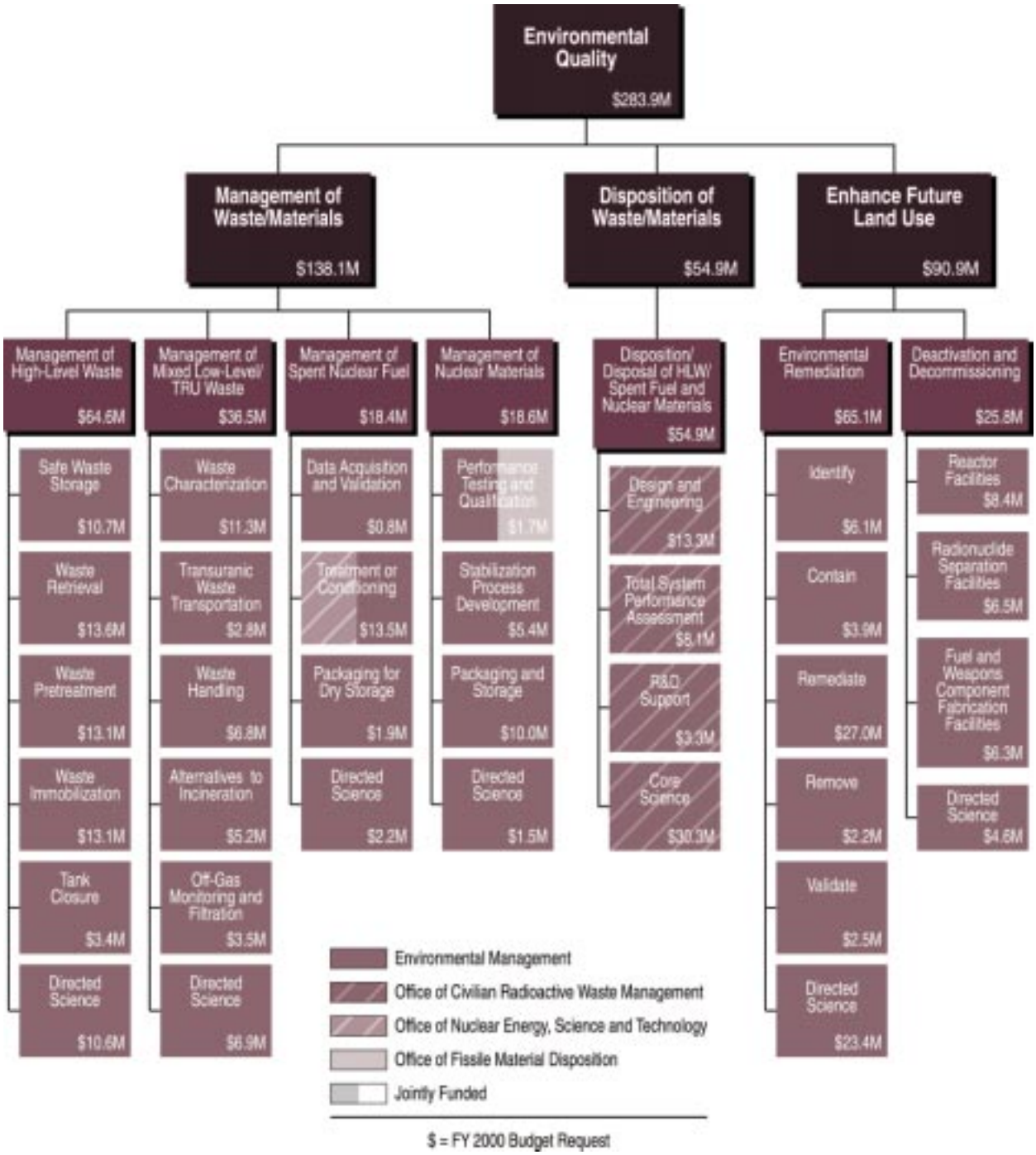
Chapter 2
Portfolio Analysis



Chapter 2

Portfolio Analysis

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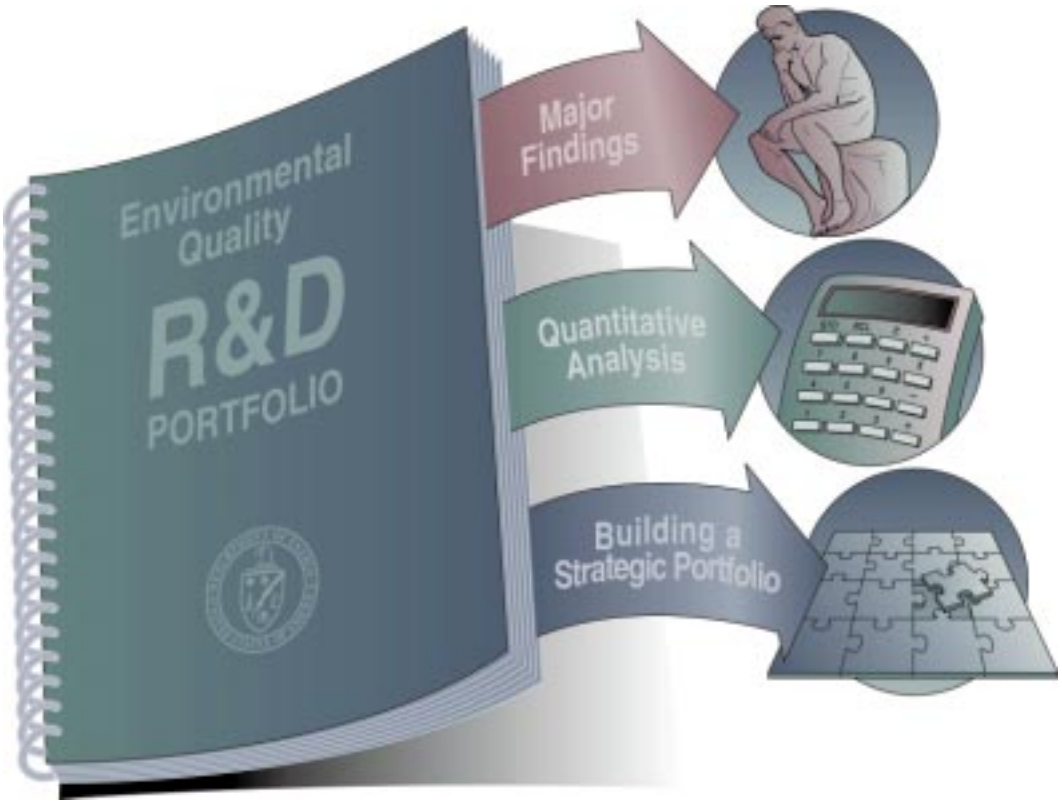
Introduction

This is the first time the Department has attempted to describe and analyze our R&D investments by business line. The effort has been both productive and informative. The process has cut across normal program lines and identified areas where improved coordination can improve the management of R&D and has identified gaps in the investments currently planned. In the past each program carefully reviewed and allocated a portion of its budget to R&D. This approach was effective along program lines but will be enhanced by the portfolio planning process from both strategic and crosscutting perspectives.

This chapter provides the first analysis ever conducted of the Environmental Quality R&D portfolio. As indicated in Chapter 1, this is a baseline document describing the current portfolio; it is not a planning document. The next step in the process is to develop a forward-looking planning tool. Our analysis will be presented from the three perspectives shown in Figure 2-1.

Major Findings describe, in qualitative terms, observations and issues that must be addressed. The Quantitative Analysis of the portfolio, performed on a first-order level, provides a picture of *what is*. Because this document provides a baseline and not a plan, the quantitative analysis will not present a comprehensive description of *what should be*. The final perspective, Building a Strategic Portfolio, is a discussion of the vision of what the portfolio could evolve into, describing *what could be*. It is important to remember that though this portfolio describes the complete Environmental Quality research and development enterprise, the activities are not managed as an integrated investment.

Figure 2-1 Three perspectives of the Portfolio Analysis



Major Findings

A variety of individuals and organizations reviewed the portfolio during its various stages of preparation. These reviews [1], both internal and external, identified a number of similar issues and observations. The majority of these can be grouped into five major findings, and are the first of the three analysis perspectives discussed in this chapter.

Major Finding 1

The portfolio is strongly tied to the Department's current objectives in Environmental Quality. The portfolio is aligned with, and highly focused on, meeting complex-wide cleanup goals and achieving the safe disposition of commercial spent nuclear fuel.

Discussion:

- The portfolio structure is consistent with the major problems associated with the cleanup effort. Within existing funding constraints, investments have been distributed in a rational and defensible manner.
- The research and development activities are developed, approved, and supported by the customer. This strong tie between the customer and the portfolio participants means that the outputs from the vast majority of the portfolio investments will be used.
- The current portfolio structure is generally broad enough to cover the full range of DOE cleanup activities as well as those of selected private sector activities (e.g., commercial reactor decommissioning).

Major Finding 2

The portfolio participants are diverse and distributed, and the portfolio is leveraged. The portfolio has been strengthened through the diversity of participants (universities, laboratories, site contractors, and industry) and the leveraging of activities with both internal and external participants.

Discussion:

- The portfolio's activities are distributed over a wide range of participants from federal laboratories, universities, site cleanup contractors, and industry. The distribution of the participants is consistent with the needs and characteristics of the various stages of maturity and of the portfolio areas. That is, there are investments that both require and have participants from all four major entities: universities, laboratories, site contractors, and industry.
- The portfolio identifies leveraged funds with research activities in the Department's other portfolios, with other Federal Agencies, international organizations and institutions, and with the private sector. Many of these activities and associations are formal in nature. These structured

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[1] Departmental review includes the Undersecretaries Office, the DOE Research and Development Council, the Offices and Programs of the Environmental Quality Business Line and the Office of Science. The Environmental Management Roadmap Core Team (which includes laboratory and M&O contractor personnel), the Environmental Management Advisory Board and members of the DOE Strategic Laboratory Council have also reviewed this portfolio.

agreements are generally more successful than informal agreements as they require co-funding and work scope commitment from all parties.

Major Finding 3

The portfolio recognizes the need for, and attempts to invest across, a full spectrum of activities ranging from basic research through technology deployment.

Discussion:

- The Department is making progress moving towards full integration of directed science with technology development and deployment activities. The directed science budget is distributed across the problem areas in proportion to the identified needs.

- Funding from the Office of Science is providing a solid basis for the existing business line missions. This funding is focused in general areas such as chemistry, physics, and biological sciences as well as targeted funding in more specific areas such as in situ biological remediation to support the overall mission objectives.

- Investments have been shifting from development and demonstration to include basic research and deployment. The Department has recognized the need to focus both on long-term intractable problems and accelerating technology deployment to reduce cleanup costs now.

Major Finding 4

The overall Environmental Quality portfolio may be under invested to sustain achievement of existing mission objectives beyond the near term, i.e. beyond 2006.

Discussion:

- On an annual basis, the Environmental Quality business line constitutes roughly 40% of the Department's budget. The business line objectives are technically challenging, generally long-term in nature, and costly. Yet the Environmental Quality R&D portfolio represents less than 4% of the Department's R&D investment. Current funding may not adequately support a long-term integrated research program.

- The downward funding trend is incongruous with the upward trend in life-cycle costs and programmatic risk levels associated with current cleanup projects. Further advancements in science and the use of new technologies will be required to meet current cost projections, much less reduce life-cycle costs.

- To offset the under investment, the Department has made science and technology investments that are heavily weighted towards basic research and the deployment of technologies. The result is a significant under investment in applied research, exploratory development, and demonstration activities. While this approach may meet the short term cleanup mission needs, it is not clear that the current portfolio adequately addresses the Department's longer term (post-2006) problems. Lack of investment in applied research, exploratory development and demonstration activities may limit the Department's ability to capitalize on its science investments for developing full scale, deployable technologies from science innovations.

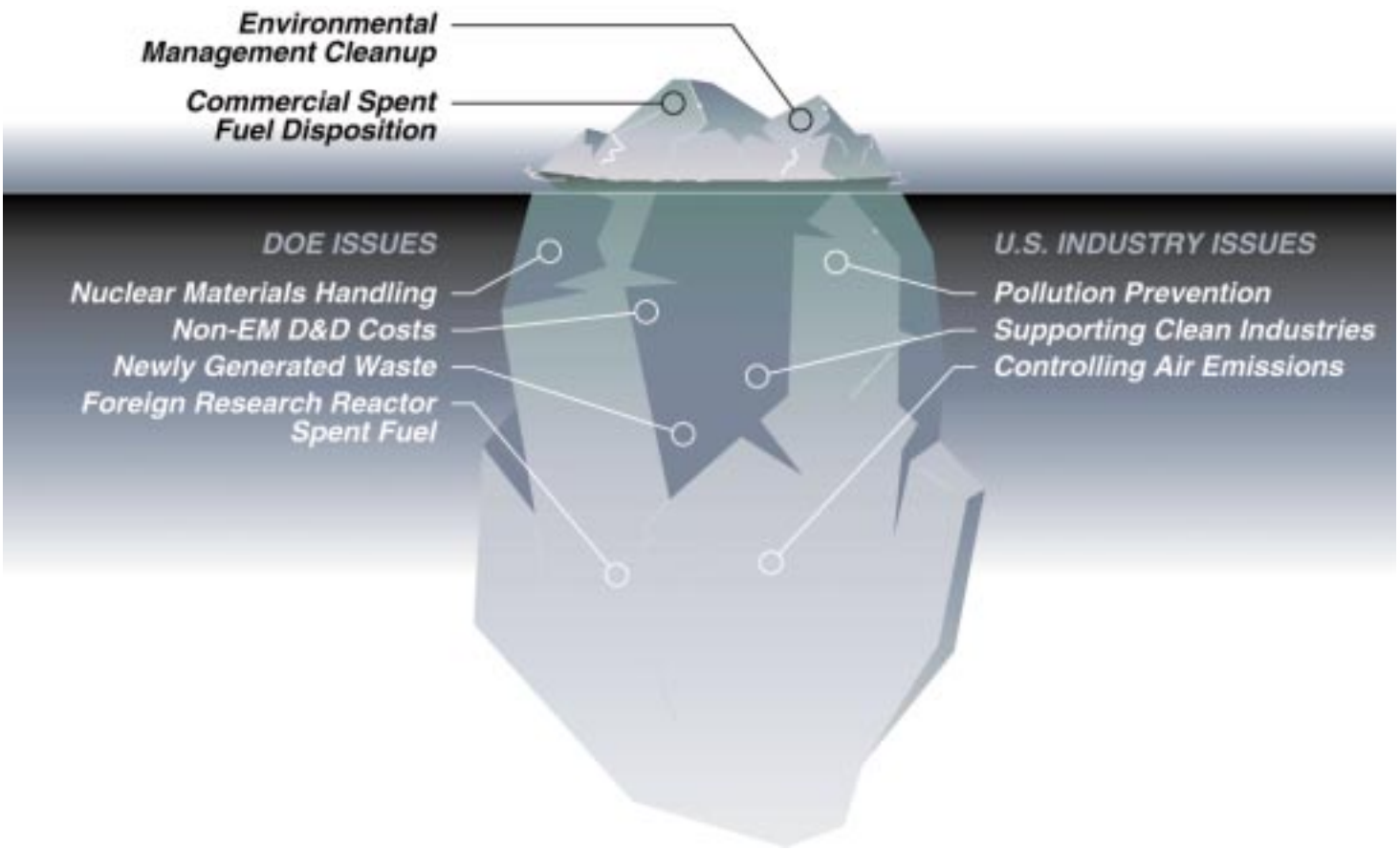
Major Finding 5

The Department should continue the portfolio planning process in order to improve the alignment of the four portfolios and make investment decisions that ensure the Department can help meet the nation's greatest challenges.

Discussion:

- An integrated review of the four business line portfolios should be coupled with the Department's Fiscal Year 2000 strategic planning process. The Department's R&D planning and strategic planning activities should be closely coupled to ensure success.
- The portfolio planning process has already enabled better integration within the individual portfolios. However, because there are significant interfaces and crosscutting elements, each of the business lines will contain some research activities that are relevant to other portfolios. The portfolio management process would benefit from improved coordination and a more integrated approach to these inter-portfolio activities.
- Expansion of the Environmental Quality portfolio will require significant federal and private

Figure 2-2 The current portfolio is just the tip of the Environmental Quality iceberg



sector interaction. The use of science and technology roadmaps must be expanded to cover a broader set of environmental quality issues. The Department needs to continue to work with industry to identify the appropriate roles and responsibilities each should have in creating and maintaining the integrity of the nation's environmental quality.

Quantitative Analysis

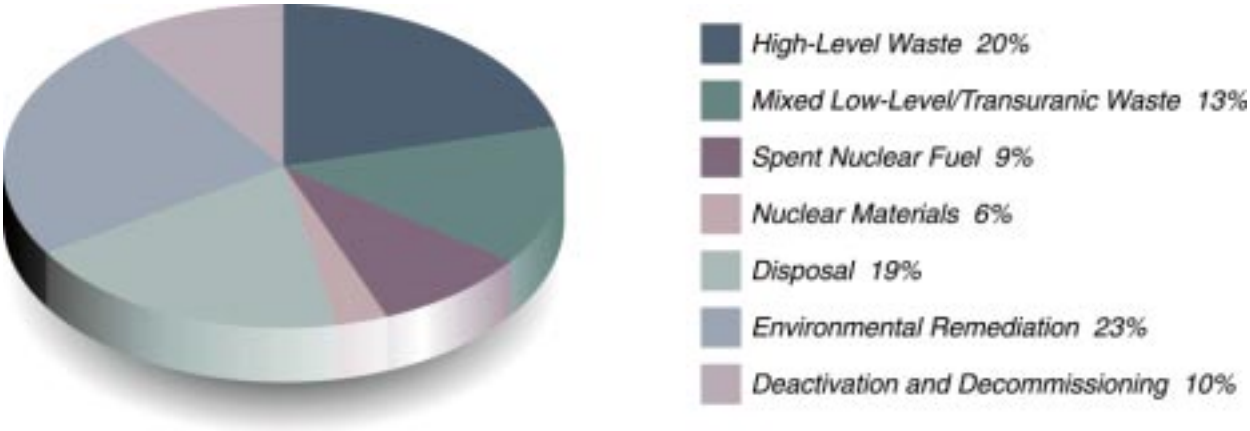
Many factors are considered when distributing the portfolio across investment areas. Defining the "correct" or best portfolio distribution is a complex and difficult task. This quantitative analysis dissects the investments to provide insight into the current investment distribution. The analysis is organized according to the following topics:

- distribution by investment area—balancing life-cycle cost and programmatic factors,
- investing in research through deployment—a nonlinear approach,
- portfolio participants—strength through diversity, and
- environmental quality—a Departmental investment.

Portfolio Funding Distribution by Investment Area

The majority of the current portfolio has been developed based on data from *Paths to Closure*. The portfolio distribution (cumulative from FY 1998 through FY 2000) across the investment areas is shown in Figure 2-3.

Figure 2-3 Planned R&D funding distribution by environmental quality/cleanup problem (FY 1998-FY 2000).

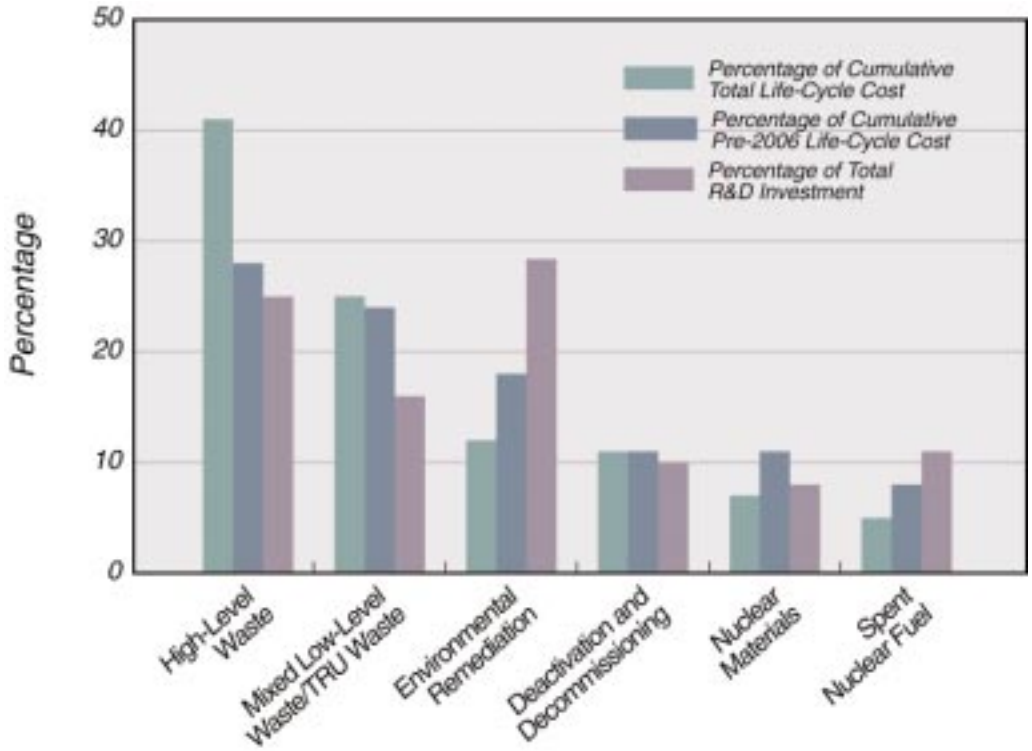


There are two main drivers for this distribution: life-cycle cost and program considerations.

A First-Order Approach: Investing Based on Life-Cycle Cost

A reasonable assumption is that the greatest potential for cost savings is in the areas that have the greatest life-cycle costs. Thus, a reasonable first-order approach is to prorate R&D funding by the life cycle cost of each investment area. For example, the high-level waste life cycle cost represents 41% of the total cleanup life cycle cost. Under this approach, 41% of the R&D investment would be placed in the high-level waste area. Figure 2-4 shows by percentage the pre-2006 and total life-cycle costs and the corresponding R&D investment.

Figure 2-4 Life-cycle costs of investment areas for weapons complex cleanup



While the correlation of investment with pre-2006 life-cycle cost is relatively strong, there are exceptions. For example, over half the total life-cycle cost for environmental remediation is expected to occur before 2006. To reduce cost, new technologies must be developed and deployed in the near-term. Thus there is a higher investment in this area than would be expected. Environmental Remediation must also address a more distributed and diverse set of problems than the other problem areas and thus receives a higher percentage of funding. In addition, the relatively large investment for Spent Nuclear Fuel is driven by a full-scale demonstration project at Argonne National Laboratory-West, which skews this percentage upward.

Investment Area Programmatic and Milestone Considerations—Meeting High Priority Needs and Reducing Risk

Accelerating Cleanup: Paths to Closure provides a projection of the technical scope, cost and schedule required to complete cleanup at the Department's remaining sites. The cost, scope and schedule projections are based on the cleanup "end state" that has been identified for each site. As

Paths to Closure information and data concerning needs and technology risk are refined it is factored into R&D work packages. Thus programmatic factors contribute directly to prioritization of research and development work packages and the subsequent distribution within portfolio investments.

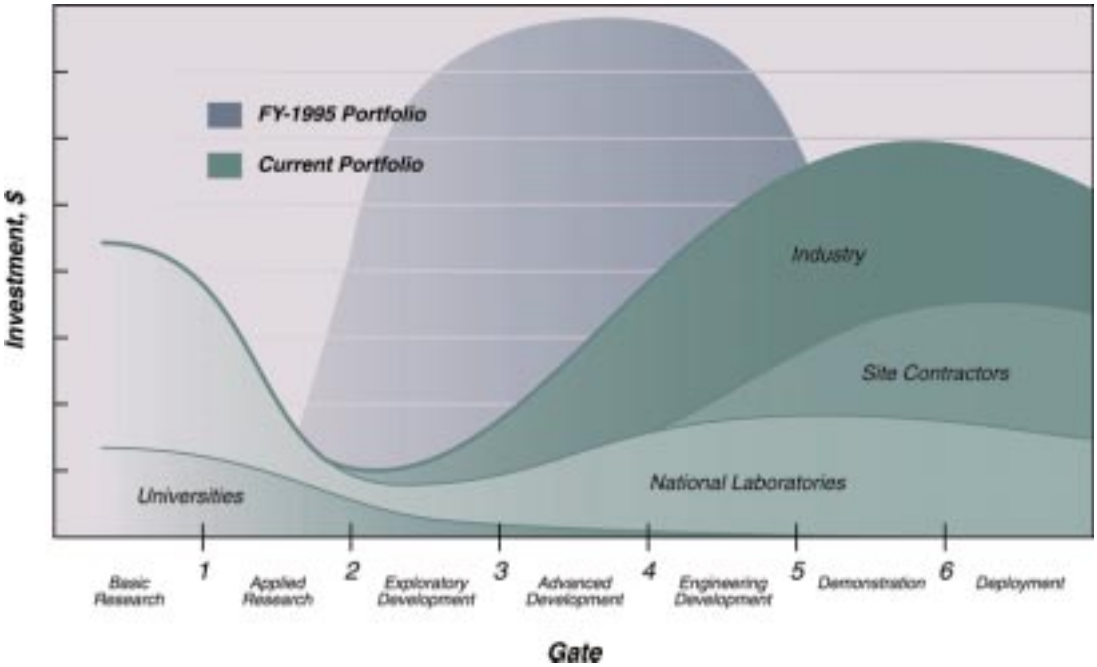
The distribution of investments across the problem areas represents one dimension of the portfolio. Figure 2-5 illustrates a second dimension of the portfolio; the distribution of investments from research through deployment.

Figure 2-5 Multiple Dimensions of Portfolio Investments

Investing in Research through Deployment

As the Department's cleanup efforts have progressed the magnitude and complexity of the problems have become more clearly defined. The initial portfolio approach, focused on technology development and demonstration, was based on a cleanup picture that was still developing. The current portfolio embraces research through deployment with the recognition that we must balance the immediate needs of compliance-driven activities with solutions for the longer-term and more expensive problems. The current portfolio distribution across research, development, and deployment and the shift in distribution are illustrated in Figure 2-6.

Figure 2-6 Investments across the research-deployment continuum



To successfully execute the optimal development of the portfolio investments illustrated in Figure 2-6 an *increase* in the portfolio funding may be required. That is, a critical level must be maintained across the technology maturity spectrum to maintain a science-technology infrastructure capable of supporting effective research and carrying scientific breakthroughs and knowledge through to deployable technologies. Attempting to shift the focus of the distribution while decreasing the overall budget is problematic. Decreasing R&D investments based on near-term progress as evidenced by closing the smaller cleanup sites, is being reviewed. Cleanup of the remaining sites, many with intractable problems, may require greater effort and investment to solve than was initially thought.

Table 2-1 Choosing between the linear and nonlinear models

One analytical tool in portfolio management is the maturity gate model. The model describes a linear progression from basic research through deployment. A technology passes from one stage to the next as it satisfies certain criteria and passes through the next maturity "gate" (hence the name). This model has been validated by experience in industry and in some federal research and development efforts. Money can be saved by testing hardware and/or processes at pilot, bench and demonstration scales before deciding to proceed with deployment. The model works well in these well-defined and controlled situations.

However, the cleanup program requires solutions that go beyond the development of a specific piece of hardware or process. In these instances the linear model is not always applicable. The exceedingly complex nature of the cleanup problems makes solution development an ongoing process. For example, during the deployment of a solution to a remediation problem we find that additional fundamental knowledge, such as reaction rates or partitioning coefficients, is required. Directed basic research must be provided to support the deployment of the solution. Research and development in an environment like this requires investments that support each phase: research, development, demonstration and deployment. This model is nonlinear. Investments may be required simultaneously at different gates, and the results of all these investments must be integrated. Investment decisions based on this nonlinear model are often different from those based on the linear approach.

Portfolio Participants—Strength through Diversity

A portfolio that invests in science through deployment must have the involvement of universities, national laboratories, site contractors, and industry. This helps maintain balance by ensuring participation from contributors whose main focus and background represents each segment of the technology maturity continuum. For example, universities provide a basic and applied science perspective whereas industry focuses on demonstration and deployment. This diverse and highly distributed, national and international "team" is difficult to coordinate and integrate—but this diversity and complexity is essential to provide the "cross pollination" and infusion of different perspectives and insights required to solve complex cleanup problems.

The participants in this portfolio are diverse and distributed; the mix of people, companies, organizations, and institutions that execute the EQ R&D portfolio activities are funded in proper proportions consistent with current investment strategy. Funding and integration of the appropriate participants at each stage of technology maturity, as illustrated in Figure 2-7, has been achieved within the constraints of current funding.

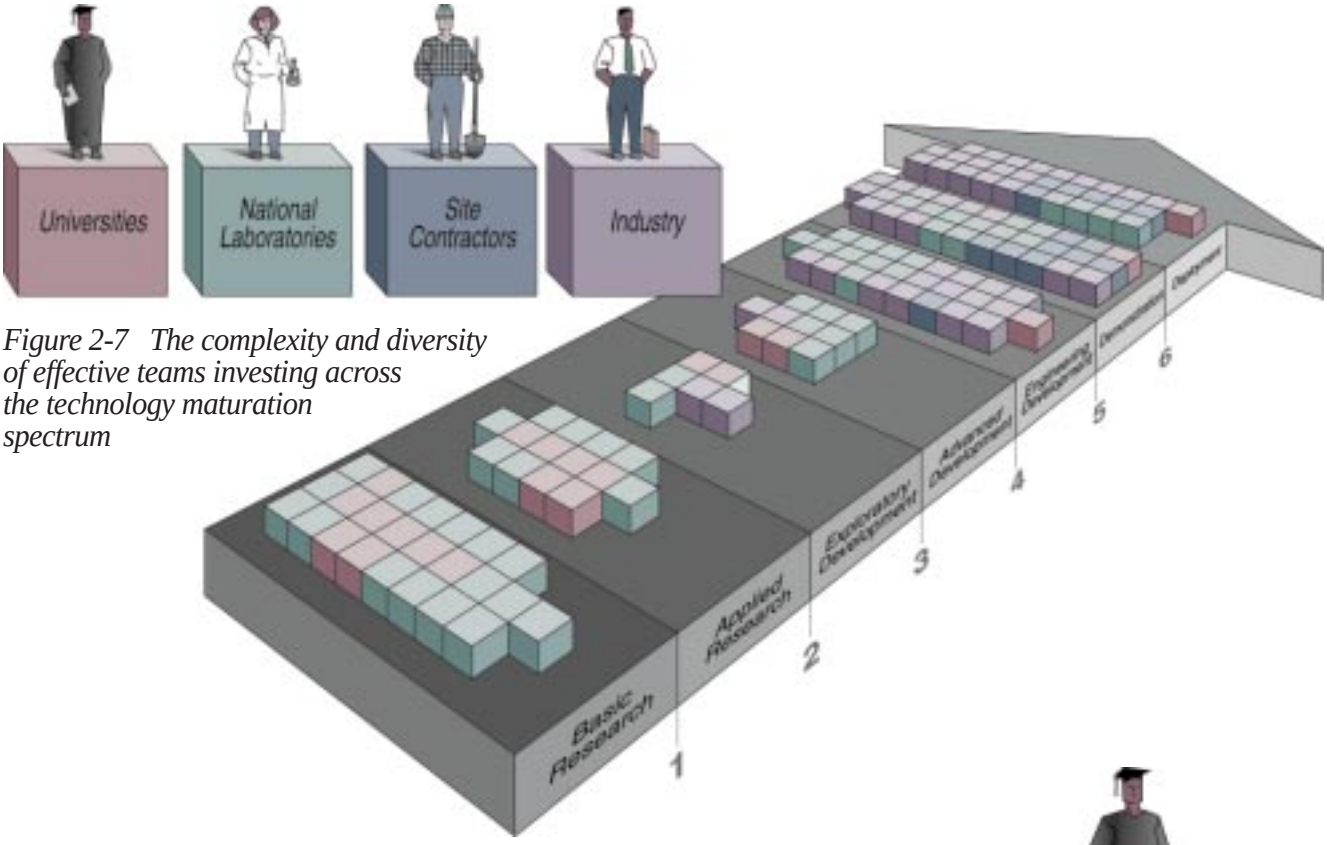
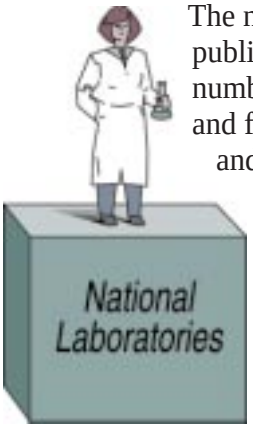


Figure 2-7 The complexity and diversity of effective teams investing across the technology maturation spectrum

Universities

The Nation's colleges and universities provide an extremely valuable reservoir of science and technological expertise. The breadth of science and technology expertise of these institutions complements the depth of the Department's national laboratory system. While only about eight percent of the portfolio is actually conducted at universities, the graduates of these institutions are a major source of technical and scientific personnel entering the laboratory system.

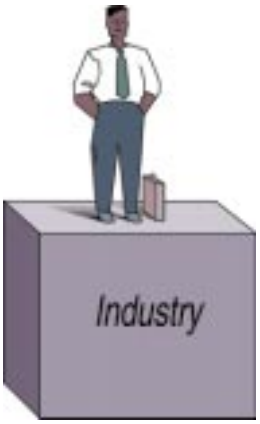
National Laboratories and Federal Facilities



The national laboratories and federal facilities provide a significant portion of the publicly funded scientific and technological infrastructure of the United States. A number of special and unique capabilities and resources exist within this laboratory and facility system that are essential to achieving the cleanup mission. The hot cells and canyons for handling and manipulating highly radioactive materials are unique. These are the only facilities capable of demonstrating and testing technologies that treat or handle high activity sources. Another resource the laboratories and facilities provide is a test bed where demonstrations on "hot" or contaminated materials can be conducted within regulatory constraints and permits.

Site Contractors

The site contractors provide critical operational expertise and in-depth understanding of the challenges associated with the cleanup tasks. Usually the business lines of large corporate enterprises, they operate many of the unique facilities of the Department's complex and help define and maintain an operating space within the regulatory environment in which to demonstrate new technologies and perform cleanup activities. This ability to provide "test beds" for demonstration projects and to aggressively deploy new technologies is an essential component of the EQ R&D enterprise.



Industry

As development efforts mature and move to demonstration and deployment the activity shifts from the laboratory to the site contractors and industry as the primary performers and partners. As previously noted, the government must support research and development to fill technology voids that the private sector will not or cannot fill. Though both the public and private sector can, and do develop technologies, only private sector companies can commercialize technologies and make them widely available. A significant part of the partnering activities between industry, the laboratories, and site contractors is the attempt to reduce the financial and technical risks in moving environmental technologies beyond demonstration to widespread deployment. Recent efforts in this area have resulted in the commercialization of a large number of environmental technologies. Over 125 companies, located in 32 states and Canada, have commercialized over 140 different environmental technologies. These technologies range from detection and characterization, to remediation and treatment, to robotics, to stabilization and immobilization. The majority of these commercial technologies are being used to support the cleanup mission.

Potential to Leverage Investments with Industry

The investment areas differ considerably in the amount of external investment by industry. The environmental remediation and deactivation and decommissioning investment areas have large industrial counterparts in the United States. The total national site remediation industry is about $6 billion a year, of which the combined contribution of the Department of Energy and the Department of Defense is about $2.8 billion. The deactivation and decommissioning investment area has a

Table 2-2 Private Sector R&D Leveraging is Dependent on the U.S. and Global Market

The 1996 global market for environmental goods and services was about $453B (Environmental Business Journal, 1997). The United States has the largest segment of that industry at about 40%, or $181B. The U.S. environmental industry is composed of two general areas—public infrastructure services (such as potable water, wastewater treatment and municipal waste management) and environmental site cleanup. The latter area grew rapidly in the early 1990's following a period of new and significant environmental legislation. However, growth has slowed and actually decreased over the past five years even though the DOE and DOD remediation expenditures have increased. A characteristic of the industry trend today is a rise in remedial construction as a proportion of total spending while site assessment work has decreased. This trend away from studies and toward actual cleanup is likely to increase.

similar industrial counterpart for the deactivation and decommissioning of commercial nuclear power plants. The potential to leverage R&D investments in these areas is reasonably high.

In contrast to these areas, the high-level waste and transuranic waste investment areas have virtually no industrial counterparts and only limited potential to benefit from external investments. This is because the Department is the sole customer for technology in these areas. Therefore, larger federal investments in these areas are required to achieve comparable technology advancements.

Note that there is a significant contribution made by the commercial nuclear utilities for the preparation of the geological repository that will house the Nation's commercial spent nuclear fuel as well as the high-level waste and spent fuel of the Department. Some of this funding supports current efforts to explore Yucca Mountain as the disposal site.

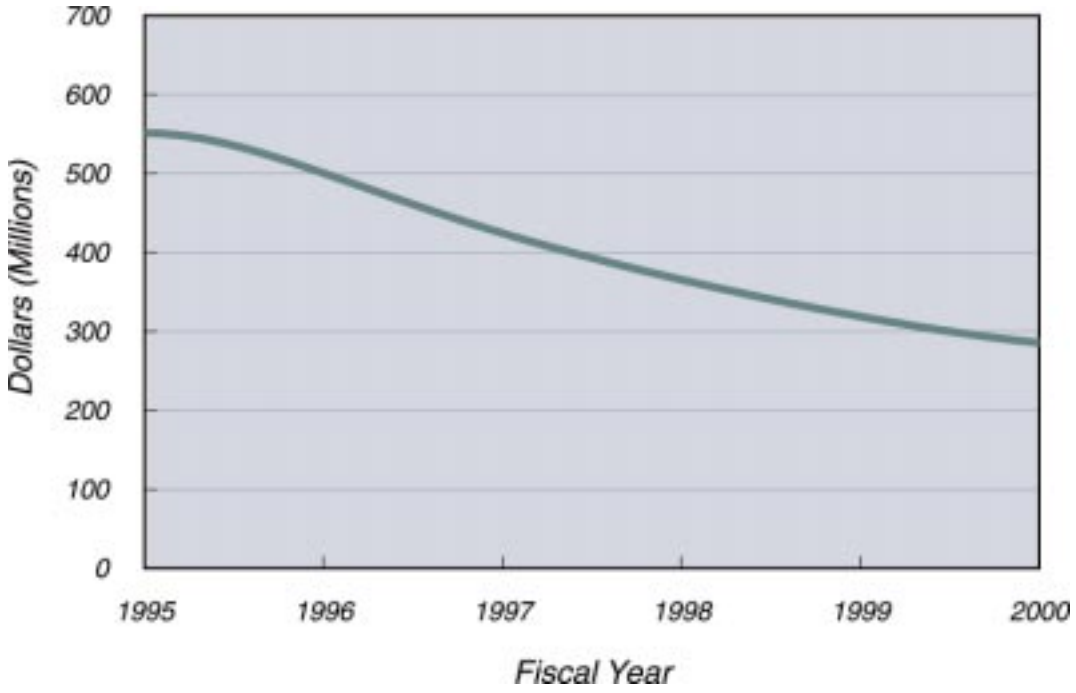
Decline of the Environmental Quality R&D Portfolio

This section of the portfolio analysis looks at the breadth or scope and depth or robustness of the overall investment trend within EQ as well as the trends within selected investment areas. While the Department has only recently started to analyze and manage its R&D activities within the four business line portfolios, it is informative to broaden the trend analysis outside the timeframe of the current portfolio. The trend is downward and approaching a level that may not be able to support an effective, long-term Environmental Quality mission.

Overall Trend for the EQ R&D Portfolio is Downward

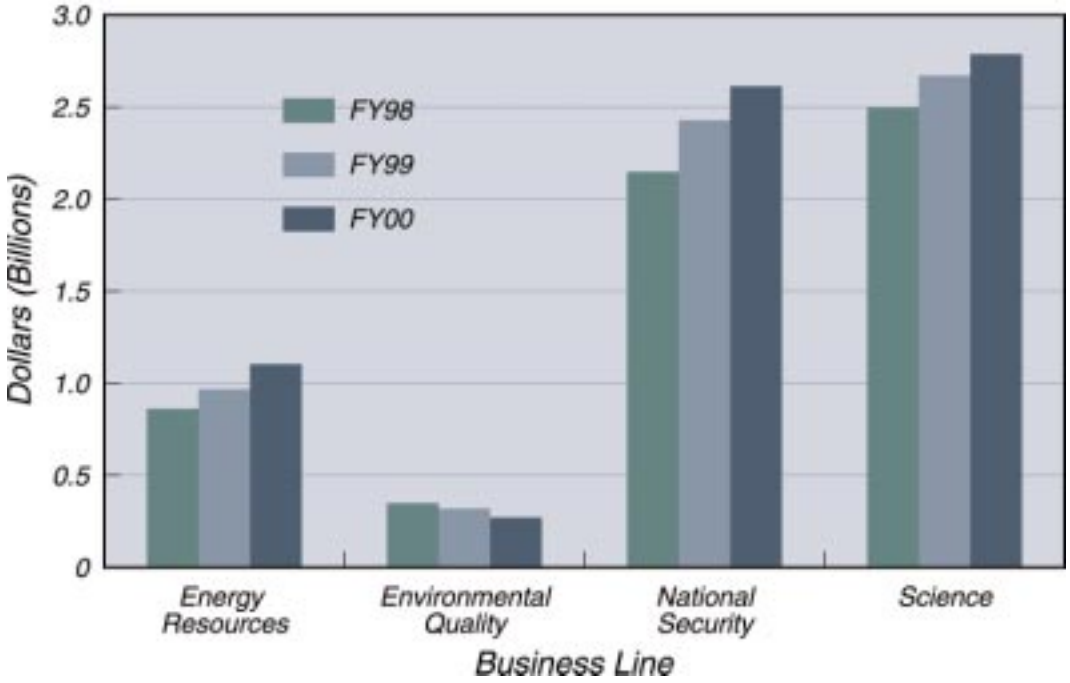
The portfolio, as currently defined by the framework, is estimated to have peaked in the mid-1990s at roughly $550 million and has declined to its current level of about $280 million—a 50% decrease in five years. This decline is depicted in Figure 2-8 and is in contrast to the growing set of needs and issues defined by the cleanup sites that the portfolio must address.

Figure 2-8 EQ R&D Portfolio Funding Trend



The decline stands in contrast to the funding increases shown in Figure 2-9 in the other Department business line portfolios.

Figure 2-9 Business line R&D Portfolio funding levels FY98-FY00



Trends within the Environmental Quality R&D Portfolio

While the overall funding trend for the portfolio has been downward there have been several changes of significance within the individual investment areas. Three-year funding levels (FY98 through FY00) are shown in Figure 2-10. These changes have been driven primarily by progress in the Department's cleanup efforts but also reflect the formation of new offices (e.g., the Office of Fissile Materials Disposition) and changes in Departmental policy (e.g., acceptance of foreign research reactor spent fuel).

Over the last few years the portfolio has invested heavily in solving problems associated with mixed waste and contaminated soil and groundwater. In the mid-1990s each of these investment areas received roughly $100 million a year. These large investments were driven by regulatory milestones in Federal Facility Compliance Agreements. That is, a large number of records of decision had to be made for mixed waste treatment and environmental remediation. To best prepare, the Department tried to prepare a range of technical options. In the year 2000, the mixed low-level waste investment will drop to $40 million and environmental remediation will stabilize at around $60 million per year. Environmental remediation research and development is continuing despite active remediation. This is primarily due to the need to reduce the costs of long-term environmental stewardship and provide options in case of near term failure of remedies already selected. A concern in this area is the relatively large decline in recent years of external investments in environmental remediation, making it increasingly difficult to leverage the portfolio's investments.

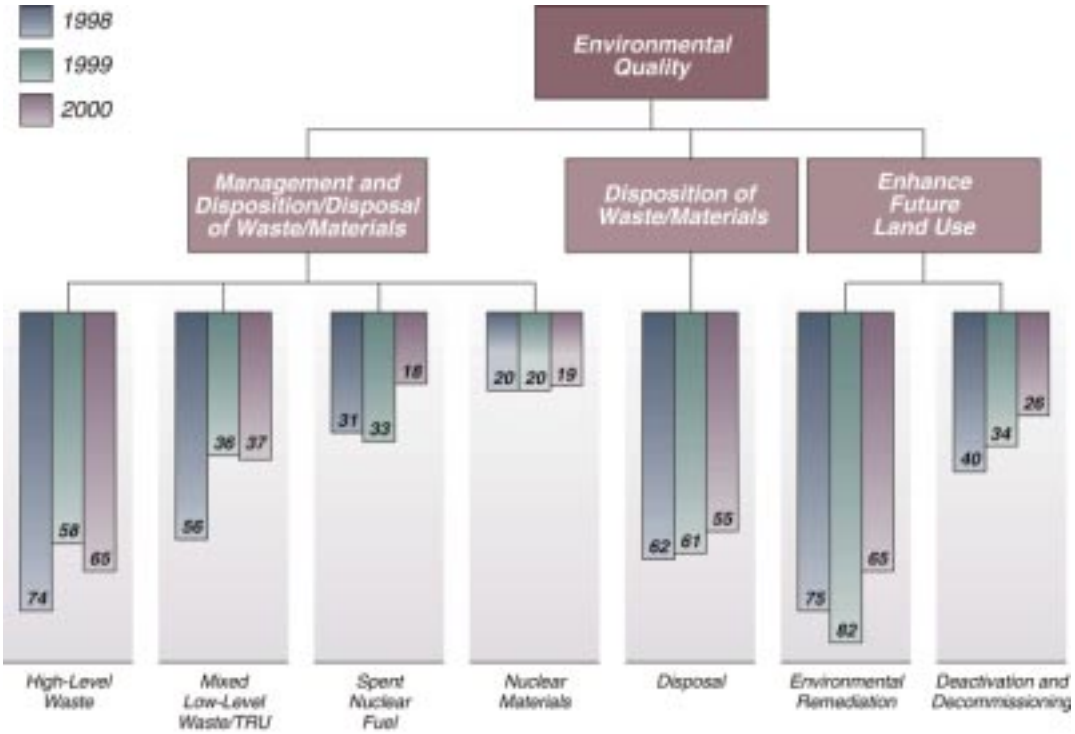


Figure 2-10 Three-year funding levels and trends

The trends within the portfolio reflect efforts to balance multiple priorities. While the Department aggressively pursued improvements in the treatment of mixed waste and contaminated soils and groundwater, there were smaller but steady investments in the longer term and higher cost cleanup efforts associated with the management of high-level waste and the management and disposal of transuranic wastes. Note that the R&D associated with the disposal of high-level waste is included in the disposal section. Technical uncertainties and costs associated with high-level waste and transuranic waste dominate the Department's cleanup profile after 2006.

The trend in D&D funding is sharply downward in direct contrast to the increasing need in the commercial sector for D&D technologies. A commitment to a longer-term view would provide the basis to achieve considerable leveraging with the private sector, which would be mutually beneficial.

Research and development funding for disposal is slightly downward, reflecting the progress achieved toward reducing uncertainties on long-term performance of disposal systems. The funding in this area is expected to continue to decrease as the program moves to submission for licensing and subsequent construction and operation.

Funding decreases justified on the basis that cleanup is progressing and the 2006 cleanup mission is partially complete ignores the fact that costly, difficult and complex cleanup problems have not been addressed. It is likely that R&D funding as a percentage of EM's annual budget, may have to actually increase to solve the remaining technically complex and difficult challenges. Increased funding would also allow parallel development of alternatives, which can minimize the risk of failure of single point-solutions to large, expensive projects. Experience with several large remediation projects such as Pit 9, In-Tank Precipitation, etc., highlights the need to invest in alternative approaches and technologies.

Understanding the Department's Investment in Environmental Quality

With the exception of the Science R&D Portfolio, there are multiple participating programs or offices within each business line portfolio, . The relative size of individual program contributions to the portfolios and the relative size of each portfolio are illustrated in Figure 2-11.

Funding for the EQ R&D portfolio for Fiscal Year 2000 is $284 million. This investment is roughly 4% of the Department's overall research and development investment and makes the portfolio the smallest of the four business line portfolios (Figure 2-12). While Environmental Management and the Office of Civilian Radioactive Waste Management (the major contributors to the portfolio) make up roughly 40% of the overall Department budget, a relatively small share of that budget is devoted to R&D (Figure 2-12).

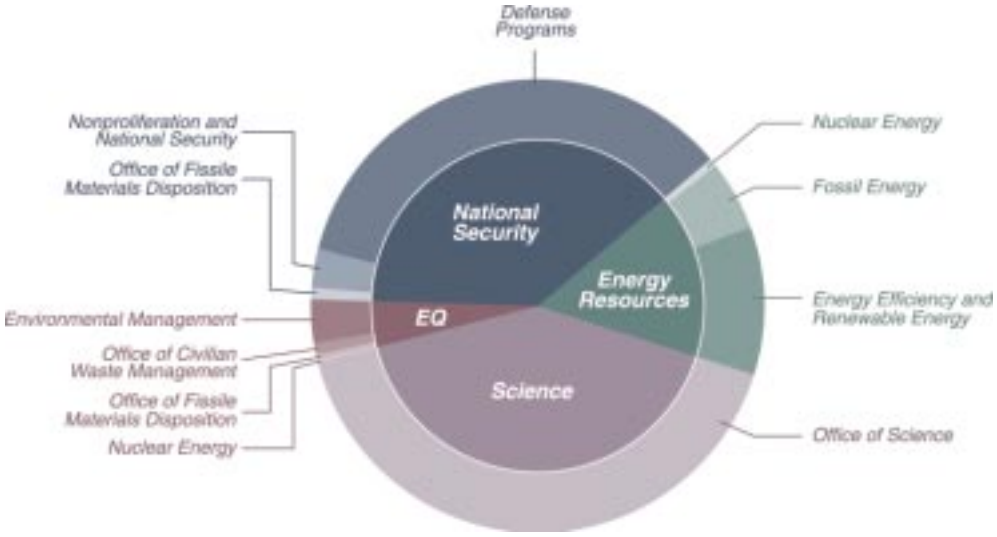


Figure 2-11 Relative size of Business Line R&D Portfolio Budgets and Business Line Participants

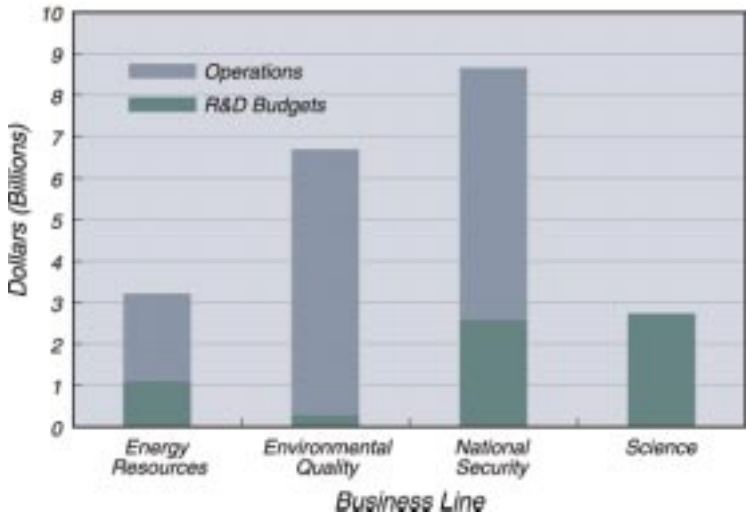


Figure 2-12 Relative size of Business Line and R&D Portfolio Budgets

Building a Strategic Portfolio

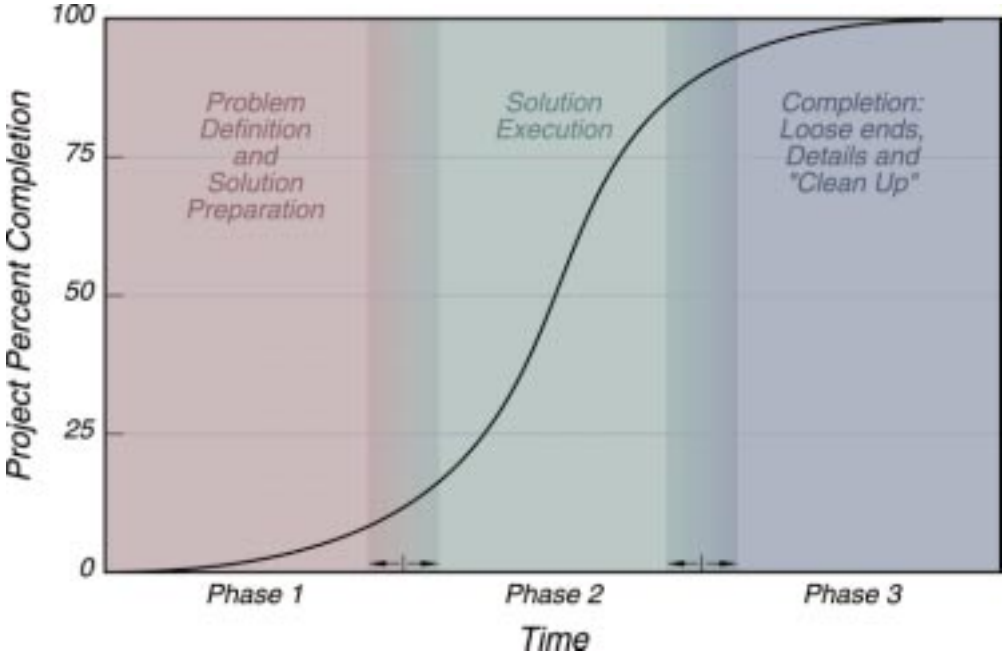
The direction and evolution of the Environmental Quality R&D portfolio will occur within two major contexts. The first context is the existing investment framework; the narrow, highly focused effort to meet the challenges of the nation's nuclear legacy. Incremental, evolutionary change will occur as the portfolio responds to the changing nature of the cleanup mission. Leveraging the Department's investments to encompass the broader range of specific national environmental challenges creates the second context. The response to this challenge may require a revolutionary, rather than evolutionary change in the portfolio framework.

Incremental, Evolutionary Change—Focus on Supporting Cleanup

The life cycle of individual cleanup activities and of the cleanup program in aggregate can be characterized by three general phases. The primary science and technology needs of each phase are different. The research and development investments supporting the program must also reflect those changing needs. An understanding of the current state and rate of progress of the cleanup program is fundamental to planning future R&D investments.

The three phases, illustrated in Figure 2-13, are: problem definition and solution assessment and preparation; solution execution; and completion. The first phase includes defining the problem as completely as possible, identifying a set of potential solutions, selecting the best solutions, and assembling or constructing the necessary tools, hardware and processes to implement the solution. In the second phase the primary solutions are executed. Most of the visible progress of the activity or project occurs during this phase. Typically 80 to 90 percent of the project objectives are achieved

Figure 2-13 The three phases of program and project activity



during the second phase. The final phase completes the final details and "loose ends" that arose during the second phase. Details and loose ends include the minority wastes, materials, and other exceptions that were not amenable to the primary solution due to some special characteristics (physical, chemical, political, etc.). The final phase also includes cleaning up and putting away the tools (e.g., facilities and hardware) used to execute the solution.

The science and technology required to support each phase is different. The first phase requires a solid scientific basis in order to completely characterize the problem and a strong technology base from which to draw alternative solutions and optimize the solution path. Science and technology roadmapping is an important tool to be used during this phase to analyze the maturity and robustness of the science and technology supporting this phase. Research and development investments must be sufficient to maintain the supporting scientific and technological infrastructure. Investments across the full research-deployment continuum are needed, although additional emphasis must be placed on research and on the development and demonstration portion of the continuum to support this phase. In the solution execution phase science and technology support focuses on improvement of operational efficiency and the support required to solve the inevitable problems that escaped identification in the first phase. Again the entire research-deployment continuum supports this phase, however additional emphasis is required at the beginning and end (research and deployment) of the continuum to improve understanding of the problems that arise and provide the technical support to deploy technologies in a way to resolve these problems. The final phase is characterized by the need for better definition of the special problems remaining and identifying new solutions. The problems remaining in the third phase represent only a small portion of the total cleanup problem, but they present the greatest scientific and technological challenges.

The complete cleanup program is comprised of projects that are in different phases of completion. Currently, many small sites are in the final phase, while most of the largest sites are still in the initial phase. Operations for several waste types are underway across the complex, while design and construction of major facilities is underway for other disposition paths. The current portfolio framework is acceptable for developing incremental evolutionary changes to address varying states of program maturity.

Revolutionary Change—A Strategic Portfolio for the 21st Century

As the nation moves into the 21st century it is appropriate to reevaluate the Department's strategic goals and objectives. This is particularly true in the case of the Environmental Quality business line and the nation's environmental challenges. The evolving activities of the current portfolio coupled with known and emerging environmental issues suggests a new framework for the portfolio. The new framework would continue to support the weapons complex cleanup and the disposition of commercial spent fuel, but could do more. The framework could encompass the full range of responsibilities within Environmental Quality—provide the technologies and institutions to solve domestic and international environmental problems. A potential framework is illustrated in Figure 2-14.

This framework is built on four key areas: sustainable development, materials management, resource enhancement, and environmental stewardship. While many of these investment areas are simply an extension or expansion of existing work, some are new. The vast majority will need to be explored

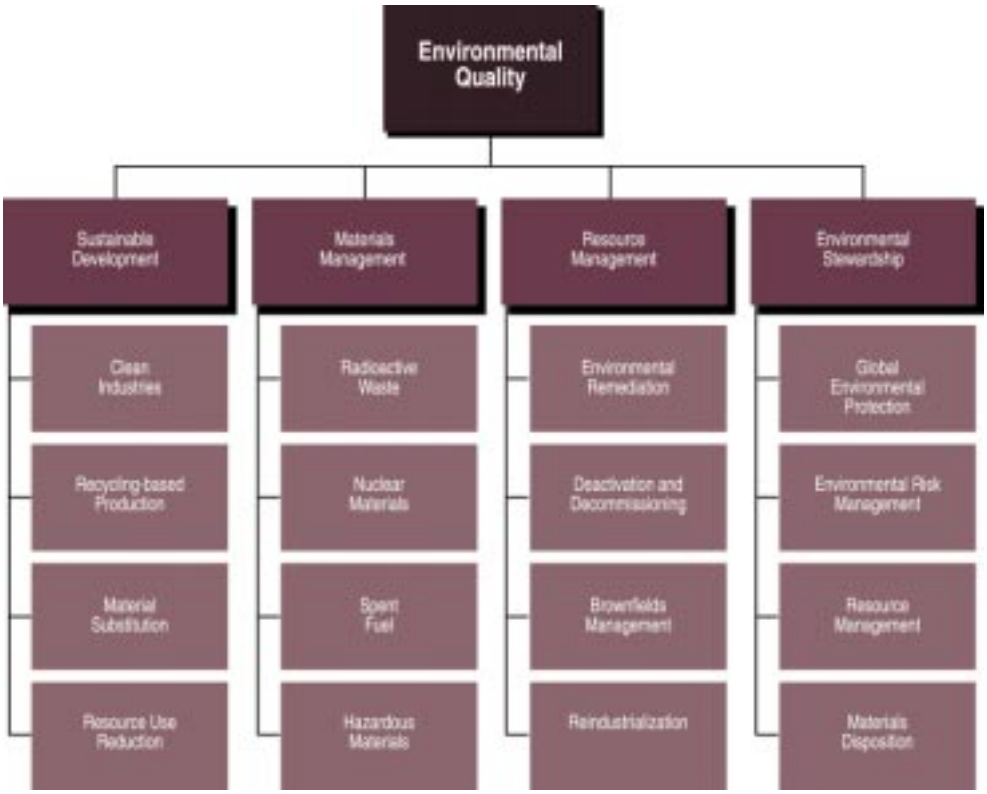


Figure 2-14 A Potential Environmental Quality Portfolio Framework for the 21st Century

and refined through the Department's strategic planning process. A summary of the proposed framework is provided in the remainder of this chapter.

Sustainable Development

Achieving sustainable development requires change to occur in a number of areas. Some of these areas, e.g., societal and political, are affected by technological advances but are certainly not driven by them. Within the context of Environmental Quality business line, we are focused on the environmental component of sustainable development.

The Department is currently investing in sustainable development research and development. These investments include: the clean industries component of the Energy Resources portfolio as well as many of the investments aimed at more efficient energy use. There are also a limited number of investments within the current portfolio, e.g., electronics recycling and other pollution prevention activities. However, these investments are limited in scope and may not support the nation's needs into the 21st century.

Additional investments focused on areas such as recycling based production, material substitution and the reduction in use of our nonrenewable resources without sacrificing our quality of life are critical. Increased population growth coupled with higher standards of living are placing an increasingly large burden on our local and global environments. Managing these demands will require scientific and technical advances. We must find a way to invest to make these advances to provide our nation with viable options well into the 21st century.

Materials Management

Investments in the management of waste and materials will continue well into the 21st century. There will continue to be large quantities of radioactive waste. New waste will be produced as environmental restoration activities proceed and facilities are deactivated and decommissioned. Nuclear materials from nuclear weapons inventories will still require safe management and disposition. Management of spent fuel from commercial nuclear power plants, research reactors, navy nuclear reactors, and the Department's production reactors will continue to be the responsibility of the portfolio.

A new addition to the portfolio might be the management of hazardous materials. Current handling and disposal of hazardous materials is expensive and time consuming, particularly for small generators. While efforts to substitute new materials will reduce the number and volumes of hazardous waste streams, this problem is not going away quickly. More effective management of these materials can reduce direct costs and reduce the potential for long term liability.

Resource Management

The Department will continue to invest in R&D to meet environmental remediation and facility deactivation and decommissioning needs. However, the current focus on the Department's liabilities will need to be expanded. Past, as well as some current, solutions to environmental contamination will have limited lifetimes. The use of engineered disposal facilities and caps and barriers to stabilize contaminated soils and groundwater is a valid approach. However, long-term success is dependent on the integrity of the disposal system. While the new systems are better engineered, these systems will ultimately fail and may need to be replaced depending on residual risk.

Large numbers of commercial nuclear power plants and research reactors are scheduled to be deactivated and decommissioned during the first few decades of the 21st century. The cost of these activities will be passed on to the customers of the utilities and the institutions currently maintaining these facilities. A new framework could focus more aggressively on reducing those costs and increasing the safety of the myriad of workers those efforts will require.

Brownfields management and reindustrialization are relatively new approaches but they may increasingly reflect reality as sites are remediated and facilities turned to new uses. Working and living in either close proximity to or within these areas and buildings will require changes in the way we think, dress, and act. If we invest properly, the impact of these changes can be minimized through scientific and technical advances.

Environmental Stewardship

Many aspects of environmental stewardship are just beginning to receive attention. A significant element of environmental stewardship is the long-term stewardship aspect of the cleanup mission.

With respect to the cleanup mission, stewardship has a very specific meaning. Because it is not possible to completely eliminate all the hazards presented by the wastes and materials encountered in the cleanup mission, these wastes and materials are mitigated to an agreed-upon acceptable level reflecting a balance of risk, cost, stakeholder values, regulations and technology capability. It is then necessary to provide an adequate level of protection to human health and the environment from the hazards that remain. For example, we must ensure that disposed or isolated wastes or hazardous materials do not "escape" their protective containment. These activities are called long-term

stewardship, and are complementary activities that transition from cleanup without discontinuity. The four phases of cleanup-stewardship are:

- Achieving the best possible end state (based on best available technology),
- Verifying the end state is achieved,
- Demonstrating end state integrity is maintained and predicting and detecting potential end state failures, and
- Quickly and effectively "re-remediating" a failed end state.

The relationship and technology requirements of these phases of the cleanup-stewardship endeavor are illustrated in Figure 2-15. Because this involves activities that have never been done before, there is a high degree of uncertainty. Significant investments in research and development will be necessary to provide adequate support. Environmental risk management, resource management, and materials disposition are all significant elements of long-term stewardship. Each of these has unique aspects that make them separate, significant components of environmental stewardship.

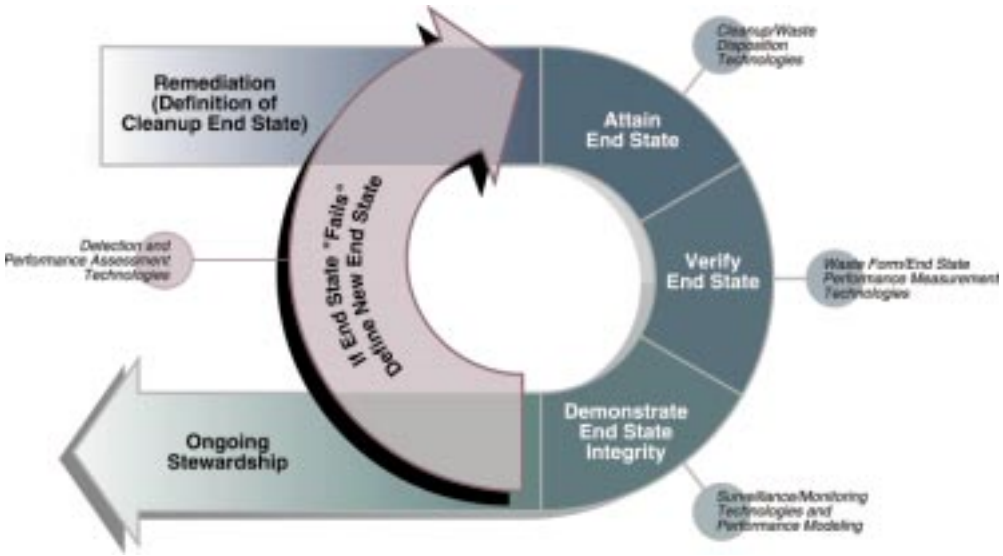


Figure 2-15 Science and technology to support long term stewardship

Long-term stewardship is usually associated with the local or regional environment. However, global environmental protection is an environmental quality issue that affects everyone. In this case stewardship has the more common, broader meaning of exercising responsible care and use of the global environment. Investments are being made by the Department in this area. Within the Science Portfolio we are investing to improve our understanding of global warming. The Energy Resources Portfolio is aimed at reducing the environmental impacts of energy generation and use. Within Environmental Quality we need to look at those research and development activities that can provide better understanding of both the robustness and fragility of elements of the global environment. These investments can support the development and implementation of appropriate national and international agreements and of more environmentally friendly production and economic development.