [Public Law 97-425, as amended by Public Law 100-203 and 102-486 (the Act)]:

- Established Department of Energy's responsibility to provide for the permanent disposal of the Nation's high-level radioactive waste (HLW) and spent nuclear fuel (SNF).
- Established the Office of Civilian Radioactive Waste Management (OCRWM) with the mission to provide for the disposal of SNF and HLW in a geologic repository.

The final area of responsibility is to provide both the technologies and institutions necessary to solve domestic and international environmental problems. Much of the scientific and technological infrastructure that has been developed and maintained to meet the first two responsibilities can be leveraged to support the third. However, the urgency of the Department's weapons legacy cleanup program and its commitment to meet aggressive cleanup goals has preempted direct support of this responsibility in the current portfolio, as illustrated in Figure 1-3. Partial support for meeting the nation's environmental challenges is also provided by the Science and Energy Resources R&D Portfolios.

Figure 1-3 EQ R&D Portfolio supports cleanup and spent fuel disposition missions



Environmental Quality Strategy

The Environmental Quality strategic goal and objectives are described in the DOE *Strategic Plan*[2], and are presented in Tables 1-1 and 1-2. This goal and set of objectives reflect the Department's commitment to respond to the challenges of the nation's environmental legacy.

The nation's nuclear environmental legacy presents several urgencies. The many real and perceived risks associated with radioactive contamination and nuclear materials must be addressed and satisfactorily resolved. Creating and maintaining safe conditions for these materials and contaminated sites is very expensive. Those costs continue until the radioactive materials, wastes and contaminated sites and facilities can be remediated or properly disposed. The current Environmental Quality strategy is narrowly defined and highly focused in response to the urgency of the cleanup program.

Table 1-1 Environmental Quality Strategic Goal:

"Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs, minimize future waste generation, safely manage nuclear materials, and permanently dispose of the nation's radioactive waste."

Table 1-2 Environmental Quality Strategic Objectives:

1. Reduce the most serious risks from the environmental legacy of the U.S. nuclear weapons complex first.
2. Clean up as many as possible of the Department's remaining 83 contaminated geographic sites by 2006.
3. Safely and expeditiously dispose of waste generated by nuclear weapons and civilian nuclear research and development programs and make defense high-level radioactive wastes disposal-ready.
4. Prevent future pollution.
5. Dispose of high-level waste and spent nuclear fuel in accordance with the Nuclear Waste Policy Act as amended.
6. Reduce the life-cycle costs of environmental cleanup.
7. Maximize the beneficial reuse of land and effectively control risks from residual contamination.

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[2] U.S. Department of Energy Strategic Plan, DOE/PO-0053, September 1997, pg. 25.

New and improved technologies and new knowledge are needed to meet the Department's cleanup commitments. The total estimated life-cycle cost of the environmental management program is $147B. Achieving this cost goal and associated program goals is based upon plans for site closures, many of which contain science and technology gaps. In many instances new or improved technologies are needed to meet projected cleanup costs. The portfolio employs the tactics presented in Table 1-3 to meet these needs.

Table 1-3 Portfolio Tactics for Weapons Complex Cleanup

- **Meet** the cleanup program's **highest priority needs**, including those on the critical path to closure and those that represent major technology gaps in project completion.
- **Reduce** the **cost** of the costliest cleanup projects:
- **Reduce technological risk** (where technology risk is defined as the programmatic risk that critical cleanup projects may not be completed on time and/or within budget due to a technology deficiency).
- **Accelerate and increase** the **deployment** of new and improved technologies into cleanup programs by bridging the gap between development and use.

Environmental Quality Portfolio Framework

The Department's cleanup effort is a unique, immensely complicated challenge of epic magnitude. The EQ strategic goal describes ***what*** the Department strives to achieve and the seven objectives describe the ***performance required*** to achieve the goal. Those objectives do not prescribe ***how*** to achieve the required performance. This epic cleanup challenge is most easily communicated through a set of "problem areas". The problem areas are carefully integrated sets of waste management, treatment, disposition and remediation activities that must be performed in a tightly orchestrated manner to complete the cleanup effort.

This problem area approach is also used to organize the R&D investments. The current R&D portfolio framework, like the EQ business line, is highly focused on specific issues. If the business line is broadened to more comprehensively address the nation's larger environmental needs, the portfolio must expand accordingly. The problem areas of the cleanup challenge are collected under three major portfolio elements:

- Management of Waste/Materials (High-Level Waste, Mixed Low-Level Waste/Transuranic Waste, Spent Nuclear Fuel, or Nuclear Materials);
- Disposition of Waste/Materials; or
- Enhance Future Land Use (Environmental Remediation and Deactivation and Decommissioning).

The major elements and problem areas are connected in the portfolio framework as illustrated in Figure 1-4.

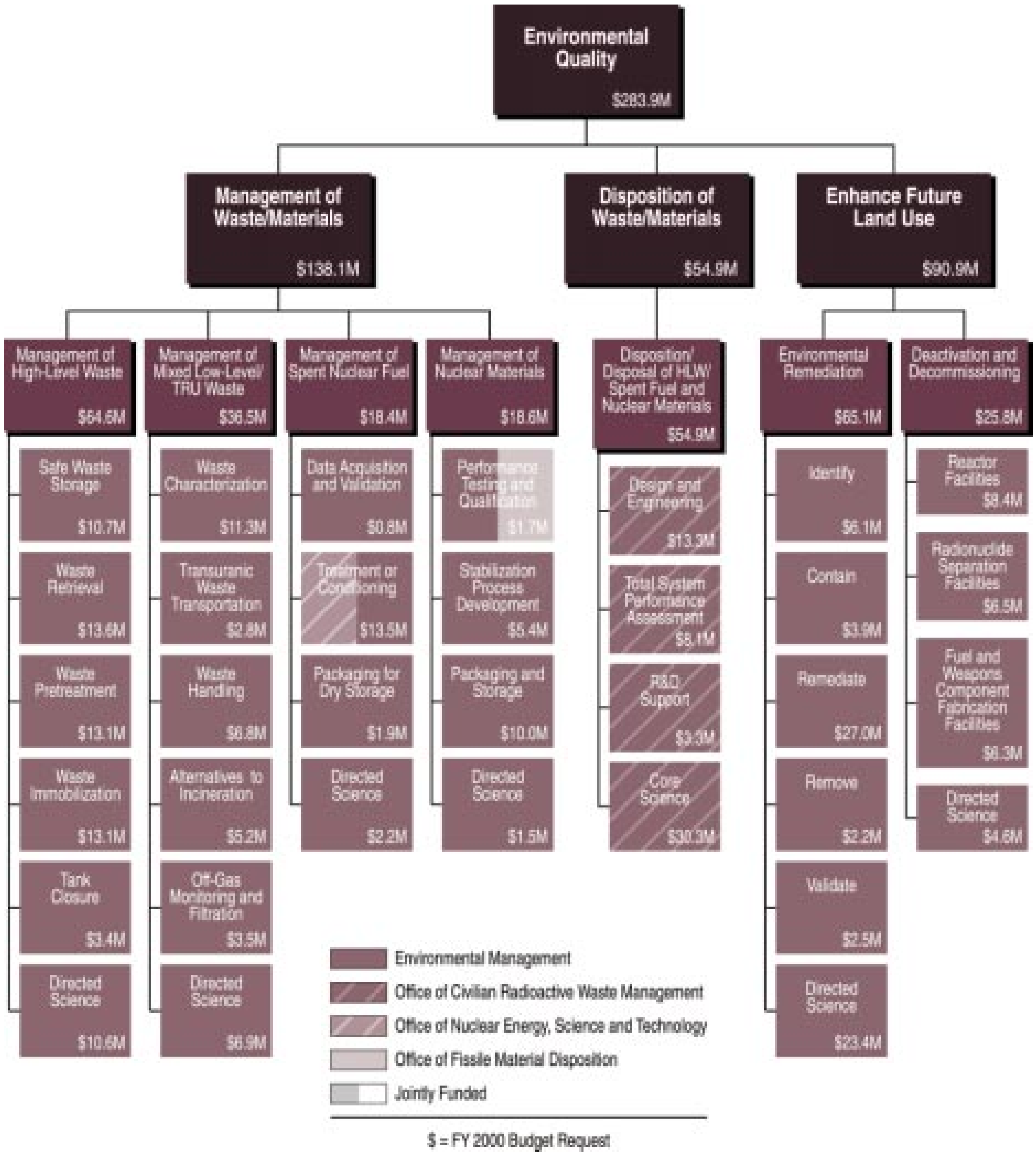


Figure 1-4 Environmental Quality R&D Portfolio Framework

The relationship of the elements of the portfolio to the seven Environmental Quality strategic objectives, and the level of support is illustrated in Figure 1-5 [3].

● Strongly Support
⊖ Moderately Support
○ Weakly Support
(1) Support as core value and operating principle

		Environmental Quality Objectives						
		Reduce the most serious risks EQ 1	Cleanup as many sites as possible by 2006 EQ2	Disposal of waste generated and make disposal ready EQ 3	Prevent future pollution EQ 4	Dispose of high-level radioactive waste and SNF EQ 5	Reduce life-cycle costs of cleanup EQ6	Maximize the reuse of land and control risks EQ7
Management of Waste/Materials	Management of High-Level Waste	⊖	○	●	(1)	●	●	○
	Management of Mixed Low-Level/ TRU Waste	⊖	⊖	●	(1)	N/A	⊖	⊖
	Management of Spent Nuclear Fuel	⊖	⊖	○	(1)	●	⊖	○
	Management of Nuclear Materials	●	○	●	(1)	N/A	⊖	○
Disposition of Waste/ Materials	Operation of Waste/Materials	⊖	○	⊖	(1)	●	⊖	○
Enhance Future Land Use	Environmental Restoration	⊖	●	○	(1)	N/A	⊖	●
	Deactivation and Decommissioning	○	⊖	○	⊖	N/A	⊖	●

Figure 1-5 Relationship of and support by portfolio elements to strategic objectives

Detailed discussions of science and technology investments and the resulting impacts and support of the Environmental Quality objectives are provided for each waste-type or activity group in Chapters 3 through 9. Each chapter describes a specific problem area. The description includes a discussion of drivers, federal responsibilities, an R&D overview, investment trends, accomplishments, and issues. Specific technology investments and supporting directed science investments for the specific problem area are also presented in each chapter. Chapter 10 describes the basic science investments (by the Science R&D Portfolio) that provide relevant support to and complement the directed science investments of the EQ R&D portfolio.

[3] The level of support indicated in Figure 1-5 was determined by the portfolio development team based upon input from each of the Programs or Offices in the Environmental Quality Business Line. This data has been reviewed by each Program or Office, the EMAB, the Strategic Laboratory Council and the Office of the Undersecretary.

Understanding the Portfolio Framework Elements

Understanding the problem areas and the magnitude and complexity of the challenges is critical to understanding the portfolio framework.

Management of Waste/Materials

Waste and materials come in many forms and types. The main waste categories or problem areas are listed and described in Table 1-4. The different types of wastes must be managed in accordance with different regulations, safety, health and environmental considerations. Management requires some or all of the following functions. Waste must be retrieved and characterized. Depending upon the type it must be treated, stabilized and then stored in an appropriate manner. Each of these functions may require special capabilities such as remote handling and special characterization techniques.

The significant technical challenges these wastes present, are further complicated by the sheer magnitude of the quantities that must be managed. For example, over 90 million gallons of high-level waste containing over 700 million curies of radioactivity are stored in large tanks at four major sites across the country. This volume is equivalent to over eight times the volume of oil spilled in the Exxon Valdez accident. Much of this liquid is highly corrosive, creating significant environmental and safety concerns about potential leaking by the storage tanks. In addition, there are many technical challenges in treating and preparing these wastes for disposal. The high level waste management investments are described in detail in Chapter 3.

The Department currently stores 165,000 cubic meters of mixed and transuranic (TRU) waste and 3,000,000 cubic meters of buried radioactive and hazardous waste. An additional 221,000 cubic meters of mixed and TRU waste is projected to be generated as a result of future remediation and deactivation and decommissioning activities. As illustrated in Figure 1-6, this covers a football field

Table 1-4 Description of Waste Types

High-level waste: the radioactive by-product generated from processing irradiated fuel to separate usable plutonium and other isotopes for weapons, research and new fuel.

Transuranic (TRU) waste: waste that contains alpha-emitting transuranic elements with half-lives greater than 20 years whose combined activity level is at least 100 nanocuries per gram of waste at the time of assay.

Low-level waste: composed of all radioactive waste not classified as high-level waste, TRU waste, spent nuclear fuel, or natural uranium or thorium by-product material.

Mixed waste: waste that contains both radioactivity and hazardous chemicals and materials such as mercury, PCBs, and organic solvents.

Spent nuclear fuel: nuclear fuel which has been irradiated, and which, through fission activation and decay, contains multiple radioactive elements with varying chemical and radiological properties.

Nuclear material: includes uranium, plutonium, and other fissile materials in the form of metals, oxides, residues, and processing intermediates left from nuclear weapons production, along with laboratory samples, radiation sources, and rare and man-made isotopes.

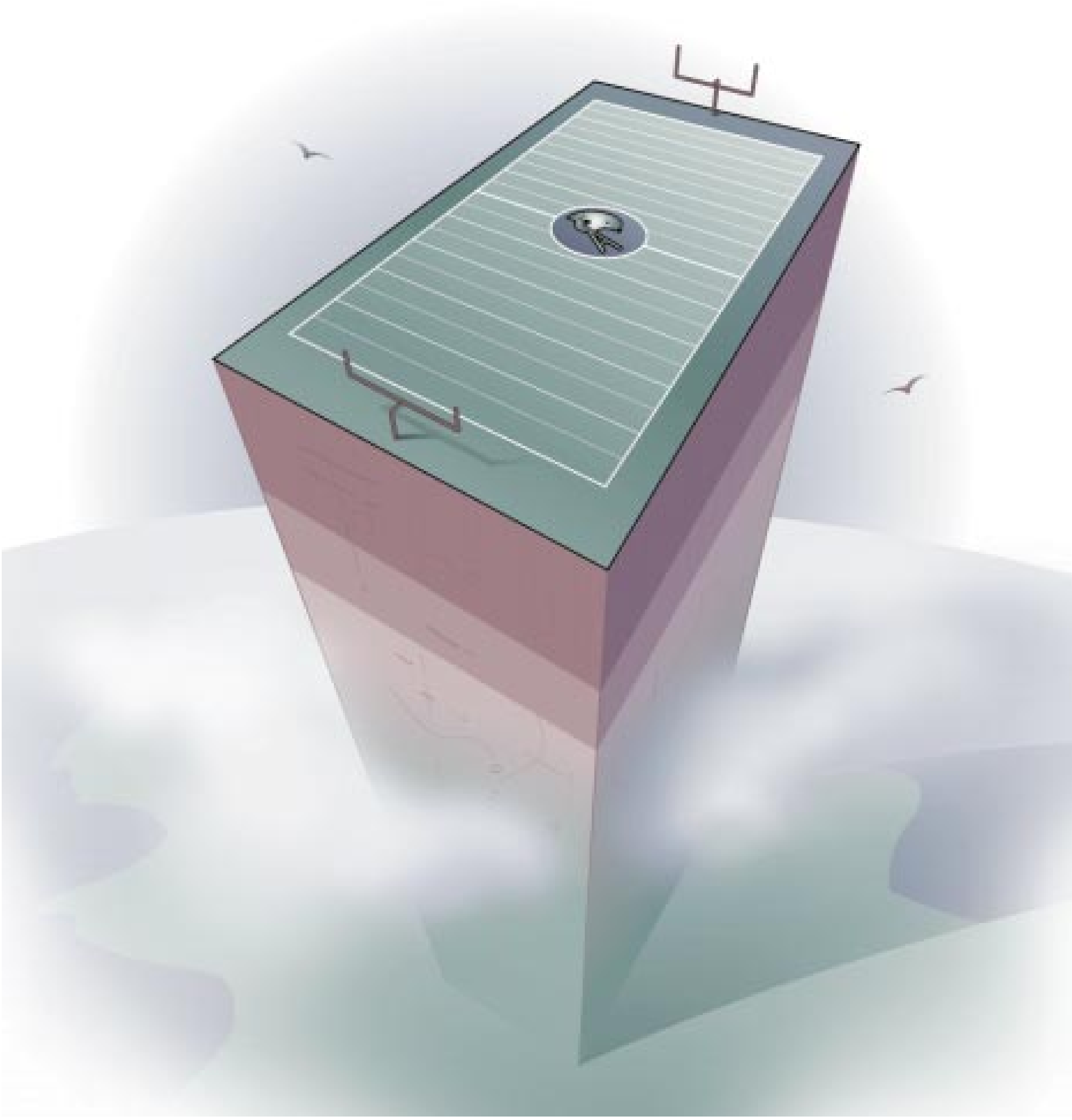


Figure 1-6 The volume of mixed, TRU and solid radioactive and hazardous waste covers a football field to a height of almost a half mile

almost a half mile high! The special challenges presented by these wastes are detailed in Chapters 3 and 8.

Approximately 2500 metric tons heavy metal of spent nuclear fuel have been, or are projected to be, generated from the Department's weapons production, naval, and research reactors. These materials are essentially nuclear reactor fuels that have been used, but still generate considerable heat and under certain conditions are capable of sustaining a chain reaction. Therefore special storage must be provided until the material can be safely dispositioned at an appropriate site, such as a geologic repository. Investments supporting spend nuclear fuel activities are described in Chapter 5.

In addition to the 2500 metric tons of spent nuclear fuel, DOE has responsibility for over 500,000 metric tons of nuclear materials, comprised of uranium and medical isotopes and industrial and laboratory radiation sources. This mass of materials is equivalent to the weight of twelve ships the size of the Titanic. Nuclear materials management is described in greater detail in Chapter 6.

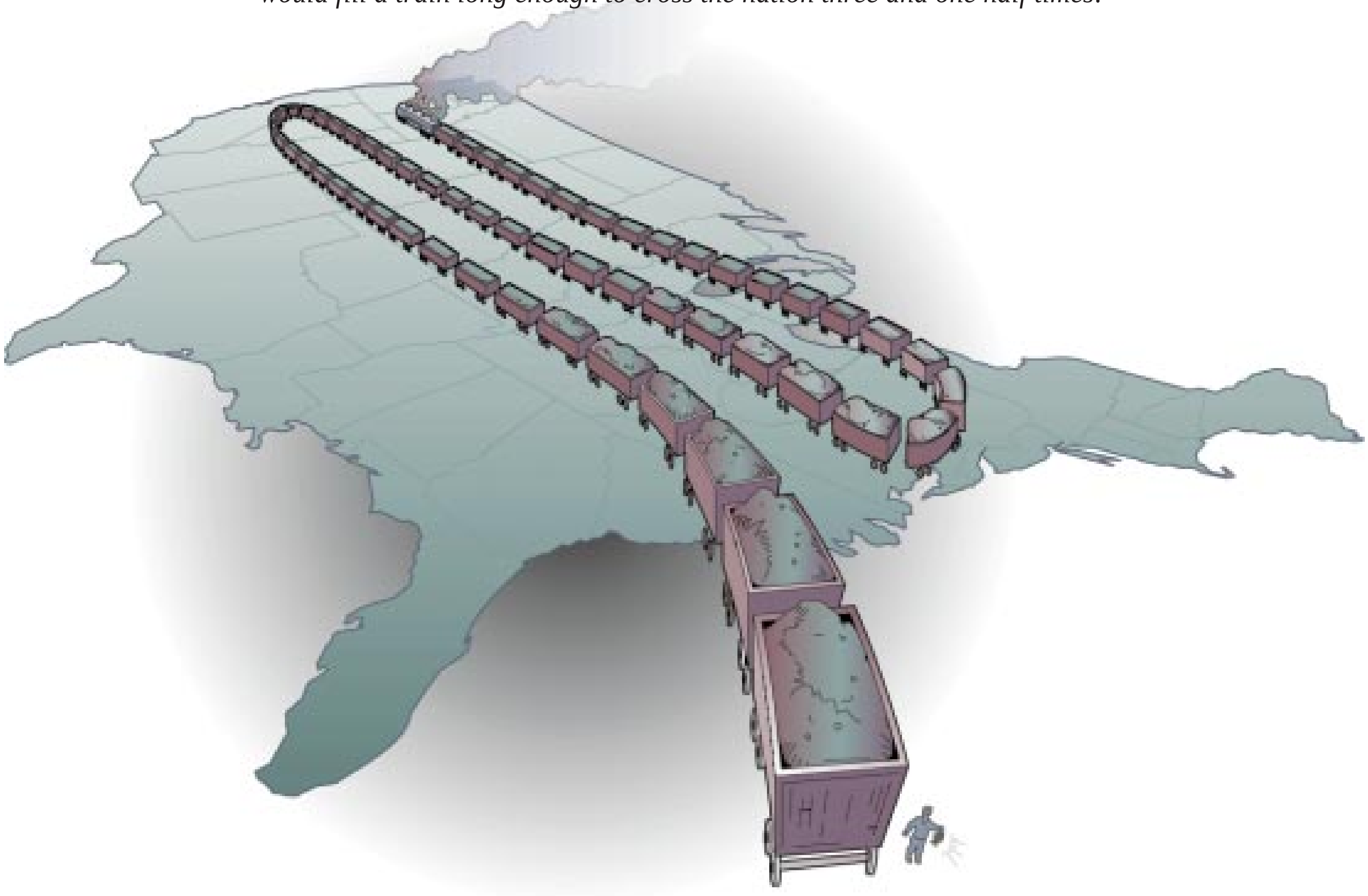
Disposition of Waste/Materials

Projections of spent nuclear fuel generated through 2035 indicate that as much as 86,700 metric tons heavy metal will be produced from electric power generation at commercial nuclear reactors and approximately 2500 metric tons heavy metal from Department research, test, weapons production, and naval propulsion reactors. That is equivalent to placing the tonnage of two Titanics in a geologic repository. In addition, immobilized high-level radioactive waste will require permanent isolation in a geologic repository. Estimates of the numbers of HLW canisters vary, but it is expected that over 20,000 canisters of HLW will be produced. Long-term geologic disposition has never been demonstrated and a large number of questions must be answered. Answers to these questions are difficult to obtain. This research is complicated by the fact that the repository's compliance period extends over many thousands of years, and no precedent exists to validate performance over this timeframe. The investments for materials and waste disposition are described in Chapter 7.

Enhance Future Land Use

The Department is also responsible for an estimated 3 million cubic meters of buried solid radioactive and hazardous wastes, 75 million cubic meters of contaminated soil, and 475 billion gallons of contaminated groundwater. The magnitude of the environmental remediation challenge presented by these quantities is shown in Figures 1-7 and 1-8, and is discussed in Chapter 8.

Figure 1-7 The volume of contaminated soil to be remediated would fill a train long enough to cross the nation three and one half times!



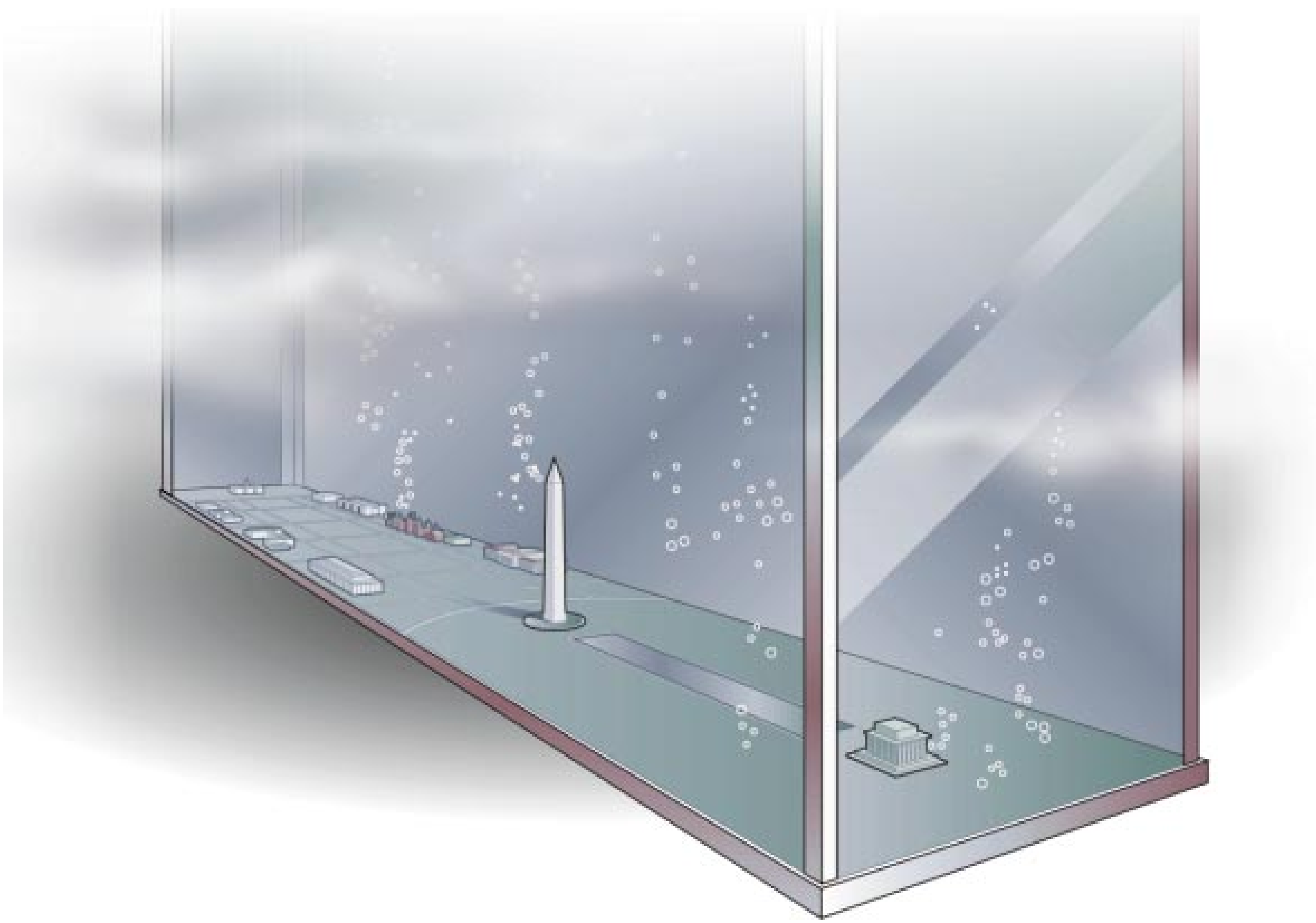


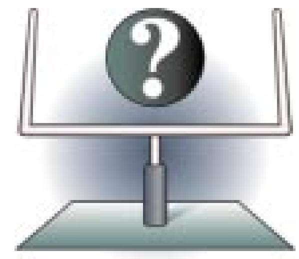
Figure 1-8 The volume of contaminated groundwater to be remediated would fill an aquarium with a base the size of the Washington Mall, seven miles high!

In addition to the environmental remediation activities, the cleanup program must also address over 20,000 facilities which require deactivation and decommissioning, as will hundreds of commercial nuclear power plants and university research reactors. Many of these facilities present very significant challenges due to the highly radioactive and hazardous environments encountered. The R&D investments supporting deactivation and decommissioning activities are described in Chapter 9.

Factors Affecting EQ R&D Portfolio

The portfolio encounters the general uncertainties associated with research and development. However, there are additional factors and uncertainties that impact the EQ R&D portfolio.

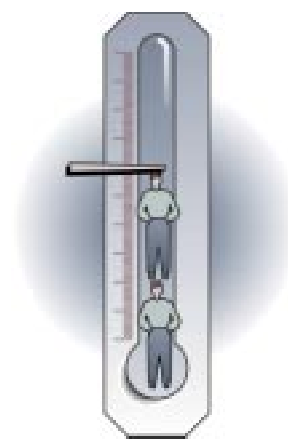
Portfolio Planning with Moving Targets



End states are not fully defined for many of the Department's larger sites and decisions regarding disposal or disposition of some waste types and materials have not been formalized. Achieving safe and affordable end states and final disposal or disposition will require a significant amount of effort and resources. The use of new science and technology is required to move closer to the end states and make further progress in the final disposal of our waste. This progress will allow the Department to better focus our R&D efforts on completion of the final cleanup and disposal missions.

Compliance-Driven Decision-Making

Federal Facility Compliance Agreements and environmental laws and regulations drive the Department's cleanup decisions. Unfortunately, some of these decisions have been made before all potential solutions are identified and/or developed. This may inhibit the development and maturation of potential alternative technologies. In some cases, existing scientific knowledge is simply insufficient to make fully informed decisions. In short, the technical complexity coupled with external regulatory uncertainty and variability can result in complex and sometimes conflicting regulatory requirements being imposed by state and federal regulatory agencies. This is not the best environment for the rapid introduction of new technology.

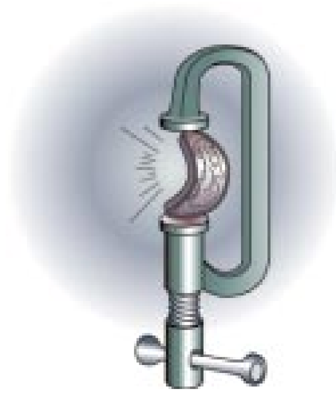


Technology Decisions and Stakeholder Values

Stakeholders are a major factor in developing cleanup options, in decision making, and in the use of new technology. Due to the inherent nature of the cleanup effort and the proximity of some sites to the general population, stakeholders have a high interest in cleanup activities. They play a key role in determining the levels of acceptable risk and can strongly affect the required level of cleanup and the ability or will of the government to fund these efforts. Seeking their participation throughout the process of solving cleanup problems and making investment decisions is critical.

Balancing Contract Reform, Privatization, and Investments

Contract reform efforts such as shifting to management and integration contracts and privatization of cleanup efforts are tactics to improve management and reduce costs. Contract reform efforts are relatively new and will need further development and improvement to ensure optimum performance. Coupling contract reform with R&D investments can help encourage industry investment in the development of new science and technology for waste management and environmental remediation.



However, this has not yet proved effective in areas that do not offer an attractive commercial market. Privatization is an alternative to traditional government-owned facilities and cost-reimbursement contracts. Under privatization, privately financed facilities are selected in competitive bids, usually operate on a fixed-price basis, and receive a fee once cleanup goals (as specified in contracts) are met. The potential for profit provides the incentive for the private sector to introduce innovative and cost effective technologies. The private sector will weigh the potential for increased profit resulting from more efficient technology against any increase in programmatic risk. As a result, lower total costs to the government are possible. Privatization of the Department's cleanup efforts has been difficult in areas where there is not potential commercial market, i.e., where the Department is the only potential customer.

Role of the Federal Government in Environmental Quality R&D

The federal government, as well as industry, must invest in basic and applied science to accomplish its mission and to maintain productivity and competitiveness in the global economy. The trend in the United States has become one in which industry is shifting investments to near-term R&D to improve short-term gains. Thus, developing and sustaining the long-term scientific and technological foundations for economic productivity is becoming the responsibility of publicly funded science. In addition to this universal federal role in R&D, there are a number of rather unique aspects of the federal role in the EQ business line, shown in Table 1-5.

Table 1-5 Federal Role in the Environmental Quality Business Line and R&D Portfolio

The Department of Energy:

- Owns the problem
- Major source for R&D funding
- Primary participant in the R&D portfolio execution (through the national laboratories and site contractors)
- Owner of unique facilities for conducting R&D (e.g., hot cells and canyons)
- Coordinates federal investments in Environmental Quality R&D
- Provides global leadership to environmental quality efforts
- Signatory of compliance regulations and agreements
- Is a market driver due to large percentage of the total cleanup market

Managing the Investment Portfolio

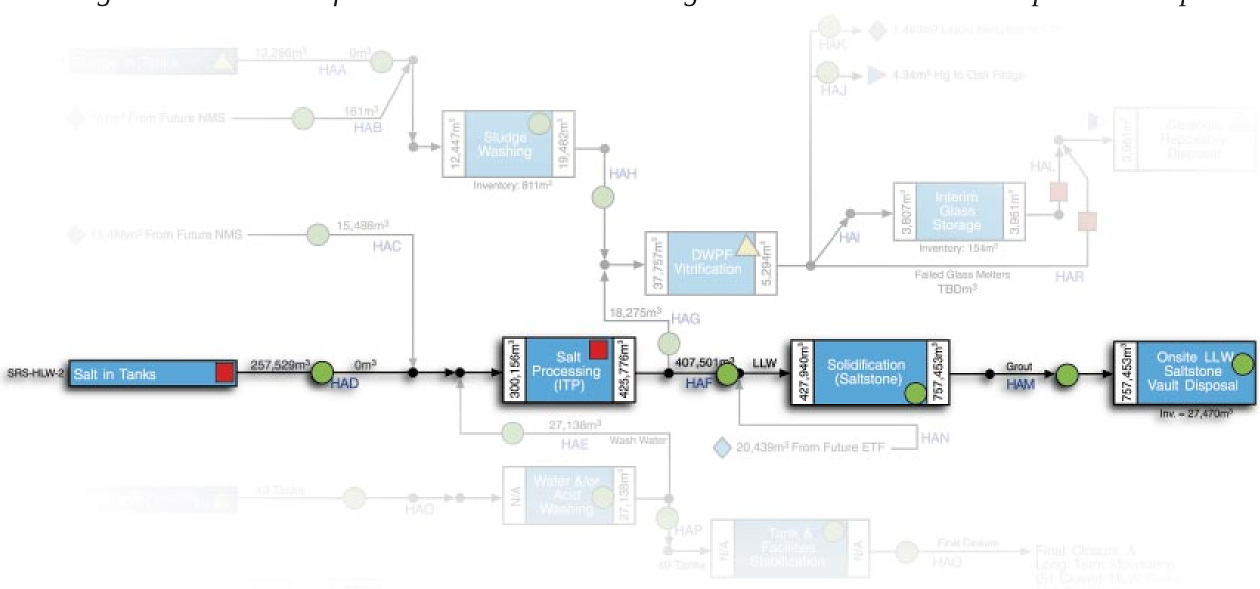
While the portfolio provides an integrated picture of EQ R&D investments, it is not yet managed as an integrated investment. The disposition element of the portfolio is managed by the Office of Civilian Radioactive Waste Management in accordance with the major founding and directive legislation[4]. The major responsibility for the environmental cleanup task resides with Environmental Management.

The approach to managing Environmental Management funded investments are in transition. The new management approach is described in recently published strategic and program plans[5], and is currently being implemented. Four essential elements of this new R&D management approach are briefly described below.

End State Development—A Systems Engineering Approach

Systems engineering principles and methodologies have been used to help define the end states that must be attained to achieve the cleanup goals. This type of approach has been confirmed by a recent study by the National Research Council[6]. The creation of complex-wide disposition maps for waste and materials has provided an opportunity to identify technology needs, alternative disposition scenarios, and the increased potential to leverage resources and facilities across the complex. Figure 1-9 provides an illustration of a disposition map. The map displays a "red light" for salt reprocessing, indicating a major technology need exists for this cleanup activity. The identification of technology needs and gaps and programmatic risk provide the basis for prioritization of Environmental Management R&D investments.

Figure 1-9 Portion of the Savannah River Site-High Level Waste Baseline Disposition Map



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4 The *Nuclear Waste Policy Act*, Public Law 97-425 as amended by Public Law 100-203 and 102-203.

5 *Environment Management Strategic Plan for Science and Technology* (November 1998) and *Environmental Management Research and Development Program Plan* (November 1998)

6 *An End State Methodology for Identifying Technology Needs for Environmental Management, with an Example from the Hanford Site Tanks*, Committee on Technologies for Cleanup of High-Level Waste in Tanks in the DOE Weapons Complex; Board on Radioactive Waste Management; Commission on Geosciences, Environment, and Resources; National Research Council, National Academy Press, Washington, D.C. 1999

Customer-Driven Research and Development

Activities necessary to achieve known end states are defined in the cleanup projects. Needs are identified in these projects by the cleanup project manager, that is, the R&D customer, and form the basis for developing the investment portfolio. The process of identifying needs, developing responsive research and development work packages, and incorporating them into planning, budget formulation and execution is illustrated in Figure 1-10 [7].

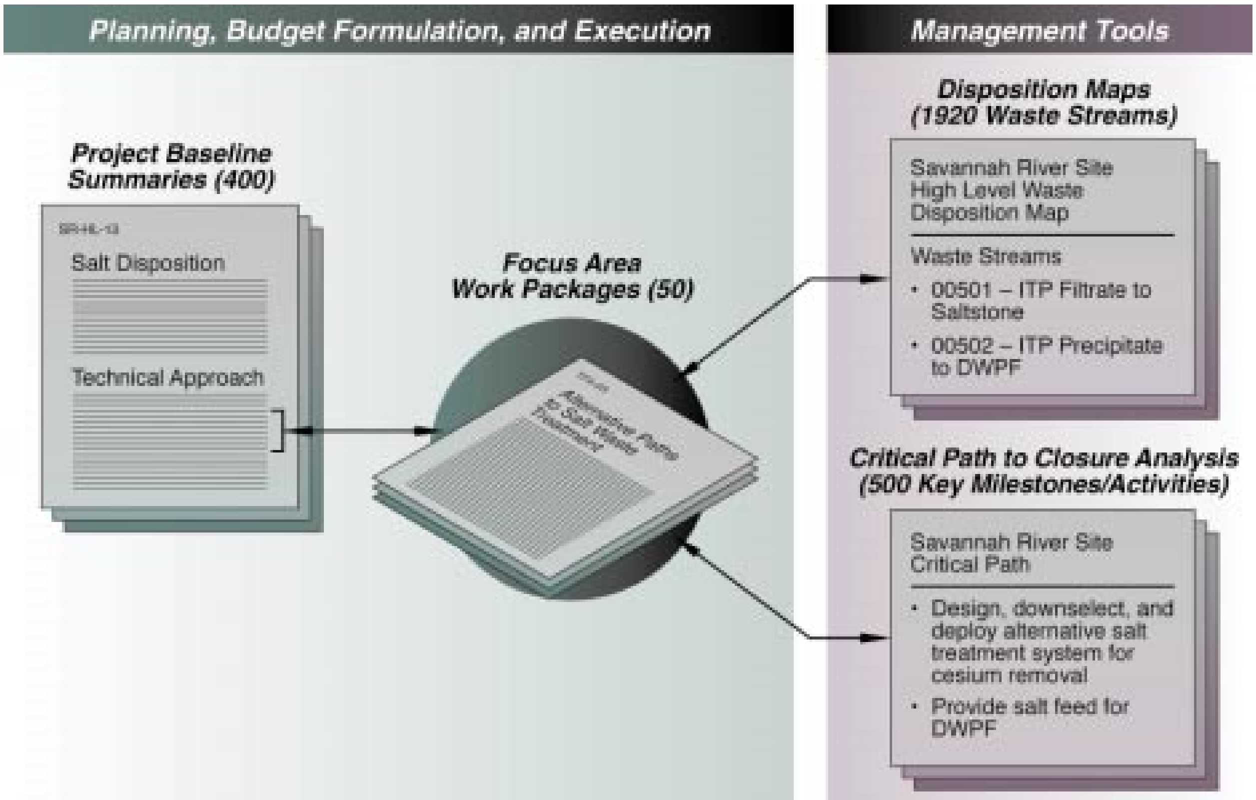


Figure 1-10 Integration of R&D Work Packages with Complex-wide budget analysis and management processes

[7] All cleanup projects are described in documents called Project Baseline Summaries (PBSs). The PBSs are grouped into sets of like problem areas, and the science and technology needs for each problem area are described in Focus Area work packages. Technology needs are also developed from gaps identified in waste disposition maps and by analysis of critical path milestones.

Prioritizing Portfolio Investments

A set of quantitative parameters are used to evaluate and score each research and development work package. The portfolio can then be developed in response to the highest scoring proposals with confidence that, with the funding available, the portfolio will be the "right" portfolio; it will address the most important research and development needs and have the greatest potential impact. Figure 1-11 illustrates the elements of the quantitative analytical process.

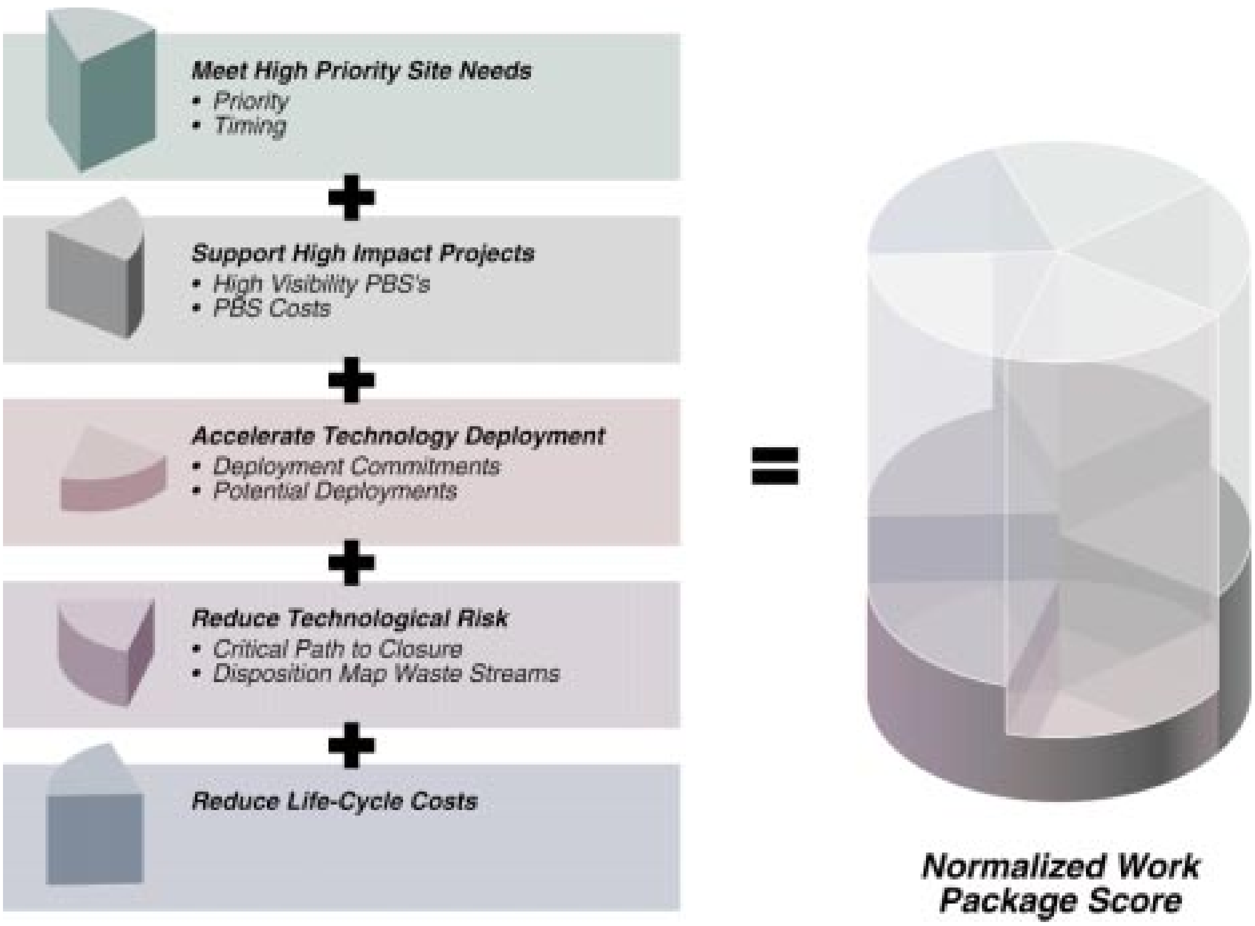


Figure 1-11 Process for quantitative determination of work package value score

Performance Measures—Managing and Evaluating the Portfolio

The Environmental Management science and technology strategic and program plans describe ***what*** and ***how*** the research and development activities are to support the cleanup enterprise. The management approach ties the investments directly to cleanup projects. The corporate research and development performance measures are used to measure ***how well*** the Environmental Management research and development investments have met cleanup project needs. The cleanup program manager defines the R&D needs, the level of performance necessary to meet those needs, and reports the actual level of performance. These performance measures, defined and reported by the customer, provide the basis to assess the performance of the portfolio and serve as a basis for modification and improvement. The four performance measures are illustrated in Figure 1-12.

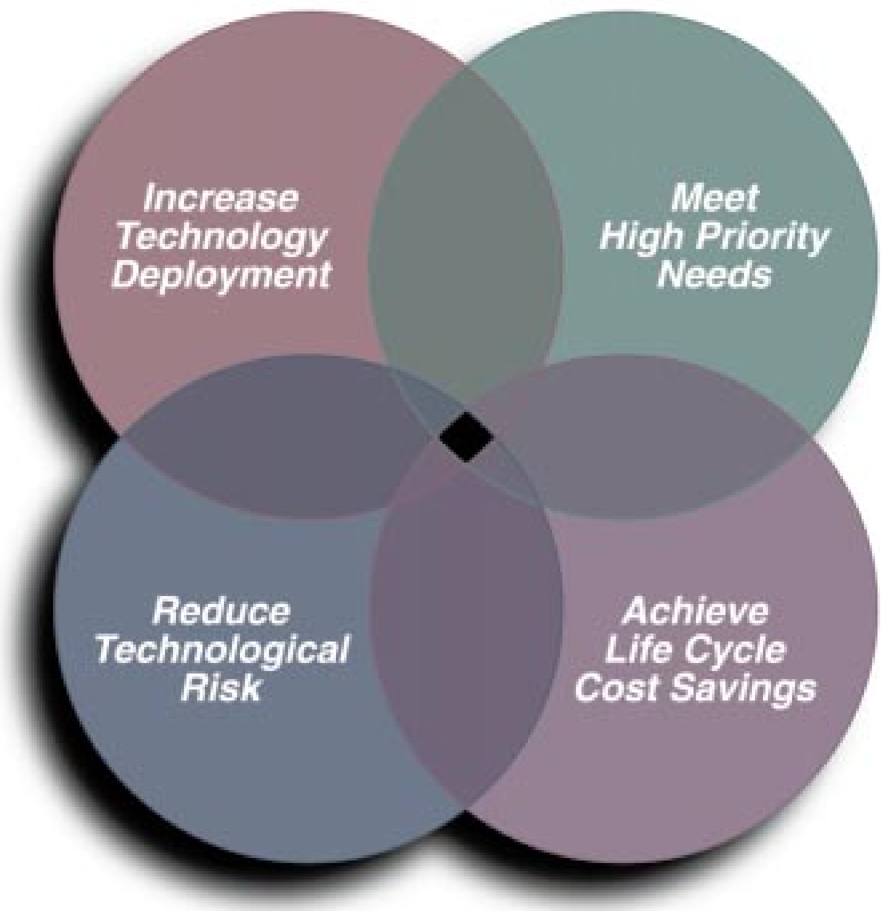


Figure 1-12 Customer-driven performance measures to improve investments management

Key Accomplishments

Environmental technologies from the EQ R&D Portfolio have been developed and applied to solve environmental problems and prepare for disposition of waste and materials in a geologic repository. This section presents highlights of these technologies, organized by the problem area or process steps. In many cases, ongoing R&D continues to enhance the effectiveness or the scope of application of these technologies. More detailed accomplishments are provided in Chapters 3 through 9.

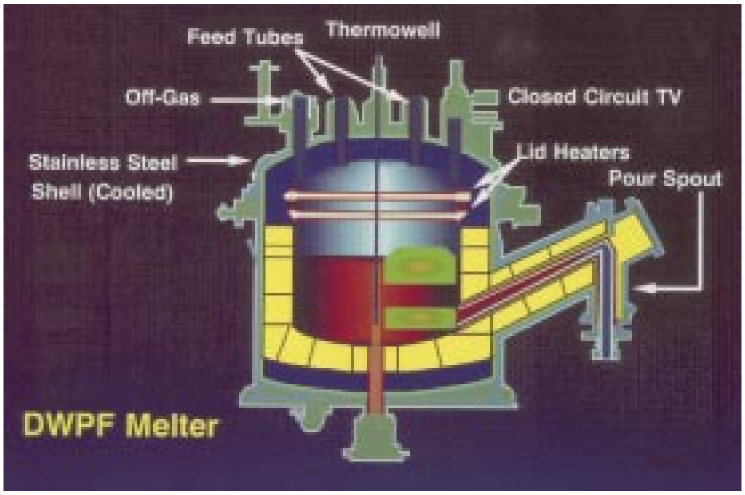
Characterization


Houdini vehicle working by remote operation in a tank.

Numerous improvements in instruments have been achieved, including portable detectors and nondestructive and nonintrusive examination techniques for both stored waste and materials and for contaminated surfaces and soils. Robots and tele-operated vehicles are now in use for facility and storage tank inspection. Collectively, these advances enable a better understanding of the characteristics of the hazardous wastes and materials to be managed while reducing the worker exposure to these materials. Several technologies, such as portable chemical sniffers and nonintrusive spatial metal detector arrays, have been adapted and used by other agencies for applications as bomb, drug, and weapons detectors.

Treatment, Volume Reduction, and Pollution Prevention

Chemical separation technologies for the removal of selected metals and radionuclides have already reduced life-cycle cleanup costs by over $6 billion. Technologies to minimize pollution by reducing waste volumes and separating out hazardous constituents have also been put to use. Examples include sizing, super-compaction and incineration.



Waste Stabilization

A number of techniques have been fielded for stabilizing material and waste forms to immobilize hazardous constituents and reduce their long term environmental impacts. Different techniques are available for application according to the level of hazard involved. Specific examples include grouting, macroencapsulation, and microencapsulation of low-level, mixed, and transuranic wastes, calcination and vitrification of high-level waste, ceramification of several waste types, safe dry storage of spent nuclear fuel, and caps and barriers for in situ containment of subsurface contamination. While all of these techniques are in use, many are still undergoing continuing development to improve and expand their application.

Deactivation and Decommissioning

Dozens of new techniques have been successfully applied to achieve deactivation of unique large scale facilities such as the Hanford C Reactor (a plutonium production reactor) and the Waste Calcine Facility, along with complete D&D of multiple smaller test reactors, storage tanks, and laboratory facilities.

Reactor Deactivation: Before and after pictures of the C Reactor at Hanford; the first production reactor to be addressed

Transportation

Achievements in transportation include the development of unique shipping casks and packaging systems for radioactive and hazardous materials. These systems allow the safe transport of materials and waste and have an excellent performance record. No major release of radioactive materials has ever occurred during transportation. When accidents have occurred, typically the greatest environmental impact has not been from the radioactive cargo, but from the diesel fuel of the transport vehicle.

Disposal

The largest R&D efforts for safe waste and material disposal are the geologic repositories for transuranic wastes and for spent fuel and high-level wastes. The Waste Isolation Pilot Plant (WIPP) is now opened and receiving TRU waste. A viability assessment of the candidate Yucca Mountain site as a repository for spent fuel and high-level waste has been completed. Other accomplishments include development of improved radionuclide transport models, installation of unique drift-scale thermal and hydrologic tests at the site, and development of complex engineered barrier system design concepts using material capable of lasting thousands of years. Numerous government and commercial shallow land disposal facilities have been constructed and placed in use supported by technologies developed by the Department.

Environmental Remediation

Successful remediation of over 50 contaminated sites has been achieved through use of innovative technologies including chemical washing, in situ bioremediation, vapor extraction, and the treatment of nonaqueous phase liquids.