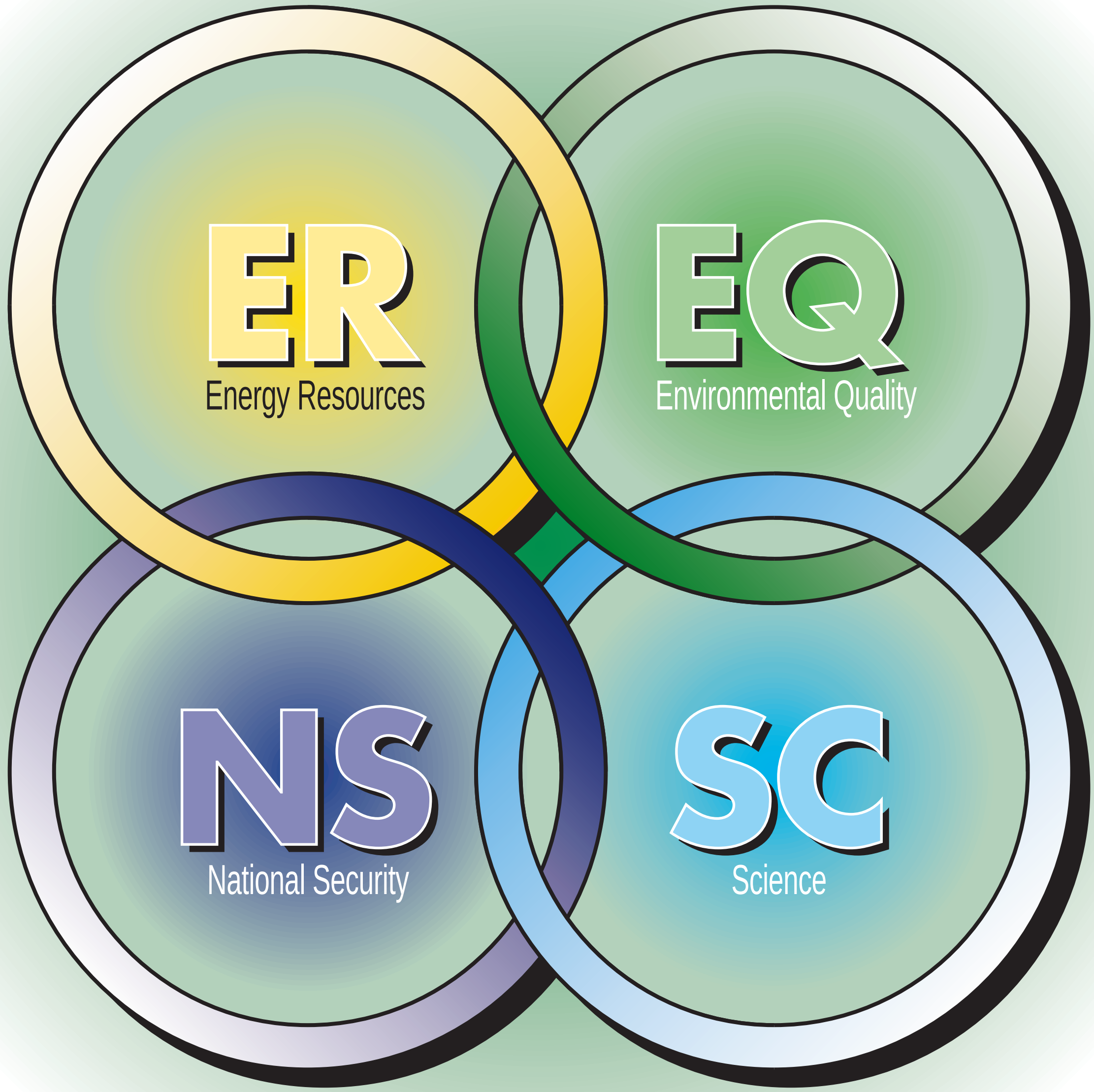
DOE Research and Development Portfolio

Overview

February 2000



U.S. Department of Energy

DOE Research and Development Portfolio

Overview

February 2000

U.S. Department of Energy

Department of Energy
Washington, DC 20585

February 2000

(Cover letter goes here.)

Foreword

"The Department of Energy has many missions,
but its heart and soul is science."

—Secretary Bill Richardson

The Department of Energy has the responsibility to operate and manage a large portion of the Nation's scientific and technological infrastructure. That infrastructure supports the discovery of knowledge and the expansion of technological innovation that helps to ensure national and economic security and environmental integrity into the 21st Century. Today, the Department of Energy is one of the Nation's largest sponsors of basic and applied research and development (R&D) and serves as host to thousands of academic and private sector scientific investigators.

The planning and management of the R&D investments supporting this R&D enterprise is a challenging responsibility. To better fulfill this responsibility the Department has begun developing and implementing a new, comprehensive portfolio approach to the planning and management of this R&D enterprise. The development of this set of DOE Research and Development Portfolios not only provides a complete and comprehensive picture of this $7 billion annual R&D enterprise, but does so within a coherent, strategic context, not beholden to organization or programmatic lines.

In 1997 the Department published the *U.S. Department of Energy Strategic Plan — Providing America with Energy Security, Environmental Quality and Science Leadership* (September 1997). This Plan organized the Departmental strategic goals according to four business lines: Energy Resources, Environmental Quality, National Security, and Science. These business lines comprise the four major mission foci, through which all the Department's activities are directed and provides a comprehensive, integrated context within which the programs and offices manage and execute their mission responsibilities.

The Department's new portfolio approach and methodology for managing its R&D investments is set within the context of the *Strategic Plan* and is designed to show how these investments support the goals of each of the four business lines. A major aspect of the new approach has been the publication in 1999, with an update in 2000, of business line R&D investment portfolios. An R&D portfolio has been prepared for each business line. Each business line R&D portfolio describes the goals, strategies for accomplishing these goals, and the highest priority R&D needs supporting these strategies. Each business line integrates the capabilities, policies and requirements of all related programs of the Department and its national laboratories. The four business line R&D portfolios together comprise a comprehensive Departmental R&D portfolio.

Table of Contents

Science, Environment, Energy and Security: A Balanced Investment for the 21st Century

"In the new century, innovations in science and technology will be the key not only to the health of the environment, but to miraculous improvements in the quality of our lives and advances in the economy."

— *President William Jefferson Clinton, State of the Union Address (January 27, 2000)*

Chapter 1

Portfolio Description and Development

It has often been said that the only constant is change. While change may be constant, progress is achieved only when change is directed toward defined goals and objectives. Innovation, which is the ability to direct change based upon a strong scientific and technological infrastructure, is a characteristic strength of this Nation. The Department of Energy exercises stewardship responsibility for the scientific and technological infrastructure that supports the innovation that has created our national and economic security and environmental integrity. Today the Department of Energy is one of the largest sponsors of basic and applied research and development for the Nation.

In 1999, the Department initiated a Research and Development (R&D) Portfolio management approach to integrate and strengthen the planning, management and administration of this $7 billion enterprise. The Department's complete R&D portfolio is described in a four volume set comprised of one volume for each business line. In addition, this Overview provides a top-down summary of the entire R&D Portfolio. It describes the background and rationale for the Department's investments in research and development and some of the resulting benefits to the Nation. It also describes the new approach to R&D management that is being implemented through the development of the R&D portfolio and provides a description and overview of the individual business line portfolios (Chapters 3-6). Chapter 2 of this volume provides an analysis of the Department's R&D investment portfolio.

The general structure and format of each business line portfolio is illustrated in Figure 1. The portfolio volumes are structured according to the four business lines, rather than according to DOE programs and offices. The participation and contribution each program or office makes to each business line portfolio is indicated in the business line portfolio. The program description of the R&D areas identifies science and technology needs, and the relevance and drivers of R&D activities. Specific R&D areas are described and the appropriated FY99, FY00, and requested FY01 funding levels for each R&D area are indicated. Key accomplishments are described and an analysis of investment trends provides a short-term picture of the general direction investments in each R&D area have taken.

Background

Successes: The Department's demonstrated performance

Scientific discovery and technological innovation in the last half-century have spurred widespread institutional and societal changes and inspired a new age of economic opportunity and promise. Advances in technology have increased our ability both to recover natural resources and to leverage and expand their conversion to products that continually expand the Nation's economy. Research at the Department of Energy has enabled our Nation to harness the power of the atom for securing our national interests, for powering our cities and industries, and for developing innovative medical tools to help diagnose and cure innumerable diseases. Research at the Department of Energy has also helped to unlock the mysteries of the quark, the building block of matter; and to map the labyrinth that is the Human Genome, the building block of life. The Department's scientists and engineers have also succeeded in developing fundamentally new energy sources to support our continued

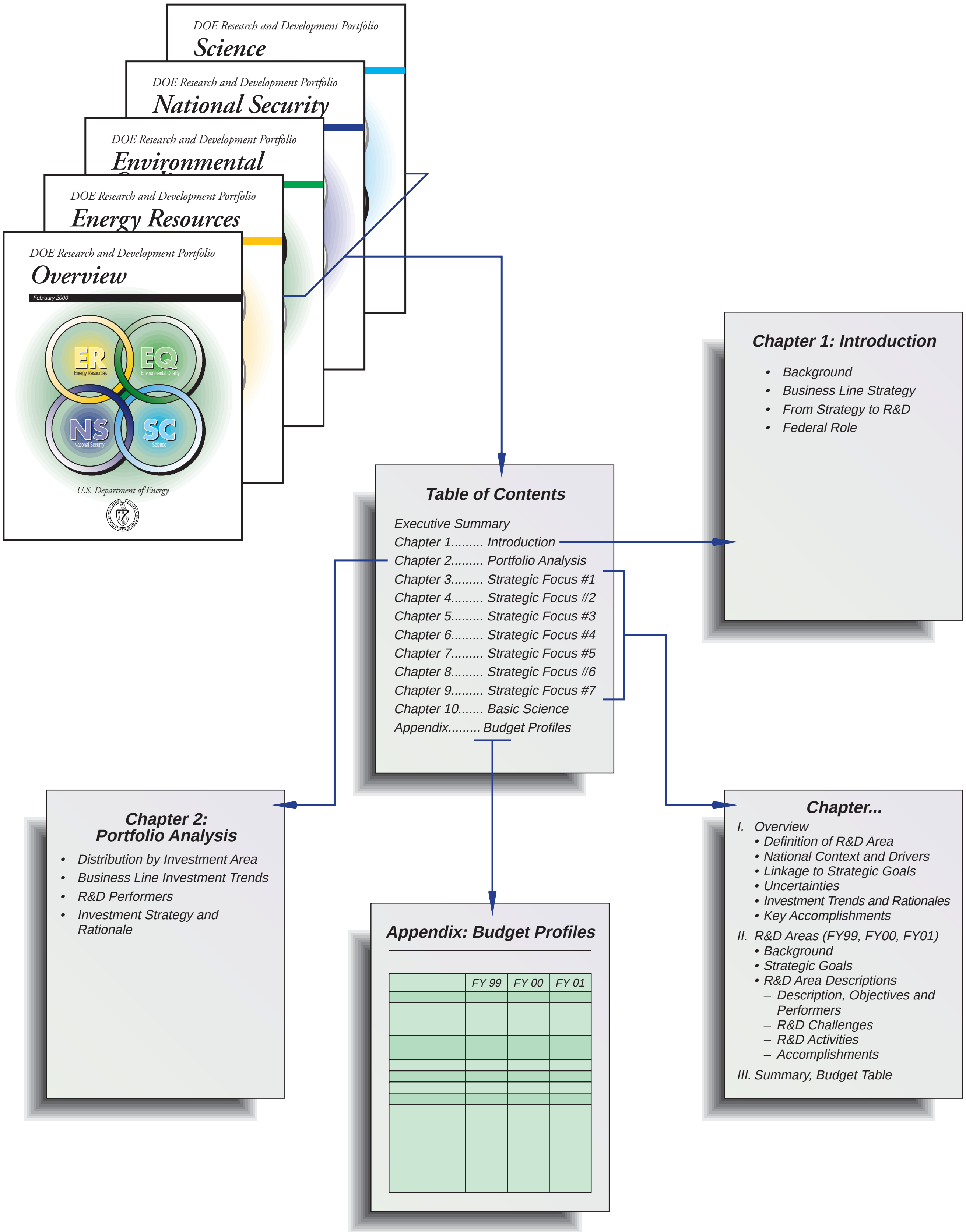


Figure 1. Portfolio Structure and Format

economic growth, and have invented new technologies for using cleaner energy and using it more efficiently. The Department's scientists and engineers have contributed significantly to the development of super computers, life sciences, human genomics, nanotechnology, and super efficient and clean energy using technologies.

Challenges: The Department's unique and critical mission

As we enter the 21st Century, our Nation faces new challenges that will require new knowledge about the world in which we live, greater understanding of the forces that rule the physical world and new innovations to solve the complex problems of today and tomorrow. For example, with at least 20 countries known to be or suspected of developing weapons of mass destruction, we will need new tools to ensure the accountability, control, and disposition of weapons, components, materials and information. Similarly, with the world population growing, and global economic activity continuing to expand, we will need new sources of energy to power U.S. economic growth into the 21st Century. At the same time, because energy use is the largest contributor to environmental impacts and waste production, we must also develop technologies and new processes that minimize and even reverse the harm energy production and use can exact on the land on which we live, the water we drink and the air we breathe.

Providing Solutions: The Department's resources, capabilities, and responsibility

Research and development provides a systematic approach to solve complex problems and stimulate innovation. The Department of Energy is the agency responsible for solving some of our Nation's largest problems associated with national security, energy resources, and environmental quality. The Department also sponsors the underlying science and technology that supports research in these mission areas and leads to the innovation to develop the tools we need to solve the problems of the 21st Century.

> "The foundation of this Agency is its scientific mission."
> —*Secretary Bill Richardson*

There are compelling reasons for federal investment in R&D. With the current emphasis on short-term R&D in the private sector, it is incumbent upon the Federal government to support the long-term basic research essential to sustaining innovation and understanding as we move into the 21st Century. Also, in several critical areas there is no incentive for private sector investments because there is no market beyond the federal system. Or, in many cases, the problems are too large, or complex, or risky, for individual firms to try to solve alone, without federal leadership and support. Similarly, though there are many secondary private sector applications of technologies developed to secure and ensure our national security, it is incumbent upon the federal government to make the necessary R&D investments to ensure that the necessary technologies and knowledge are available to support these needs.

New Approach and Methodology

In 1994, the Department of Energy published its first strategic plan (*Fueling a Competitive Economy*, April 1994) and in 1997, published the first update (*U.S. Department of Energy Strategic Plan — Providing America with Energy Security, Environmental Quality and Science Leadership*, September

1997). This updated Strategic Plan organizes the Departmental strategic goals according to four strategic business lines:

- Energy Resources,
- Environmental Quality,
- National Security, and
- Science.

It is important to understand that the business lines are not administrative or organizational elements. They are the four major mission foci through which all the Department's activities are directed. They provide a comprehensive, integrated view of the Department's programs and offices. The business lines have no funding per se; they provide the context within which the funded programs and offices manage and execute their funding. The extensive, diverse R&D investments and activities of the Department must be planned and managed to maximize the support they provide to these four business lines.

The underlying management philosophy of the Department's R&D portfolio is to view the entire portfolio as an integrated system of R&D requirements, activities and performers, all driven by and focused upon achievement of the Department's goals and strategic objectives. The Department has initiated three actions to improve the management of its R&D enterprise and facilitate greater innovation in pursuit of National strategic goals:

- Revitalize R&D oversight and coordination functions,
- Implement a new portfolio management approach, and
- Institutionalize programmatic and technology roadmapping as a planning and decision tool.

Steps Taken

In addition to this new portfolio approach and methodology, several initiatives have been undertaken to assert more effective oversight and coordination of the Department's R&D investment portfolio planning and management process. The R&D Council, composed of the Assistant Secretaries responsible for R&D, and chaired by the Under Secretary, has been activated, and charged with a number of oversight and analysis activities. Input by the Laboratory Operations Board has been requested. The Directors of the Department's National Laboratories have been asked to become more engaged in providing input to the portfolio management process. In addition, individual business lines have established appropriate external and expert review processes and mechanisms through which technical input is received.

In FY 1999, an R&D portfolio was prepared and has been updated for FY 2000, for each business line. These portfolios define the R&D needs that must be met to accomplish the strategic program goals of the Department. Each business line portfolio integrates the capabilities, policies and requirements of all the Departments programs and laboratories relevant to that business line. These portfolios have provided the basis for a number of additional, strategic level reviews.

Programmatic and technology roadmapping is being instituted as a planning and decision tool to develop and execute a balanced R&D portfolio in future years. Technology roadmaps derive from the needs of the programs. They help define what is known and what future R&D and technology programs are needed to accomplish specific program objectives, and help communicate technological needs and expectations between science and technology users and the R&D community.

Just as we use a conventional atlas and geographic map to travel in geographic space, programmatic and technological "atlases" and "roadmaps" can be used to help chart the best routes through programmatic and technological space. In this sense roadmapping is used to identify programmatic and technological barriers, challenges and opportunities the business lines will encounter as they work to accomplish their mission objectives. Barriers and challenges create the risk of not accomplishing the mission, while opportunities provide the basis to excel. The roadmaps thus become central planning and decision tools in the development of the R&D portfolios.

Technology roadmaps help define the level of maturity of science and technology that will be needed in the near-, mid- and long-term (e.g., 1-2, ~5 and ~10 years in the future) to meet the projected needs of the business lines. An understanding of the maturity level anticipated in various science and technology areas provides a basis for determining the R&D investments that will be required to give reasonable assurance that critical science and technologies will be available when needed. These projections are accomplished through consensus building workshops involving subject matter experts from the laboratories, the Federal Energy Technology Center, academia, industry, business line program managers and stakeholders. The roadmapping process also strengthens technology partnerships between the laboratories, academia and industry, resulting in greater synergy, improved communication of R&D results, and broader application and transfer of technology and significant discoveries.

Portfolio analysis is another initiative embodied in the new approach and methodology. In the analysis of the first portfolio, key questions were posited regarding the strategic goals to be achieved and the adequacy and balance of the portfolio investments needed to achieve them. As a result of those analyses some gaps and areas requiring a shift in focus were identified and are being addressed in the current update of the Department's Strategic Plan. These gaps and refocusing are also addressed in the updated portfolio, represented in significant shifts and new initiatives. Each business line has a unique set of processes to address this aspect of portfolio management.

Results and Conclusions

In this new effort to create a Departmental R&D portfolio, the resulting portfolio provides a baseline upon which integrated, Departmental decisions can be based. It describes where the Department is now and describes the path that has brought us to this current baseline. It is the foundation upon which future planning will be based. This is our first step forward toward a fully integrated R&D planning process, not the last. The next iteration of portfolios will lead to forward looking planning documents, firmly established on the foundation of this baseline.

The preparation of this current set of R&D portfolios is a significant and essential step toward planning and managing the Department's investments in science and technology in a comprehensive and integrated manner. This set of portfolios now provides a complete compilation of the Department's R&D investments aligned according to a hierarchy of strategic goals and objectives, rather than according to organizational stovepipes. Several important results have been achieved by this initial portfolio preparation activity.

The preparation of the portfolio, in conjunction with the revitalization of the Department's internal R&D Council, has provided the agency with a unique opportunity to engage its most senior leaders in meaningful, regular, corporate-level discussions about the R&D portfolio. These discussions have considered the portfolio as a whole, rather than as a composite of separate pieces. It has focused more scrutiny on the strategic objectives of the portfolio and whether or not the R&D investments are adequately aligned to achieve these objectives.

Viewing the Department's R&D activities in an integrated, comprehensive manner has highlighted certain issues about integration, coordination, and collaboration across different programs working on complementary or interfacing goals and objectives. For example, the inextricable link between energy use and environmental quality, clean industries and pollution prevention, and science investments in biological remediation and environmental quality provide significant opportunities to attain greater synergy in R&D investments. The portfolio planning and management process provides a mechanism to identify and achieve these opportunities.

Finally, these portfolios provide both an historical context and status of the Department's R&D investments. They establish a baseline upon which to plan and build the Department's future portfolios and against which to measure progress in effectively planning and managing the DOE R&D enterprise. The focus and clarification of the Department's strategic goals and objectives achieved through the development of these portfolios provides important input to the articulation of the next Departmental strategic plan.

In conclusion, the comprehensive, integrated view and understanding of the Department's research and development investments and the analysis and planning tools presented for portfolio analysis and development have facilitated greater communication and insights. It is our strong belief that continued development and use of the portfolio management process will increase the effectiveness of the Department's research and development activities in supporting our primary mission and objectives.

Chapter 2

Portfolio Analysis

An essential element of the portfolio management process is comparison and analysis of the business line portfolios to obtain a corporate-level view of the balance and integration of the entire R&D enterprise. The business line portfolios are presented by Volumes 1 through 4. The business line and the corresponding strategic objective of the respective volumes are outlined in Table 1.

Volume	Business Line	Business Line Objective
1	Energy Resources	Meeting the Federal commitment to abundant, affordable, secure, and clean energy.
2	Environmental Quality	Making continued progress in cleaning up the environmental legacy of the cold war nuclear weapons program, while minimizing risks to human health and safety.
3	National Security	Ensuring the safety, security, and reliability of our nuclear arsenal, and helping to reduce the dangers of the spread and use of weapons of mass destruction.
4	Science	Ensuring preeminent research and insight into the physical, computational, and biological sciences, and a continued commitment to the underlying infrastructure that will enable remarkable discoveries in the future.

Table 1. Portfolio Volumes 1 through 4

Building a comprehensive, mission-oriented R&D portfolio requires asking the following types of questions:

- Does the allocation of resources match our strategic objectives?
- Are the investments distributed appropriately across basic and applied research, development and deployment?
- Is there an appropriate mix of R&D performers?
- Have science and technology needs and gaps been identified and prioritized?

A number of different analyses of volumes 1 through 4 have been made to help provide answers to these questions and to provide insight into the relevance and balance of the entire R&D portfolio. The analyses presented here compare and contrast the business line portfolios, addressing these questions from a corporate level. In addition, an analysis of each business line portfolio appropriate to the unique aspects of each business line has been performed and is presented in the individual portfolio volumes. The corporate level analyses will be presented next, followed by a brief overview of each business line portfolio.

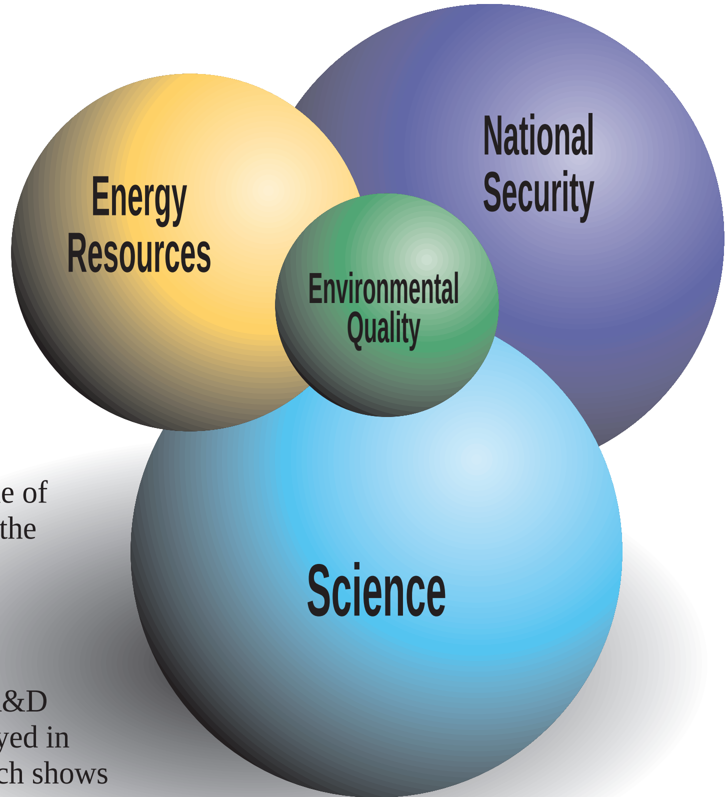


Figure 2. Relative Magnitude of the Business Line R&D Portfolios

The relative size, represented by the volume of each sphere, and major interfaces between the four business line portfolios is indicated in Figure 2.

The four business line portfolios together comprise a comprehensive Departmental R&D portfolio. The complete portfolio is portrayed in the foldout illustration in Appendix A, which shows the business line R&D activities down to the second level of goals and objectives. This "boxology" portrays the contribution Departmental programs or offices make to the subelements of each portfolio's major strategic objectives. Because the Office of Science defines their investments in terms of scientific disciplines, rather than strategic objectives, it is not possible to directly describe the distribution of R&D investments in terms of their strategic objectives in the boxology.

To more easily compare the relative size of the business line portfolios and the relative contribution made by the programs and offices, the boxology data is presented in a pie chart format in Figure 3. The inner circle of the pie shows the relative size of the business line R&D portfolios. The outer circle shows the relative contribution each program or office makes to the respective business line portfolios.

Each portfolio contains budget profiles comprised of the FY 1999 and FY 2000 Appropriated budgets and the FY 2001 Requested budget. The R&D budget profile totals for each portfolio are shown in Figure 4. This three-year budget profile shows both the relative magnitudes of the portfolio R&D budgets and the trend over this time period.

A more detailed analysis of each portfolio reveals significant funding increases or decreases (including the initiation of new activities or the cessation of a previous activity) within a given business line. Table 2 indicates the areas of significant increase or decrease in funding in FY 2001 relative to FY 2000 within each business line.

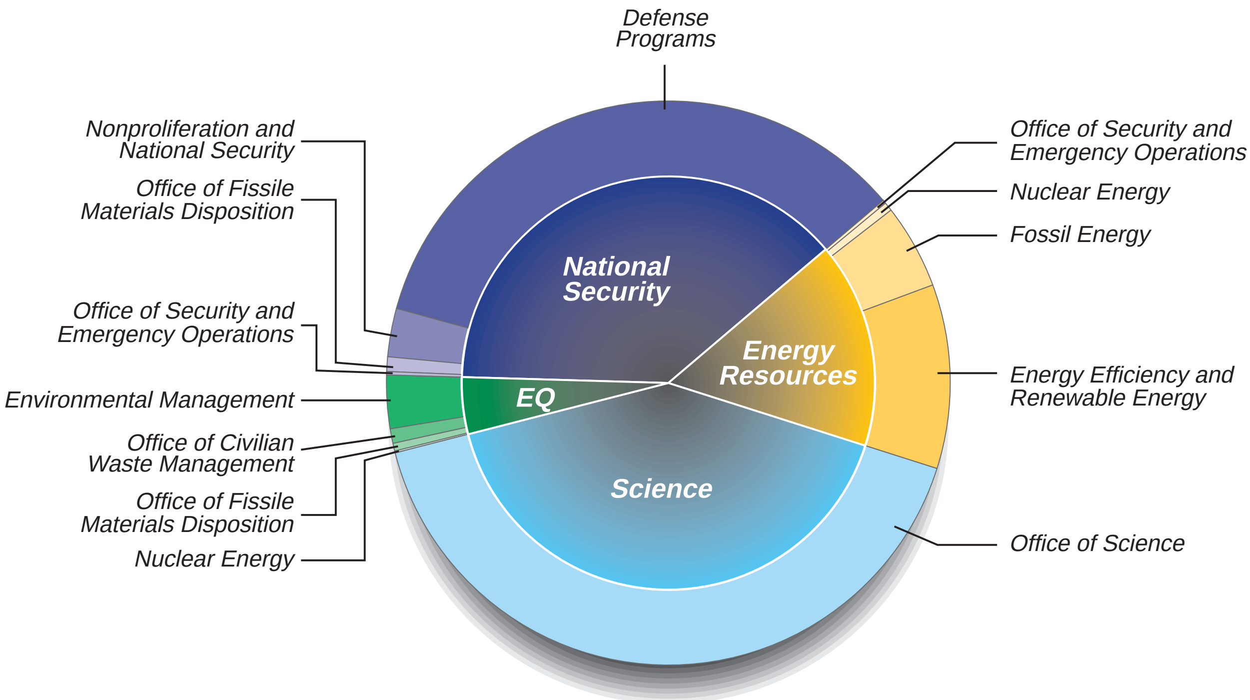


Figure 3. Relative size of Business Line R&D Portfolios and Relative Contribution to Business Line by Programs or Offices

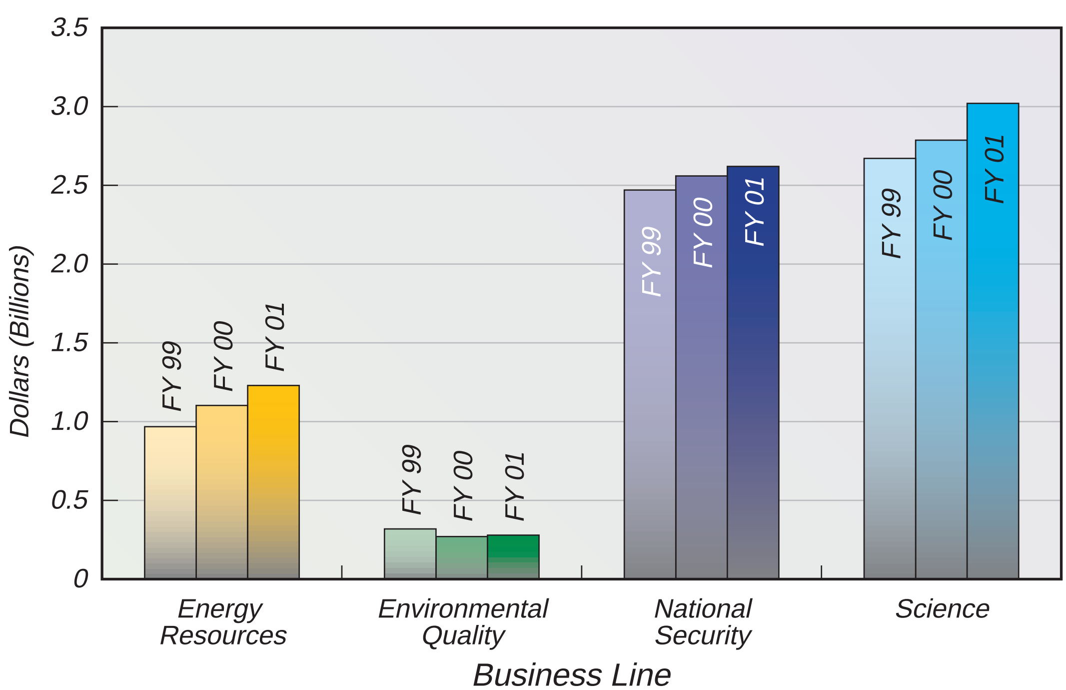


Figure 4. Business Line R&D Portfolio Funding by Year

Business Line	Program Area	Major Increases	Major Decreases
Energy Resources (2% increase)	Clean Transportation Fuels	• Ultra-clean Transportation Fuels from Oil, Gas and Coal, Integrated Bioenergy Technology R&D, Ethanol Production	
	Advanced Power	• Wind, Photovoltaic, Biopower, Carbon Sequestration, Nuclear Fission	• Advanced Utility and Industrial Turbine Systems
	Systems Reliability	• Transmission Reliability, Natural Gas Infrastructure, Physical and Cyber Threats to Energy Grid	• Electric and Magnetic Fields R&D (terminate)
	Clean and Productive Industries	• Agriculture and Forest Products (bioenergy-driven), Technical Assistance	
Environmental Quality (1.9% decrease)	High-Level Waste	• Safe Waste Storage, Waste Retrieval, Tank Closure	• Directed Science
	Mixed/Low-Level/TRU Waste	• TRU Waste Characterization, Waste Handling, Alternatives to Incineration, Unique Wastes, Directed Science	• Waste Characterization, Off-Gas Monitoring and Filtration
	Nuclear Materials	• Stabilization, Packaging, Transportation and Storage	• Performance Testing and Qualification, Directed Science
	Environmental Remediation	• Identify, Validate, Directed Science	• Remediate, Remove
	Deactivation & Decommissioning		• Laboratory Facilities, Fabrication Facilities, Directed Science
National Security (2.5% increase)	Maintaining the Nuclear Deterrent	• Advanced Simulation and Computing, Stockpile Assessments and Certification	• Stockpile Science
	Preventing Proliferation	• Proliferation Resistant Fuel Cycle Technologies	
	Countering WMD Terrorism	• Responding to Chemical and Biological Proliferation	
Science (8% increase)	Fueling the Future	• Carbon recycling and improved energy efficiency, simulation for combustion/ chemistry/geosciences/ plasmas, microbes for fuel production, fusion energy research	• Large pre-commercial fusion test facilities and in particular, fusion technology development
	Protecting our Living Planet	• Carbon sequestration, human and biological genomics, structural biology, environmental remediation, microbes for remediation and sequestration, regional climate modeling/simulation, and advanced monitoring and sensors, bioengineering	• Radioisotope development and high-dose radiation biology
	Exploring Energy and Matter	• Nanoscale science and engineering, neutrino science and non-accelerator HENP, university research in high energy and nuclear physics, international collaboration on large HEP facilities, high-performance computing/simulation for all major disciplines, functional genomics and organisms in extreme environments	• Unilateral support in next generation high energy physics facilities and for university-based accelerator facilities
	Extraordinary Tools for Extraordinary Science	• Advanced computation hardware and scientific data management, SNS, LHC, collaboratories, synchrotron radiation sources for life sciences and structural biology, partner with NIH, NSF and others on facility design and use, science education, robotics and intelligent machines	• Outdated experimental facilities

Table 2. Major Funding Increases or Decreases in the Business Line R&D Portfolios

Of the Department's $18.9 billion budget, nearly 40%—$7.1B a year— goes to scientific research and development. The remaining 60% supports program execution. Comparisons of the relative size of program execution and R&D investments between and within business lines are shown in Figures 5 and 6. Figure 5 indicates the relative portion of the DOE budget ($18.9B) of each business line and the relative size of the R&D budget of each business line.

Figure 6 presents this same data as a bar graph to indicate the relative magnitude of the R&D and program execution budget of each business line.

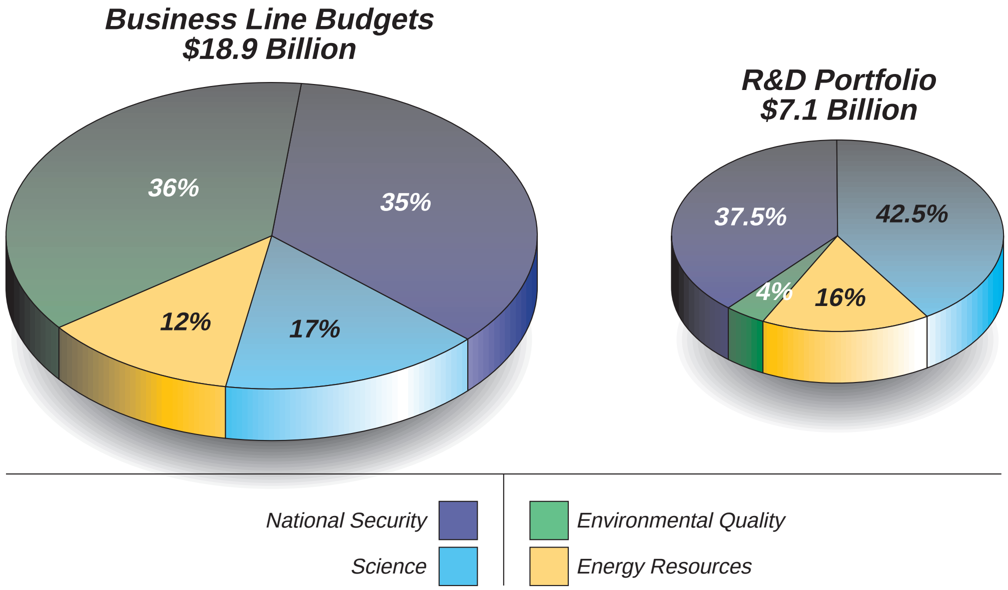


Figure 5. Business Line Operation and R&D Portfolios

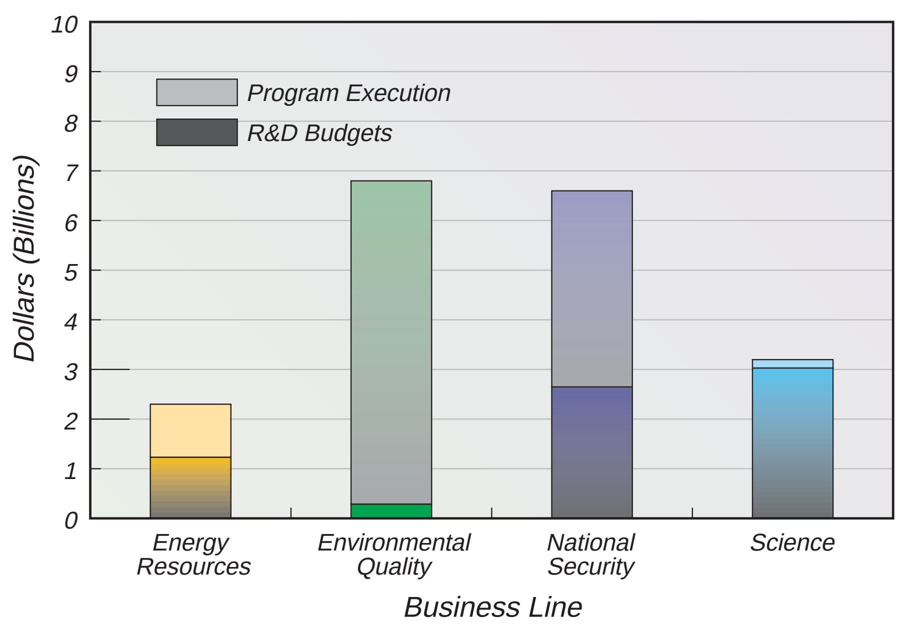


Figure 6. Relative size of program execution and R&D budgets of each business line.

An important factor in developing a well-balanced portfolio that takes maximum advantage of the scientific and technological expertise of the nation is involvement of R&D performers from all relevant sectors. Figure 7 shows the relative proportion of R&D budget that is performed by universities, national laboratories, industry, or other (i.e. by Federal employees at DOE or other Federal Agencies).

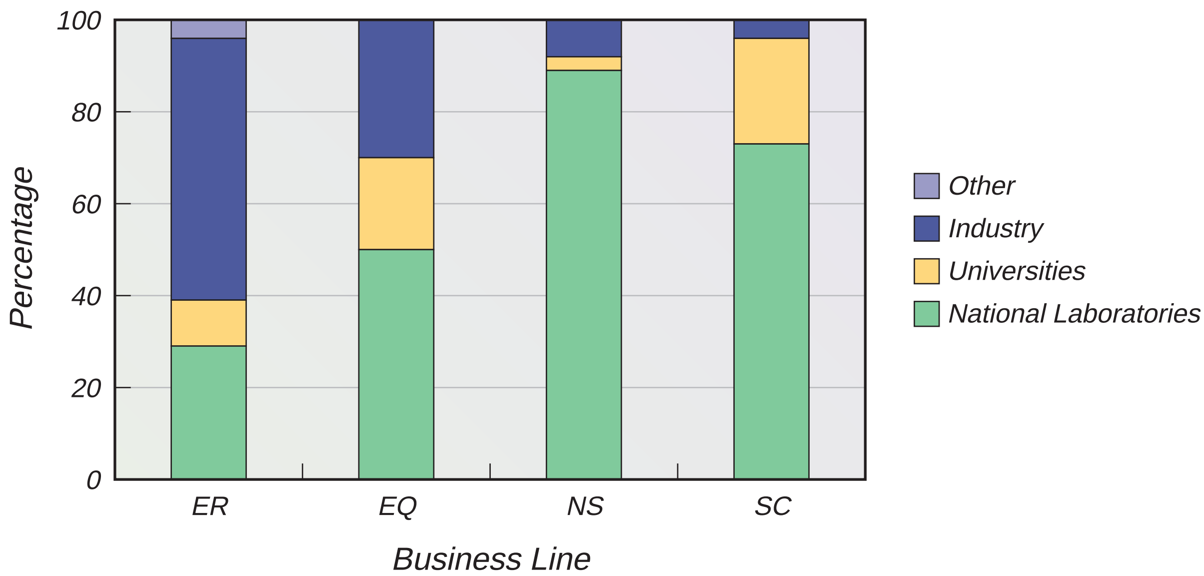


Figure 7. Distribution of Business Line Budgets among R&D Performers

The differences in the distribution of R&D budgets among R&D performers are consistent with the differences in focus and objectives of the business lines. The ER business line is heavily focused in public arenas, supporting development and transfer of technology to the industrial sector. Thus a high involvement with industry is expected. The EQ business line is focused more on problems unique to the federal sector and so there is less involvement with industry. The NS portfolio is mainly focused in the national laboratories as a result of security issues related to much of its R&D activities. The SC portfolio is focused on basic research and has very little industrial participation.

The distribution of the overall R&D portfolio among R&D performers, portrayed in figure 8, is indicative of the major emphasis of the Department in developing and maintaining a strong scientific and technological infrastructure. The National Laboratory system is a significant and valuable national resource.

Another dimension of funding distribution that indicates the balance in the portfolio is R&D maturity stage. Maturity stages range from Basic Research to Applied Research, through Exploratory Development, Advanced Development, Engineering Development, Demonstration, to Deployment. Investment in each stage is essential to maintain both the foundation for new technologies and the flow of innovations to actual application. Figures 9 and 10 show the percentage of R&D investments in each maturity stage within each business line and the composite relative investments for the whole portfolio.

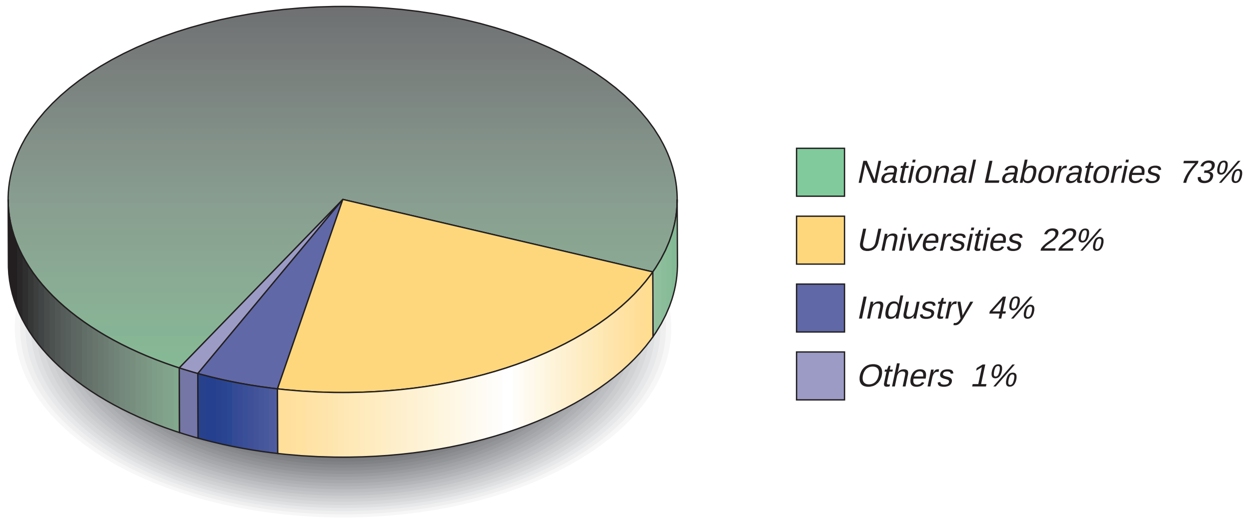


Figure 8. Distribution of R&D Portfolio among R&D Performers

The distribution across the technology maturity spectrum illustrated in Figure 9 is quite different for each of the business lines. This is consistent with the fundamental differences in business line objectives. One analytical tool used for portfolio analysis and 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, controlled situations. When deployment typically occurs in the non-federal sector the investments for demonstration and deployment are borne by that sector.

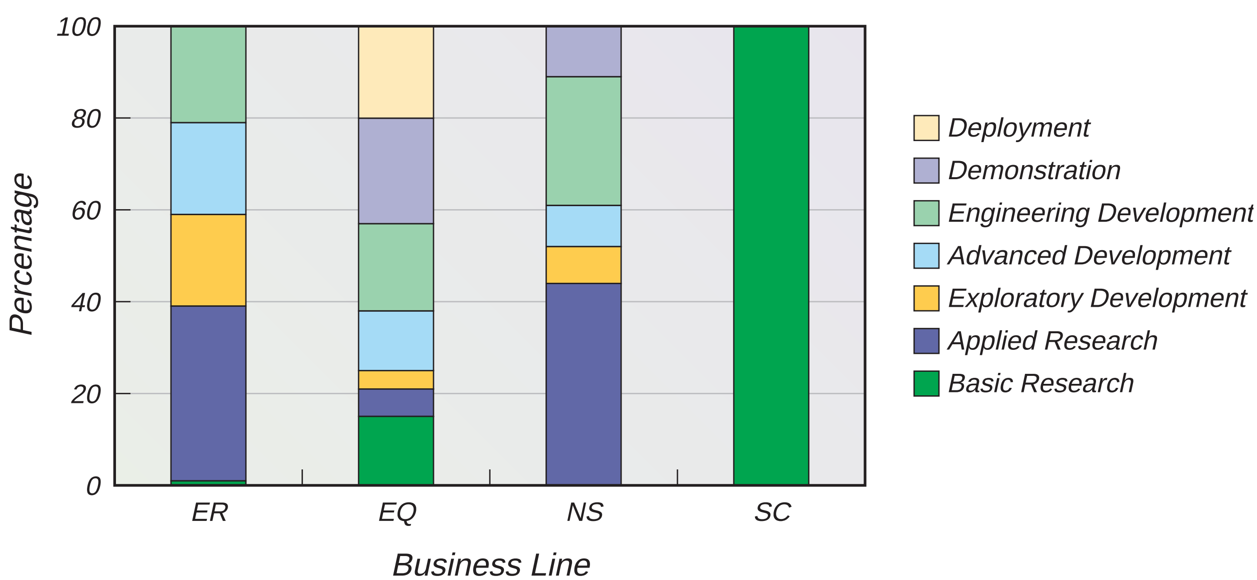


Figure 9. Distribution of Business Line R&D Investments by R&D Maturity Stage

The Energy Resources portfolio illustrates this situation. When the federal sector is the primary customer, then investments are carried through the spectrum to deployment, illustrated by the Environmental Quality portfolio.

In some instances the linear model is not appropriate. Often basic research is required to help support the development of a technology or technical solution during each phase of the technology maturity spectrum. The exceedingly complex nature of environmental cleanup problems makes solution development an ongoing process. For example, during the deployment of a solution to a remediation problem we may find that additional fundamental knowledge, such as reaction rates or absorption coefficients, is required. Basic research is therefore required to support the deployment of the solution. Research and development in such an environment requires investments that support each phase: research, development, demonstration and deployment. This model is non-linear. Investments are required simultaneously at different gates, and the results must be integrated. Investment decisions based on this non-linear model are different than those based on the linear approach.

The large percentage of investments in basic and applied research shown in Figure 10 must be understood in the context of the non-linear model of technology maturation. These investments are foundational to supporting the investments throughout the rest of the technology maturity spectrum.

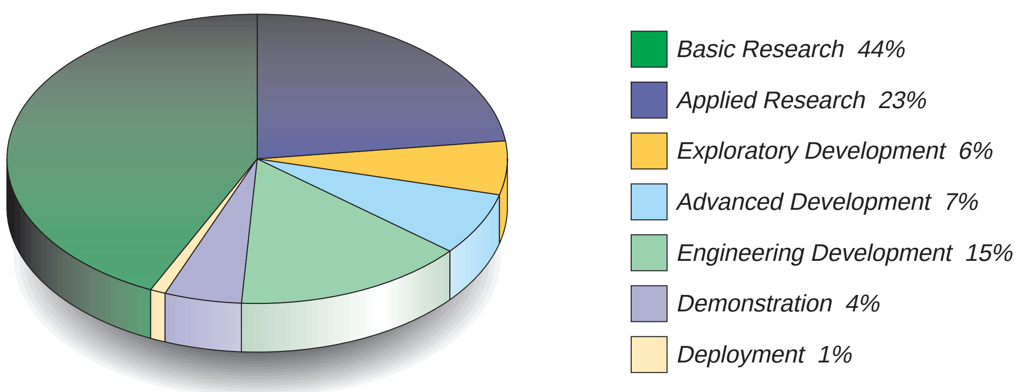


Figure 10. Distribution of R&D Portfolio Investment by R&D Maturity Stage

Chapter 3

Energy Resources R&D Portfolio Overview

Introduction

The United States spends over one-half trillion dollars annually for its energy—$200 billion for electricity, $90 billion for natural gas, and $60 billion for unleaded gasoline. Our "primary" fuel sources come from oil (40 percent), gas (24 percent), coal (24 percent), nuclear (8 percent) and renewable sources (4 percent). By historic standards, the U.S. energy situation is very good. Supplies are affordable and abundant, and it has been almost two decades since there was a serious energy disruption. Some regulated environmental emissions have been reduced significantly despite increased energy use (although some emissions closely related to energy use, such as nitrogen oxides and smog in urban areas, continue to be a problem).

From a national planning perspective, however, there are future scenarios that should not be ignored. For example:

- A national consensus to take actions to significantly reduce greenhouse gas emissions could have a major impact on energy use, which is the dominant source of these emissions.
- Oil exports are expected to become increasing concentrated in the Persian Gulf over time as demand by developing countries increases, creating a situation reminiscent of those that led to oil disruptions in the 1970's.
- A restructured electric and natural gas marketplace may have a major impact on electric and natural gas infrastructure reliability, security and integrity.

New energy technology, such as those supported in the Energy Resources R&D Portfolio, can address such scenarios by providing alternatives that reduce or even eliminate potential economic impacts, while minimizing impacts on personal lifestyles. Technologies in the portfolio have the potential to produce large national benefits, but have a risk/reward profile that is not sufficiently attractive for the private sector to carry out development on its own. In fact, there has been a general trend in the 1990's, during which energy markets have become increasingly competitive, of significant decreases in industry-sponsored R&D, with the exception of R&D addressing near-term, operational and new product issues.

Portfolio Framework and Major Focus

The Energy Resources R&D Portfolio has been developed with the recognition that the energy needs of the country are diverse, involving many products, technologies, and scientific disciplines. The Energy Resources R&D Portfolio addresses these needs by allocating its $1.13 billion funding (FY 2001 Congressional budget request) among three major thrusts:

1. *Reliable and diverse energy supply (15 percent)* – Ensure reliable and diverse domestic fuels supplies
2. *Clean and affordable power (46 percent)* – Ensure that the electricity generation industry can reliably deliver adequate, affordable supplies with acceptable environmental impacts.
3. *Efficient and productive energy use (39 percent)* – Increase the efficiency and productivity of energy use, while limiting environmental impacts

In addition, energy-related basic research is carried out by DOE's Office of Science that supports these three areas. Major activity areas in the Energy Resources R&D Portfolio, associated funding, and DOE organizational affiliations are shown in Figure 11.

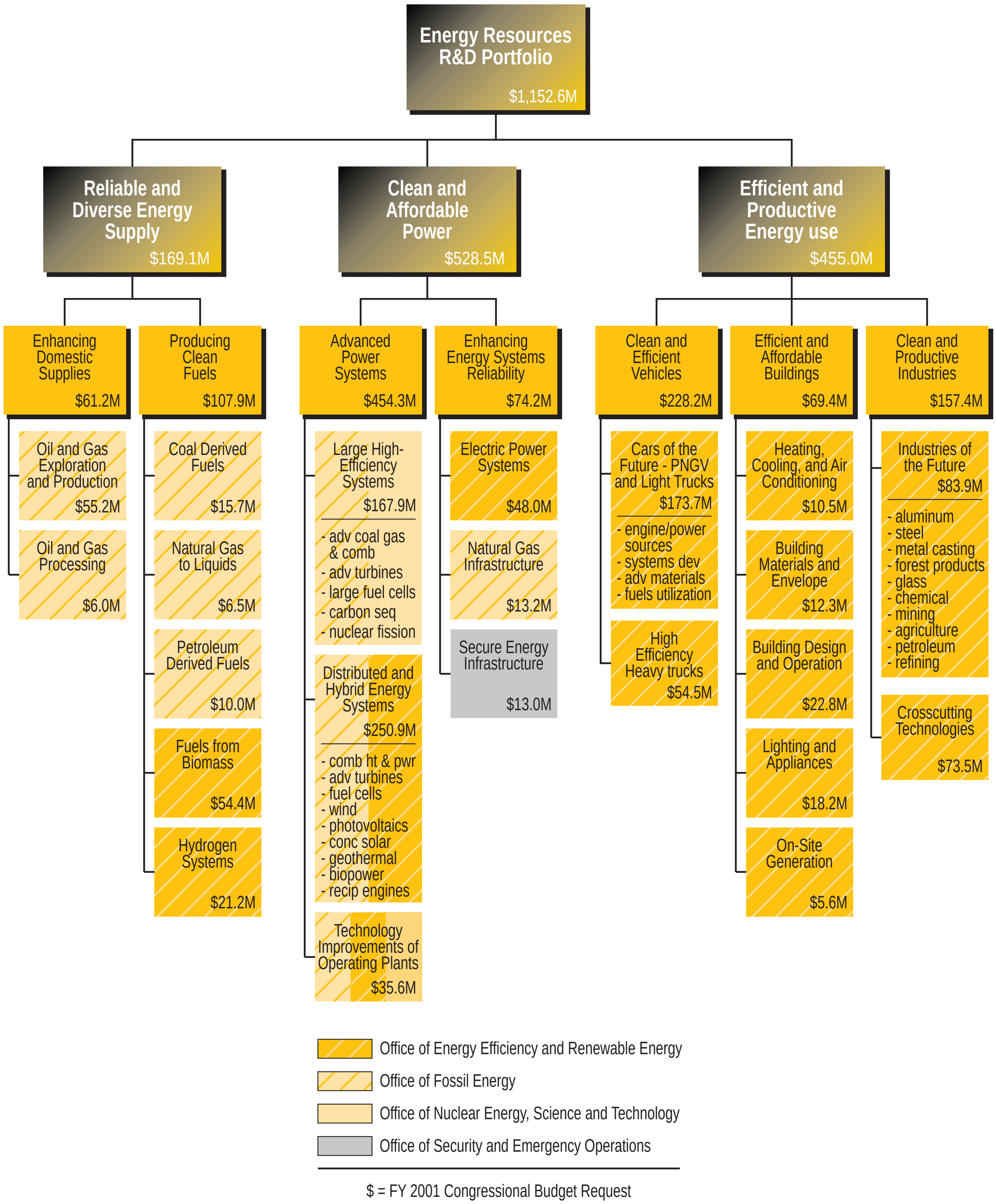


Figure 11. Energy Resources R&D Portfolio

There are many ways to view the "appropriateness" of the Energy Resources R&D Portfolio, but any method must address major uncertainties associated with both future energy and environmental scenarios, as well as the potential success/impacts of new technology. The April 1998 *Comprehensive National Energy Strategy* (CNES) attempted to balance these uncertainties, and one measure of appropriateness is how well the Portfolio supports the CNES goals and objectives. Figure 12 shows a qualitative evaluation of the relevance of the R&D Portfolio to CNES goals and objectives, and illustrates how activities in the Portfolio simultaneously address multiple strategic objectives.

Energy Resources R&D Portfolio
Relevance to CNES Goals and Objectives

● Strong Relationship
◒ Moderate Relationship
○ Weak Relationship
(1) The majority of this research is basic science
(2) All R&D generically supports this objective

		Improve the efficiency of the energy system			Ensure against energy disruptions		Promote energy production and use in ways that respect health and environmental values		Expand future energy choices		Cooperate internationally on global issues	
		Support competitive and efficient electric systems	Significantly increase energy efficiency in the transportation, industrial, and buildings sectors by 2010	Increase the efficiency of Federal energy use	Reduce the vulnerability of the U.S. economy to disruptions in oil supply	Ensure energy system reliability, flexibility, and emergency response capability	Increase domestic energy production in an environmentally responsible manner	Accelerate the development and market adoption of environmentally friendly technologies	Maintain a strong national knowledge base as the foundation for informed energy decisions, new energy systems, and enabling technologies of the future	Develop technologies that expand long-term energy options	Promote development of open, competitive international energy markets, and facilitate the adoption of clean, safe, and efficient energy systems	Promote foreign regional stability by reducing energy-related environmental risks in areas of U.S. security interest
Reliable and Diverse Energy Supply	Enhancing Domestic Supplies	◒			●	●	●	●	(1)	●	◒	(2)
	Producing Clean Fuels	○	○		●	◒	●	●	(1)	●	◒	(2)
Clean and Affordable Power	Advanced Power Systems	●		◒	○	●	●	●	(1)	●	◒	(2)
	Enhancing Energy Systems Reliability	●	○	○		●		●	(1)	●	◒	(2)
Efficient and Productive Energy Use	Clean and Efficient Vehicles		●	●	●	●		●	(1)	●	◒	(2)
	Efficient and Affordable Buildings	○	●	●	○	○		●	(1)	●	◒	(2)
	Clean and Productive Industries	◒	●	◒	○	◒	○	●	(1)	●	◒	(2)

Figure 12. Relationship of and support by ER portfolio elements to strategic objectives

Changes and New Initiatives

The Ultra-Clean Transportation Fuels Initiative (UCTFI) promotes, in partnership with the refining and transportation industries, the development and deployment of technologies that will produce ultra-clean, high performance transportation fuels for the 21st Century from both petroleum and non-petroleum sources. These will enable the introduction of advanced, highly efficient fuel/engine combinations being developed by the Department, which offer the promise of lower regional emissions and greater than double the miles per gallon of fuel. In the nearer term, ultra-clean transportation fuels can be produced from improved or new refinery upgrading technology. In the mid-to-longer term, ultra-clean transportation fuels from natural gas, coal and other carbonaceous feedstocks would enjoy a high level of compatibility with the existing infrastructure, and could provide environmental benefits due to their suitability for use in advanced, high-efficiency vehicle engines.

The Energy Grid Reliability Initiative includes three broad areas. Electric Power Systems Reliability focuses on systems that will help ensure the availability of a robust, reliable electricity infrastructure required to serve emerging, competitive regional and interregional markets. Activities relate to transmission reliability, distributed generation and energy storage. The Natural Gas Infrastructure program is a FY 2001 initiative that seeks to enhance gas pipeline system reliability and increase deliverability and operational flexibility of gas storage facilities. The Secure Energy Infrastructure program was initiated in FY 2000 and is primarily a FY 2001 initiative and is focusing efforts on protecting critical energy system infrastructures from physical and cyber threats.

The Biobased Products and Bioenergy Initiative is a government wide, integrated research, development and deployment effort in bio-based technologies that convert crops, trees, and other "biomass" into a vast array of fuels and products. Biobased industries use agricultural, forest, and aquatic resources to make commercial products including fuels, electricity, chemicals, adhesives, lubricants, and building materials. The initiative supports the President's August 1999 Executive Order 13134 and Memorandum on Promoting Biobased Products and Bioenergy, aimed at tripling the use of biobased products and bioenergy in the United States by 2010. The major goal of this initiative is to make biomass a viable competitor to fossil fuels as an energy source and chemical feedstock, while protecting the environment.

The International Clean Energy Initiative is in response to the June 1999 report by the President's Committee of Advisors on Science and Technology (PCAST) titled "Powerful Partnership —The Federal Role in International Cooperation on Energy Innovation." This report addresses ways to improve the U.S. program of international cooperation on Energy R&D to best support U.S. priorities and address the key global energy environmental challenges of the next century. The report includes funding recommendations for a variety of initiatives that include approaches such as tax credits, regulatory assistance, training and Federally supported R&D. In response, the Department is proposing a variety of international activities in FY 2001 that total $46 million, spanning most of the ER business line objectives, and that include R&D and other forms of assistance.

Research and Development Accomplishments

Energy Security activities address the Nation's need for stable, secure and clean sources of domestic energy. Dramatic improvements in cost and performance have been achieved in many areas, including the cost of: ethanol from biomass; liquid fuels from coal; oxygen production via ceramic membranes, which is important for certain processes that convert hydrocarbons to liquid fuels;

improved drilling technology utilizing new bit materials and directional steering capabilities; oil and gas exploration based on 3-dimensional and 4-dimensional seismic and vertical seismic profiling; and sorbent enhanced reformers used to make hydrogen fuel.

Clean and Affordable Power includes a broad range of generation technology options that utilize fossil fuels, renewable energy resources, and nuclear power in both large, high efficiency energy systems and in distributed and hybrid energy systems. Also included are systems that will help ensure the availability of the robust, reliable electricity and the natural gas infrastructure required to serve emerging competitive regional and interregional markets, and approaches for dealing with physical and cyber threats to this infrastructure. Considerable progress has been made through DOE support toward achieving advanced power systems goals. Low NOx burners are installed in about half of U.S. coal-fired capacity. Key technologies are in advanced stages of development, including: coal gasification-based technologies that can be integrated with advanced gas turbines and fuel cells; biomass power using dedicated feedstocks; and advanced geothermal power. Photovoltaic modules and advanced wind machines are already economically viable in some applications. Superconducting wires have been developed with over 10 times the current carrying capability of wires made with older methods. Three DOE advanced nuclear reactor designs have been certified by the Nuclear Regulatory Commission for construction in the U.S. Fusion research continues to raise the power achieved in test reactors.

Efficient and Productive Energy Use seeks to reduce the growth of energy use by highway vehicles, in buildings, and in the industrial sector. Considerable progress has been, and continues to be made through DOE-supported improvements in energy end-use efficiency. The auto industry is moving toward adopting many technologies developed in the DOE program. The impact of five building efficiency technologies developed in the 1970s-80s have resulted in present value savings estimated at over $30 billion. Current efforts focus on integrating building efficiency technologies to optimize building performance. A series of improvements in industrial processes promise major reductions in cost, energy requirements, productivity, and/or environmental emissions. These include major improvements in a casting process for steel and aluminum, a new cleaning process allowing recycle of lower grades of paper, new materials for high temperature, corrosive environments and a new firing process for glass melting furnaces.

Path Forward

The Energy Resources R&D Portfolio represents a comprehensive description of the Department's investments in research and development to achieve the goals of maintaining available and reliable low-cost energy services in the context of national security and environmental quality. This document indicates that the portfolio meets multiple objectives and demonstrates robustness for an uncertain future, but continuing and expanded planning and analysis is needed to ensure appropriate prioritization and efficient utilization of taxpayer funds applied to these efforts. Future steps should include expansion of current technology and program roadmapping to all areas as well as portfolio analysis that models R&D outcomes relative to R&D investments.

Future changes to the portfolio will also occur because of new opportunities, such as fossil fuel decarbonization with CO_2 sequestration, ultra-clean fuels for use in a new generation of high-mileage vehicles, and technologies to help protect and sustain the energy infrastructure. Technological developments, such as methods for efficient conversion of coal or gas resources to liquid fuels, or economical methods for directly producing hydrogen from sunlight, will also drive portfolio shifts. Finally, institutional changes such as electricity re-structuring, critical infrastructure protection, and international developments are likely to influence changes to the focus of DOE's energy R&D. Thus strategic planning and portfolio planning and analysis will continue apace with the R&D programs.

Chapter 4

Environmental Quality R&D Portfolio Overview

Introduction

In Environmental Quality, the Department's task is clear. We will continue to make progress in cleaning up the environmental legacy of the cold war nuclear weapons program, and we will do so while minimizing the risks to human health and safety. Our goal is to finish the cleanup program at most of our sites by the year 2006, while systematically addressing the persistent challenges at our largest cleanup sites, in accordance with various regulatory agreements. The scientific and technical issues involved in meeting this challenge are among the most complex of any job anywhere in the world. DOE's strong science and technology base and our capacity to conduct interdisciplinary, leading edge R&D will help us accomplish our cleanup goals. Furthermore, we will continue to work towards resolving the scientific and technical issues surrounding the storage of spent nuclear fuel.

Portfolio Framework and Major Focus

The strategic goal for the Environmental Quality business line is *to 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 wastes*. The Department has developed seven objectives to support this goal:

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

These seven objectives provide the basis for the business line program and help define the structure of the business line R&D portfolio.

The Environmental Quality R&D Portfolio is designed to provide the new science and technologies necessary for successful completion of the business line program. The portfolio structure and FY-2001 Congressional budget request is shown in Figure 13.

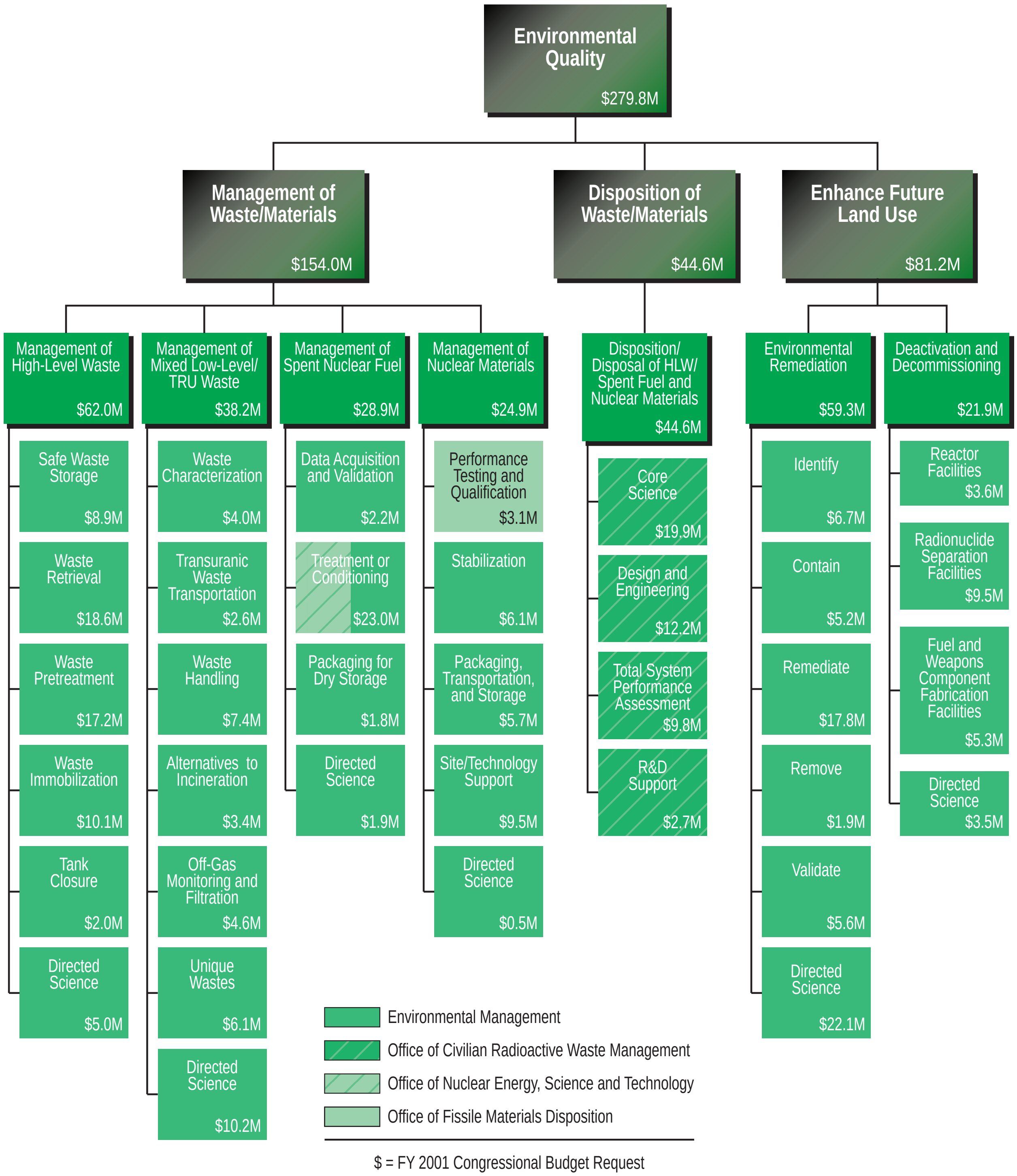


Figure 13. Environmental Quality R&D Portfolio

The Environmental Quality R&D Portfolio is structured to align with the major operational organizations of the business line. This allows the portfolio to be responsive to the scientific and technological needs of cleanup operations. Each operational line, and therefore each portfolio element, addresses one or more of the strategic objectives. Figure 14 indicates the relationships between the strategic objectives and the portfolio major elements.

- ● 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	Disposition of Waste/Materials	◒	○	◒	(1)	●	◒	○
Enhance Future Land Use	Environmental Remediation	◒	●	○	(1)	N/A	●	●
	Deactivation and Decommissioning	○	◒	○	◒	N/A	◒	●

Figure 14. Relationship of and support by EQ portfolio elements to strategic objectives

Changes and New Initiatives

The overall Environmental Quality research and development funding decreased slightly in the FY 2001 request, and represents approximately only four percent of the total business line. The major thrust remains investments in the high-risk, high-cost, and long-term problems associated with cleanup of the DOE complex and safe and permanent disposal of civilian spent nuclear fuel.

During FY 2001, efforts will focus on improving the balance of investments in the portfolio by transitioning basic research results into the applied research and development phase to address the Department's mid- and long-term cleanup needs.

Also, added emphasis will be placed in FY 2001 on developing long-term stewardship activities related to more reliable and cost-effective characterization and monitoring technologies and approaches. Long-term stewardship will ensure human health and the environment are protected after cleanup is completed, sites are closed, waste is emplaced for disposal, and/or facilities are stabilized for long periods awaiting possible further remediation.

The Environmental Systems Research and Analysis activities, conducted by the Idaho National Engineering and Environmental Laboratory, will continue focusing on research initiatives supporting subsurface science and long-term stewardship activities. Research activities will focus on better understanding of transport aspects of selective mass transport agents; chemistry of environmental surfaces; materials dynamics; characterization science; and computational simulation of chemical and mechanical systems. Emphasis will also continue on identifying opportunities for multi-site environmental management integration.

Regarding disposal, the Yucca Mountain Site Characterization Project is focused in FY 2001 on completing major R&D efforts to support a decision on whether to recommend the site to the President as the Nation's first repository for spent nuclear fuel and high-level radioactive waste in FY 2001.

Research and Development Accomplishments

A number of technologies from the Environmental Quality R&D portfolio have been developed and applied to solve environmental problems and to prepare for disposition of waste and materials in a geologic repository. In many cases, ongoing research and development efforts continue to enhance the effectiveness or the scope of application of these technologies. Highlights of some of these technologies are:

- Instrument improvements—portable detectors and nondestructive and non-intrusive examination techniques for stored waste and materials, contaminated surfaces, and soils; chemical sniffers and non-intrusive spatial metal detector arrays.
- New robots and tele-operated vehicles to characterize and retrieve waste in high radiation, chemically hazardous, and potentially explosive environments.
- Advanced chemical separations technologies for the removal of selected metals and radionuclides have already reduced life-cycle costs by over $6 billion.
- Improved technologies for stabilization of waste and materials—macroencapsulation, microencapsulation, calcination, and ceramification. Two vitrification facilities are safely operating.
- A geologic repository for the disposal of transuranic waste is in operation. A viability study for the disposal of spent fuel and high-level waste has been completed.
- R&D achievements also supported the successful remediation of over 50 contaminated sites through use of innovative technologies such as chemical washing, in situ bioremediation, vapor extraction, and the treatment of nonaqueous phase liquids.

Path Forward

The analysis of the Environmental Quality R&D Portfolio resulted in five major findings that help define the direction of the portfolio planning and management process for the Environmental Quality business line research and development activities. In summary, three of the findings are that the portfolio is closely aligned and focused on the complex-wide cleanup effort and the safe disposition of spent nuclear fuel, that it is invested across a full spectrum of activities ranging from basis research through technology deployment, and that it supports a complex and diverse set of participants.

The fourth finding is that the portfolio may be underinvested to sustain achievement of existing mission objectives beyond the near term, i.e. beyond 2006. 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 portfolio represents only 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 upward trends 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. A more comprehensive application of programmatic and project level roadmapping will provide the basis for more rigorously defined, defensible budget submissions for research and development support of the business line.

The fifth finding highlights the utility of the portfolio planning process and the need to continue the process to improve the alignment of the four portfolios to make investment decisions that ensure the Department can help meet the nation's greatest challenges.

Chapter 5

National Security R&D Portfolio Overview

Introduction

The National Security R&D Portfolio for the Department of Energy develops scientific understanding and technologies for reducing the global danger posed by weapons of mass destruction (WMD), while maintaining a safe, secure, and reliable nuclear deterrent. The Portfolio is implemented by four principal DOE organizations: 1) the Office of Defense Programs (DP), 2) the Office of Nonproliferation and National Security (NN), 3) the Office of Fissile Materials Disposition (MD), and 4) the Office of Security and Emergency Operations (SO). Effective March 1, 2000, DP, NN, MD and the Office of Naval Nuclear Propulsion will be transferred to the newly established National Nuclear Security Administration (NNSA). The NNSA will report to the Secretary of Energy, as defined by the FY 2000 National Defense Authorization Act (P.L. 106-65).

The portion of this R&D Portfolio titled "Maintaining the Nuclear Deterrent" summarizes unclassified R&D activities conducted by DP. A comprehensive and classified description of the DP's SSP can be found in the "FY 2001 Stockpile Stewardship Plan," also known as the "Greenbook." This Plan is prepared annually, and is submitted by the Secretary of Energy to Congress by March 15 of each year, as mandated by the FY 1998 National Defense Authorization Act (P.L. 105-85).

Portfolio Framework and Major Foci

The Department's National Security R&D Portfolio is organized into five major areas: 1) Maintaining the Nuclear Deterrent, 2) Monitoring Nuclear Treaties and Agreements, 3) Preventing Proliferation, 4) Detecting Proliferation, and 5) Countering Weapons of Mass Destruction Terrorism. The framework of the Portfolio is illustrated in Figure 15. The planned FY 2000 and 2001 funding is as follows:

Portfolio Areas	FY 2000 Funding ($ millions)	FY 2001 Funding ($ millions)
Maintaining the Nuclear Deterrent	2,306.2	2,343.6
Monitoring Nuclear Treaties and Agreements	39.1	39.4
Preventing Proliferation	75.1	94.4
Detecting Proliferation	66.1	67.5
Countering WMD Terrorism	71.6	76.2

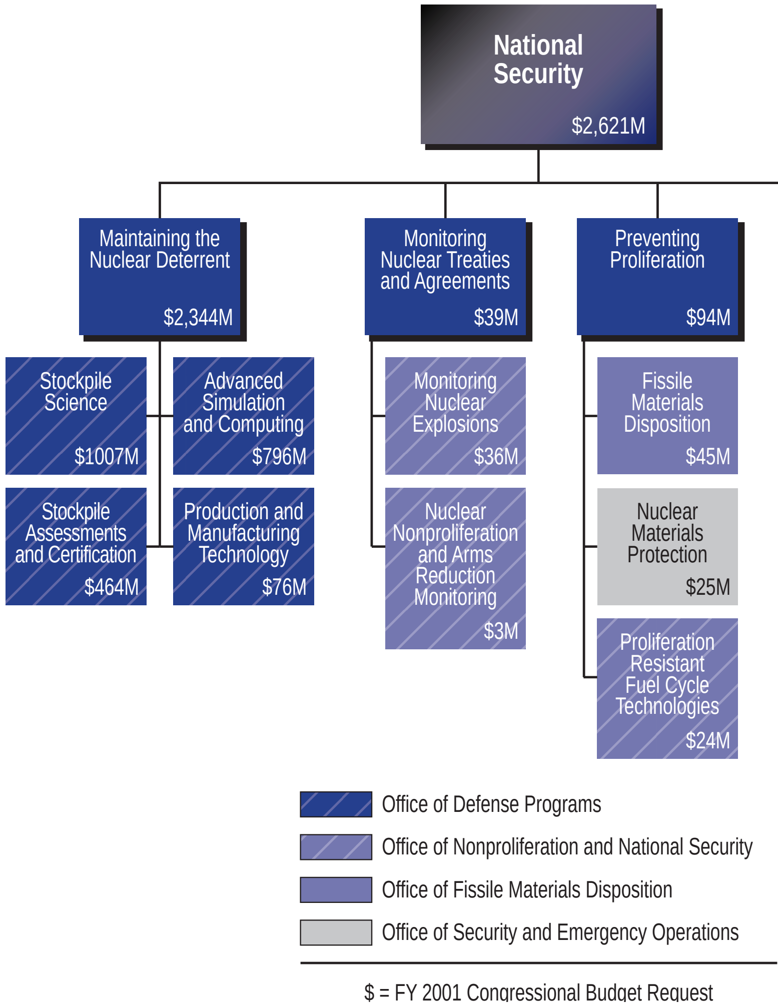


Figure 15. National Security R&D Portfolio

Over the past several years, U.S. national security policies have undergone profound change, reflecting the new and evolving geopolitical and military exigencies of the post-Cold War world. The Department has shifted its priorities toward activities that advance the nation's nonproliferation and international nuclear safety policies. Bolstered by balanced and integrated R&D efforts, these priority programs provide global leadership in meeting their critical goals and objectives while maintaining the viability of the nuclear deterrent with a smaller, more cost effective, and secure nuclear weapons complex.

Maintaining confidence in the nation's nuclear deterrent in the absence of nuclear testing is a complex, resource-intensive scientific and technological challenge, and is the primary focus of DP's Stockpile Stewardship Program (SSP). A successful SSP requires a large investment in new technology and research during the next few years to develop and validate science-based methods to ensure the safety, security, and reliability of the nuclear-weapon stockpile.

To evaluate the performance path of SSP, Secretary of Energy Richardson directed Under Secretary Moniz to conduct a comprehensive review of the program. The review concludes that the SSP is "on track," but faces many challenges. A fifteen-point action plan was developed in response to the Review's recommendations, and steps to implement the action plan will be undertaken during FY 2000. A report that summarizes the results of the review is available on the World Wide Web at http://www.dp.doe/dp_web/doc/CONRAD.pdf.

The National Security R&D Portfolio has been balanced to achieve seven national security goals:

1) Maintain and refurbish nuclear weapons to sustain indefinitely the confidence in their safety, security, and reliability, without conducting nuclear testing,

2) Achieve a robust and vital scientific, engineering, and manufacturing capability to enable present and future assessment and certification of the enduring stockpile, and develop the ability to design and manufacture nuclear components without conducting nuclear testing,

3) Ensure the vitality of DOE's science, engineering and production enterprise required for nuclear stewardship,

4) Reduce nuclear weapons stockpiles and the proliferation threat caused by the possible diversion of nuclear materials,

5) Continue to provide leadership in policy support and technology development for international arms control and nonproliferation efforts,

6) Meet national security requirements for naval propulsion and for other advanced nuclear power systems, and

7) Improve international nuclear safety.

The relationship of the Portfolio elements to these goals, as well as the level of support provided to each goal, is indicated in Figure 16.

Changes and New Initiatives

DP has undertaken a major shift in program management strategy during the last year, resulting in the adoption of a business model for R&D management. This has resulted in significant changes to the organizational structure of the SSP relative to previous years. As a result, the SSP is organized into three focus areas: 1) Directed Stockpile Work (DSW), designed to ensure that stockpiled weapons meet military requirements, 2) Campaigns, designed to provide the science and engineering capabilities needed to meet ongoing and evolving DSW requirements, and 3) Infrastructure that is required for stockpile work and computational and experimental facilities at the DP laboratories and the Nevada Test Site. Within these three areas, R&D primarily is focused in DSW and Campaigns, which are multiyear research-intensive initiatives that are designed to resolve DP's highest priority stockpile related scientific issues.

National Security Research and Development Portfolio Relevance to DOE Strategic Plan
National Security Goals and Objectives

● Strongly Support
◒ Moderately Support
○ Weakly Support
(1) Support as core value and operating principle
(2) Not Applicable

		Maintain confidence in the safety, reliability, and performance of the nuclear weapons stockpile without nuclear testing	Replace nuclear testing with a science-based Stockpile Stewardship and Management Program	Ensure the vitality of DOE's national security enterprises	Reduce nuclear weapons stockpiles and the proliferation threat caused by the possible diversion of nuclear materials	Continue leadership in policy support and technology development for international arms control and nonproliferation efforts	Meet national security requirements for naval nuclear propulsion and for other advanced nuclear power systems	improve international nuclear safety
Maintaining the Nuclear Deterrent	Stockpile Science	●	●	(1)	(2)	(2)	(2)	(2)
	Advanced Simulation and Computing	●	●	(1)	(2)	(2)	(2)	(2)
	Stockpile Assessments and Certification	●	●	(1)	(2)	(2)	(2)	(2)
	Production and Manufacturing Technologies	●	●	(1)	(2)	(2)	(2)	(2)
Monitoring Nuclear Treaties and Agreements	Monitoring Nuclear Explosions	(2)	(2)	(1)	(2)	●	(2)	(2)
	Nuclear Proliferation and Arms Reduction Monitoring	(2)	(2)	(1)	●	●	(2)	(2)
Preventing Proliferation	Fissile Materials Disposition	(2)	(2)	(1)	●	●	(2)	(2)
	Nuclear Materials Protection	(2)	(2)	(1)	●	●	(2)	(2)
	Proliferation Resistant Fuel Cycle Technologies	(2)	(2)	(1)	●	●	(2)	(2)
Detecting Proliferation	Effluent Detection	(2)	(2)	(1)	○	●	(2)	(2)
	Physical Detection	(2)	(2)	(1)	○	●	(2)	(2)
Countering WMD Terrorism	Nuclear Materials	(2)	(2)	(1)	●	●	(2)	○
	Responding to Chemical and Biological Proliferation	(2)	(2)	(1)	(2)	●	(2)	(2)

Figure 16. Relationship of and support by NS portfolio elements to strategic objectives

During FY 2000 and 2001, the SSP will significantly enhance experimental and computational facilities needed for assessing and certifying the stockpile's safety, security, and reliability in the absence of nuclear testing. These enhancements target improved scientific understanding and new scientific and computational facilities in six areas in FY 2001:

1. Assessment and certification of nuclear weapon primaries,
2. Assessment and certification of nuclear weapon secondaries,
3. Additional advanced radiography,
4. Inertial confinement fusion,
5. Defense applications and modeling, and
6. Enhanced surveillance of the enduring stockpile.

International/cooperative efforts for proliferation prevention are a high priority for the Department of Energy Office of Nonproliferation and National Security. Both the United States and Russia have interests in and responsibilities for reducing the risk of nuclear proliferation from civilian nuclear power, and both are pursuing technology development programs to accomplish that goal. Continuing interactions with Russian officials on this topic will lead to the identification of many areas where the U.S. and Russian philosophies and technologies contributing to the development of proliferation-resistant nuclear systems will overlap. Successful collaboration between the United States and Russia will identify areas of mutual interest. The Department of Energy intends to accelerate development of proliferation-resistant nuclear systems by implementing a new research initiative (the Proliferation Resistant Reactors and Fuels Research Program) during FY 2001.

The Chemical/Biological nonproliferation R&D research focus is to develop technologies to deter, detect, and effectively respond to the use of chemical and biological weapons. The Chemical/Biological R&D area will receive a modest increase in fiscal year 2001, growing from approximately $40 million to over $42 million, with more growth anticipated in the out years. This program builds upon ongoing activities in other agencies, and addresses specific scientific and technical areas in which DOE has unique expertise.

R&D Accomplishments

Accomplishments made in the area of maintaining the nuclear deterrent include:

- Completing the fourth annual certification of the nuclear weapons stockpile without recourse to nuclear testing,
- Meeting the first production unit milestone for the refurbished W87 ICBM warhead,
- Completing the first hydrodynamic test using the first axis of the Dual-Axis Radiographic Hydrodynamic Test facility,
- Winning the 1999 Gordon Bell Prize in computing,

- Sustaining the world record for high-performance computing,
- Partially certifying the MC4380 neutron generator to hostile-environment specifications, and
- Determining plutonium high-pressure thermodynamic properties by using first-principles methods.

Accomplishments in the area for monitoring nuclear treaties and agreements include:

- Delivering an x-ray instrument with increased capability that will enable detection of the evasive testing in space of primitive nuclear weapons,
- Utilizing the DOE Fast On-orbit Recording of Transient Events (FORTE) small satellite to successfully demonstrate the next generation autonomous electromagnetic pulse sensor technologies for monitoring nuclear test ban treaties, and
- Delivering Release 3 of the ground-based nuclear explosion monitoring “Knowledge Base” to the U. S. National Data Center, providing a near-operational structure for managing large data bases pertaining to multiple technologies, regional geophysical, and geologic information.

Accomplishments in the area of preventing proliferation include:

- Developing an approach to measure unclassified nuclear weapon attributes such as the threshold mass and $^{240}Pu/^{239}Pu$ isotopic ratio for verification of warhead dismantlement and reductions,
- Demonstrating the feasibility of a fully solid state, low power, no moving parts cryogenic cooling system that will enable the fielding of advanced cryogenically cooled sensor systems, and
- Developing and testing major components of the technology to disassemble and convert nuclear weapon pits (a component of a nuclear weapon) to a plutonium oxide form which have been integrated into a system, selecting the baseline ceramic formulation for immobilizing plutonium, fabricating, irradiating, and examining MOX fuel samples to study the performance of MOX fuel, and initiating studies, tests and demonstrations in Russia to assist in selecting a process to convert plutonium from Russian weapons to an oxide form suitable for fabrication into a MOX fuel.

Accomplishments in the area of countering WMD terrorism include:

- Completing the DNA sequencing of the virulence plasmids in two key biological threat pathogens, *B. anthracis* (anthrax) and *Y. pestis* (plague), enabling detection and attribution technologies,
- Development of a solid state fiber optic neutron and gamma ray detector that won an R&D 100 award and was successfully transferred to the commercial sector resulting in a Federal Laboratory Consortium Award, and
- Development of a miniaturized system (the Lab-on-a-Chip) for performing wet chemistry operations that has demonstrated separation of compounds faster than full-size laboratory instruments. The technology has been licensed to industry and has been declared by R&D Magazine to be one of the 40 most significant technological achievements since the magazine began their R&D 100 Awards program in 1963.

Path Forward

The Office of Defense Programs is aggressively pursuing a suite of activities that defines the Office's R&D Path Forward. Many of DP's R&D activities (including several Campaigns) have completed five-year project planning and execution documents, similar in scope and detail to technical roadmaps, to guide their operations. These planning and execution activities will be expanded to include full-scale roadmapping for DP's entire R&D spectrum over the next few years. The roadmap-like activities conducted to date have identified the need for significant investments in new facilities over the next five years, and have identified new programmatic pathways for meeting DP's goals.

DP's project planning and execution activities have illuminated the science and engineering challenges that DP will face in the coming years. To deal effectively with these challenges, DP has instituted a series of focused Campaigns, each with distinct weapons refurbishment and certification milestones and goals. DP has also made a commitment to pursuing novel concepts to meet it's stockpile stewardship responsibilities, including the use of advanced radiography in the certification of weapon systems. Estimating pit lifetimes and producing and certifying new pits are challenging issues for DP, with certification of new pits to be required in the FY 2004-2005 time frame. Production of these new pits is driving significant investments in obtaining a greater fundamental understanding of pit materials.

DP recognizes the immense array of challenges it must meet in the coming years, and actively seeks expert external advice on it's R&D portfolio and direction. This advice, much of which is obtained through scientific and programmatic reviews, is used to establish baselines, to gauge and track progress, and to tune and balance R&D programs. Many of these reviews are conducted by well-respected scientific organizations, including the JASON group and the National Academy of Sciences. It is anticipated that the SSP and its constitutive elements will continue to be the subject of multiple external reviews each year. During FY 2000, for example, it is anticipated that several of the Campaigns will be reviewed by JASON. As an offshoot of these reviews, DP is creating the Defense Programs Advisory Committee, which will be formed to further guide and refine the R&D portfolio and DP's newly-adopted business model.

A component critical to DP's Path Forward are the human resources of DOE, the national laboratories, and the production plants. Of equal magnitude as the scientific and engineering challenges facing DP R&D is the challenge of maintaining the appropriate human capital to tackle these challenges. It is widely accepted that the quality of the work conducted in the National Security R&D Portfolio is directly related to, and dependent upon, the quality, capability, and motivation of the researchers themselves. A review was recently conducted by the Congressionally directed Commission on Maintaining U.S. Nuclear Weapons Expertise (chaired by Admiral H.G. Chiles, Jr.) to assess the current state of the human capital in the weapons complex. The Commission's findings call for the development of work force plans for each DP facility. These plans will address the human resource needs of the laboratories and production plants over the next decade, ensuring that the weapon complex has in place qualified scientists, engineers, and technical experts who can ensure the safety and reliability of the enduring stockpile.

Volume 3 of the Portfolio contains chapters on "Monitoring Nuclear Treaties and Agreements," "Preventing Proliferation," and "Countering Weapons of Mass Destruction Terrorism" providing comprehensive descriptions of their contributions to the DOE National Security R&D Portfolio. (Due to classification issues, Chapter 6 of the National Security R&D Portfolio, "Detecting

Proliferation," is published as a separate classified supplement.) This presentation and description of the Portfolio and its relevance to national interests is an important step in portfolio development and analysis. This document demonstrates that the National Security R&D Portfolio meets multiple objectives, with the robustness required to meet an uncertain future. Continued and expanded planning and analysis is needed to ensure appropriate prioritization and efficient utilization of taxpayer funds applied to these efforts. Future steps should include expansion of current technology and program roadmapping.

During FY 1999, the DOE established a Nonproliferation and National Security Advisory Committee in accordance with Section 9 of the Federal Advisory Committee Act, P.L., No. 92-463, and Executive Order 12838. The Advisory Committee has completed its review of the nonproliferation R&D program and is finalizing its report. The Committee is available to provide an external review of any activity within the Office of Nonproliferation and National Security.

Future changes to portions of the Portfolio will occur as new opportunities, technological developments, and requirements arise from evolving national and international events. Strategic planning, portfolio analysis, and technology roadmapping will provide the framework to keep pace with demanding national security needs.

Chapter 6

Science R&D Portfolio Overview

Introduction

The major goal of the DOE Science business line is:

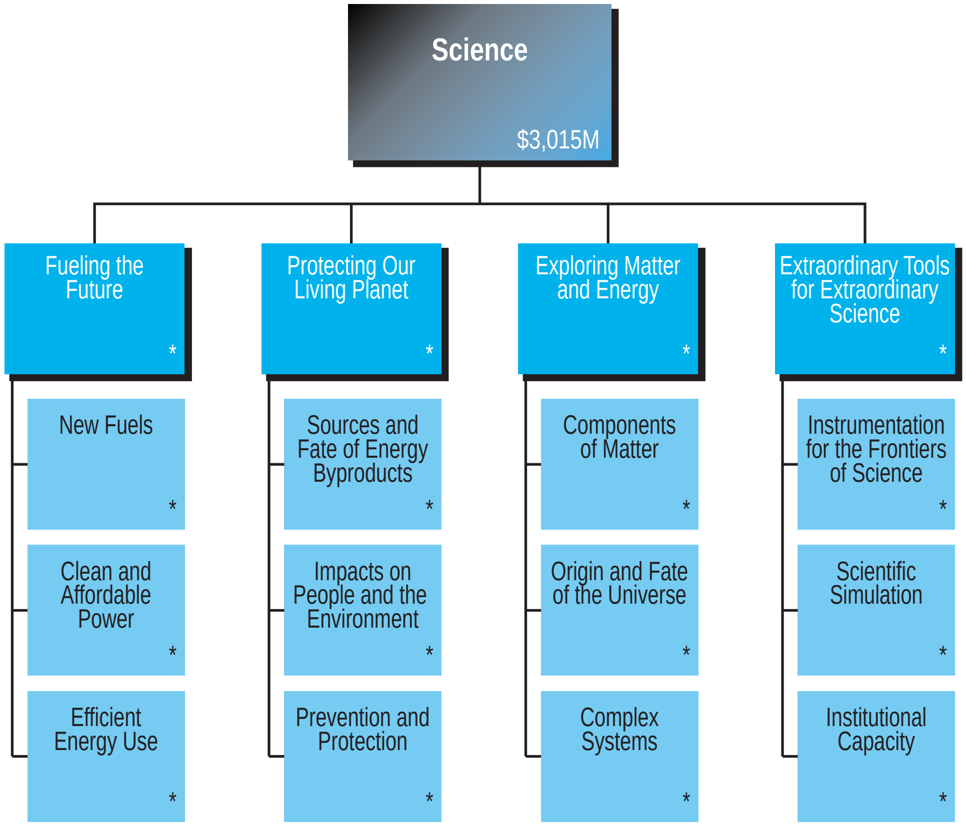
To advance the basic research and the instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.

With a focus on exploring the mysteries of the natural world, the Office of Science leads the nation in its support for the physical sciences. Powerful capabilities in computational science underpin many of these programs, and accelerators, light sources, neutron beam facilities, plasma and fusion science facilities, genome centers, and advanced computational centers are just some of the major instruments of science that distinguish DOE's capabilities and enhance the nation's science base and infrastructure.

Portfolio Framework and Major Focus

The science portfolio of the Department is contained within and managed by DOE's Office of Science. The Department of Energy is responsible not only for research in the basic sciences, but for maintaining the necessary infrastructure to conduct this research—the national laboratories, advanced instrumentation, computational abilities, the next generation of scientists, and supporting infrastructure. Beyond its own research programs, DOE operates many scientific facilities that provide open access to the nation's public and private sector scientists.

The Department has recently organized its research and science activities around four major science themes, reflecting a crosscutting perspective on the science goals of the agency. These themes constitute the major elements of the science R&D boxology, illustrated in Figure 17. The subelements of the portfolio define the major objectives that support and define the breadth and depth of the Science business line goal, as well as the scope of the corresponding research and related activities supported by the Department.



* Because investments appear in multiple research areas, there are instances of multiple counting, and the research area totals do not sum to the overall science business line budget.

Figure 17. Major Science R&D Themes

Detailed tables contained within the actual Science Portfolio, Volume 4 of the portfolio set, identify the distribution of Science R&D investments. Though the Science R&D investments are represented by a boxology similar to the other business lines, the Science Portfolio is actually structured by scientific disciplines rather than strategic objectives. The portfolio is portrayed by Figure 18. The investments in a given discipline may have greater or lesser relevance or impact on any given strategic objective and a direct one-to-one mapping of an investment to a strategic objective is not possible.

*DOE's Office of Science Budgets ($ Millions)**

	FY99	FY00	FY01
Basic Energy Sciences	759	720	963
Biological and Environmental Research	428	435	445
High Energy Physics	664	669	685
Nuclear Physics	321	330	350
Fusion Energy Sciences	216	238	240
Advanced Scientific Computing Research	153	125	175
Total All Other Science R&D Portfolio	154	144	*157*
Total	2,695	2,660	3,015

* Excludes Program Direction
** Totals reflect accurate summation of numbers above, each carried to significant figures not shown.

Figure 18. Distribution of Science R&D Portfolio by Science Disciplines

A distinguishing feature of the Department's basic science, and indeed basic science in general, is that it is primarily knowledge driven rather than application driven. That is to say, its main purpose is to *explore the complex phenomena and processes that define our physical world, to determine what factors influence them, and to understand how we may ultimately control them*. As such, discoveries usually have broad-reaching, diverse implications, not only for applied R&D and technology, but also for other scientific investigations, revealing investments with extremely high leverage and societal benefit. Scientific discoveries resulting from basic research have had an enormous impact on technology development.

It should be noted that the development of a portfolio in science requires a different approach, or at least a different frame of reference than that for applied research and technology programs. In the latter case, it is possible to link investments more closely with segments in the industrial sector and/or applied benefits to society that they produce. The issue then becomes one of performing tradeoff analysis of the desired, oftentimes competing objectives. Such an approach is much less valid for science, and most experts agree that the collective wisdom of the science community and the recommendations of technical advisory committees may do more to inform proper investments in science and subsequent breakthroughs in discovery and knowledge than any quantitative approach ever could. Appropriately then, the quantitative aspects of Volume 4 analysis are intended to provide some measure of additional insight into the general motivations and framework for our science investments—they are not intended to validate specific science investments.

Further guiding our analysis, eight *major goals* of a balanced portfolio were considered important.

Eight Goals for a Balanced Science Portfolio

(1) **Support vital science infrastructure**, including the national labs and advanced scientific instruments that will ensure the nation's future ability to conduct complex, multidisciplinary science; support a workforce of scientists prepared to meet our future science challenges

(2) **Maintain and build required core competencies**, in particular, those vital to our future science programs, such as scientific simulation, anticipating the needs and domains of science.

(3) **Provide strong support to DOE's applied research programs**, particularly the energy, environmental, and defense missions of the Department, ensuring research is responsive to broad categories of user-defined problems and barriers to technology development.

(4) **Support a balanced portfolio across the continuum of science**, from exploratory basic research to strategic basic research, the latter informed but not limited by potential applied research problems.

(5) **Examine connections at the boundaries of science disciplines**, recognizing that some of these offer the greatest potential areas for discovery in the years ahead and that required systems-level investigations/solutions will introduce a higher degree of scientific complexity than ever before.

(6) **Collaborate for greater science impact**, pursuing international collaborations for large fundamental science investigations and, to the extent possible, industry and university partnerships to increase the leverage of smaller scale, basic research.

(7) **Promote diversity of performers and diversity of ideas**, working to ensure that an open, competitive process enables the best and the brightest to flourish in a creative science environment, rewarding risk-taking, ingenuity, and excellence in pursuit of scientific discovery.

(8) **Expand access to science and to scientific results**, ensuring that research facilities and research results are responsive and easily accessible to the scientific community.

Changes and New Initiatives

Contained within the overall directions of research summarized in the Science Portfolio, there are some areas where emphasis and corresponding investment trends are changing. The motivations behind these changes are described in more detail in Volume 4.

Within the science theme of *Fueling the Future*, there is increased emphasis on the science that underpins carbon recycling and improved energy efficiency, simulation for combustion and materials, and fusion plasmas. De-emphasis is occurring in large pre-commercial fusion test facilities and in particular, fusion technology development.

Under *Protecting Our Living Planet*, there is increased emphasis on science for carbon sequestration, human and microbial genomics, structural biology, radiopharmaceuticals and functional imaging, biomedical engineering, the health impacts of low dose radiation, environmental remediation, regional climate modeling/simulation, and advanced monitoring and sensors. De-emphasis is occurring in radioisotope development and high-dose radiation biology.

Within *Exploring Energy and Matter*, there is an increased emphasis on science for complex systems and the underlying interdisciplinary mix that will enable advances on this frontier, neutrino science as well as accelerator and non-accelerator based investigations into the nature of energy and matter and the origins and fate of the universe, university research in high energy and nuclear physics, international collaboration on large high energy physics facilities, plasma turbulence theory and experiments, understanding the complete workings of a microbial cell, and functional genomics and investigations of the properties and implications of organisms in extreme environments. There is less emphasis on unilateral support for next generation high energy physics facilities.

Under *Extraordinary Tools for Extraordinary Science*, there is increased emphasis on advanced computation and associated hardware and software, imaging and visualization science and technology, scientific data management, upgrades to neutron science facilities and building the Spallation Neutron Source, collaboratories and interconnected science facilities, use of synchrotron radiation sources for research in the life sciences and structural biology, collaborations with the National Institutes of Health and the National Science Foundation and others on facility design and use, and science education. Also, there is increased attention to R&D on the Next Linear Collider, a proposed electron-positron collider for high energy physics research, with the goal of significantly reducing costs by applying such techniques as “design for manufacture” and with Fermilab joining to form a four-lab U.S. partnership. De-emphasis is occurring in the continued support for outdated experimental facilities.

Aside from these general trends, there are new or expanded areas of science emphasis in FY 2001 as highlighted below:

- ***Nanoscale science***, engineering and technology research to understand how deliberate tailoring of materials can lead to new and enhanced functionality and to provide new experimental and computational modeling tools for nanoscale research. *($36 M)*.

- ***Advanced scientific computing***, including computational modeling and simulation in broad areas of fundamental science *($51 M)*.

- ***Biomedical engineering sciences***, capitalizing on unique instrumentation at DOE’s national labs that enable the advancement of fundamental concepts in biologics, materials, processes, implants, devices and informatics systems for subsequent prevention, diagnosis, and treatment of disease *($5 M)*.

- ***Microbial cell research*** aimed at understanding the complete workings of a microbial cell to help meet needs in many diverse research areas such as energy, bioremediation, and carbon sequestration *($12 M).*

- ***Climate Change Technology research***, a program addressing carbon management in areas of science for efficient technologies, fundamental science underpinning advances in low/no-carbon energy sources, and sequestration science *($4 M)*.

- ***University-based research in robotics and intelligent machines*** for future applications important to DOE missions and to enable remote access to the DOE Office of Science user facilities *($2 M).*

- ***Construction of the $1.4 billion Spallation Neutron Source*** at Oak Ridge National Laboratory to regain the U.S. position of international leadership in neutron scattering for the physical, chemical, materials, polymer, and biological sciences *($163 M).*

- ***Support for scientific user facilities*** by providing funds to optimize operating time and user support to serve more than 15,000 scientists in academis, industry, and federal laboratories who use these facilities annually. *($68 M).*

- ***The Large Hadron Collider***, reflecting continued participation in the foremost High Energy Physics facility of the next decade.

Research Accomplishments

DOE's science programs have a long and rich history of remarkable discoveries leading to 70 Nobel Prizes awarded to scientists supported by DOE—a total that far surpasses that of any other public or private institution. Recent scientific breakthroughs that were the result of DOE supported research include:

- The journal *Science's* 1998 Discovery of the Year for innovative experiments looking at supernovas and redshift that indicate that the universe is expanding at an accelerating rate, suggesting a strange and yet-to-be explained property of space.

- Genomic sequencing that confirmed a third kingdom of life on Earth, completed 300 million base pairs of draft and high quality human DNA, and coded select microbes that have important implications for bioremediation and carbon sequestration.

- World record for sustained fusion reaction in both length of reaction and peak energy.

- Discovery of the top quark, the last, unusually large subatomic element that helps flesh out the Standard Model.

- Calculation of Black Hole entropy from super-string theories.

- Improved high temperature superconductors through research into pairing mechanisms and vortex physics.

- Potential new ways to store hydrogen through the discovery of new graphite nanofibers that can store three times their weight of hydrogen.

- Computational ability that recently exceeded 1 teraflop in sustained performance for an application.

- Artificial photosynthesis through research into light-matter interactions and solar photochemistry.

- Collaboration in the development of a photovoltaic cell that holds three world records for efficiency.

- Improved miniaturization through research into nanowires: "magic structures" and conductance quantization.

- Improved models and measurement of the carbon cycle, the phenomenon of global warming, and the role of cloud formation.

- A tenfold increase in the electrical conductivity of semiconductors through research into gallium injection.
- Development of the current generation of high energy, power lithium and lithium ion batteries from research into non-aqueous electrolytes.
- Treatment of disease/addiction derived from PET brain imaging studies.

Path Forward

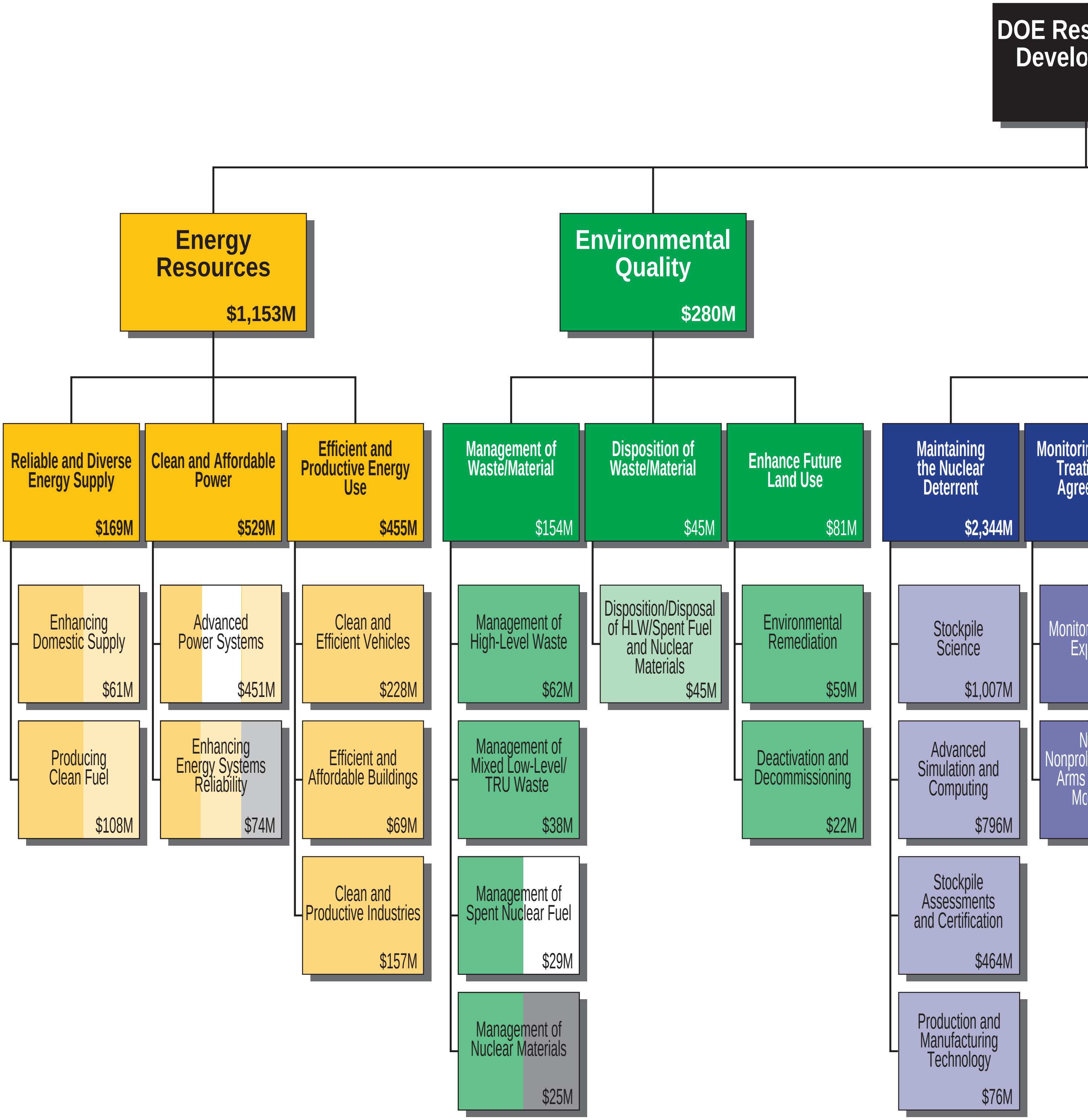
Over the past two years, the Department has prepared this new strategic framework to enhance its long-term thinking. It is a framework that reveals new opportunities across the boundaries of science disciplines, and one that identifies the major science themes and corresponding science challenges that, in keeping with our mission, define our purpose and guide our long-term actions.

Recently, and stemming from the early insights of the strategic planning and portfolio development efforts, the Office of Science launched efforts to develop detailed roadmaps in several areas of science investigation: complex systems, carbon sequestration, non-defense scientific supercomputing, and science facilities. Unlike either the Science Portfolio or the Science Strategic Plan, the roadmaps chart the *necessary steps* and *sequence* to achieving a desired end goal. This path includes considerable *detail* at the research and activity level, and relative to the Portfolio level, extends over a longer time-frame. Undoubtedly, the need for additional roadmaps will emerge over time and will be the subject of analysis.

Collectively the Science Portfolio, the Science Strategic Plan and these emerging Science Roadmaps help to ensure that Department charts a promising path forward. Coupled with a rigorous scientific advisory committee and peer review process, these combined efforts ensure that not only promising research directions are pursued, but that the highest quality of science is realized.

Appendix A

Research and Development Portfolio "At-a-Glance" (Boxology)

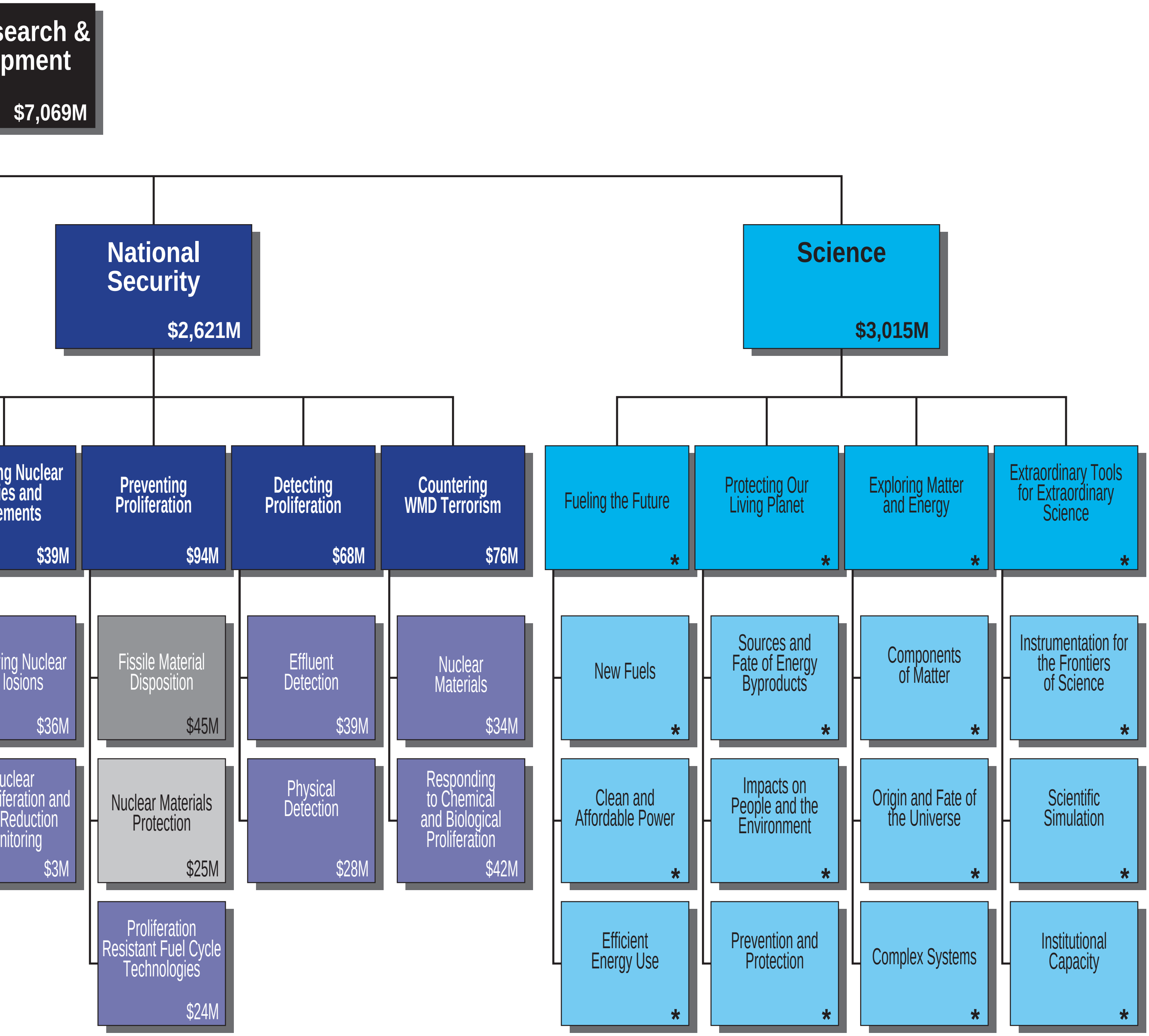


U.S. Department of Energy

Research and Development Portfolio

Funding data are based on FY2001 Congressional Budget Request

The Research and Development Portfolio Volumes are available at http://www.osti.gov/portfolio



- Energy Efficiency and Renewable Energy
- Fossil Energy
- Environmental Management
- Office of Civilian Radioactive Waste Management
- Defense Programs
- Office of Nonproliferation and National Security
- Office of Science
- Office of Fissile Materials Disposition
- Office of Security and Emergency Operations
- Office of Nuclear Energy, Science and Technology

* *Because research investments in Science support multiple strategic objectives, the investments are not broken out separately by individual strategic objective.*