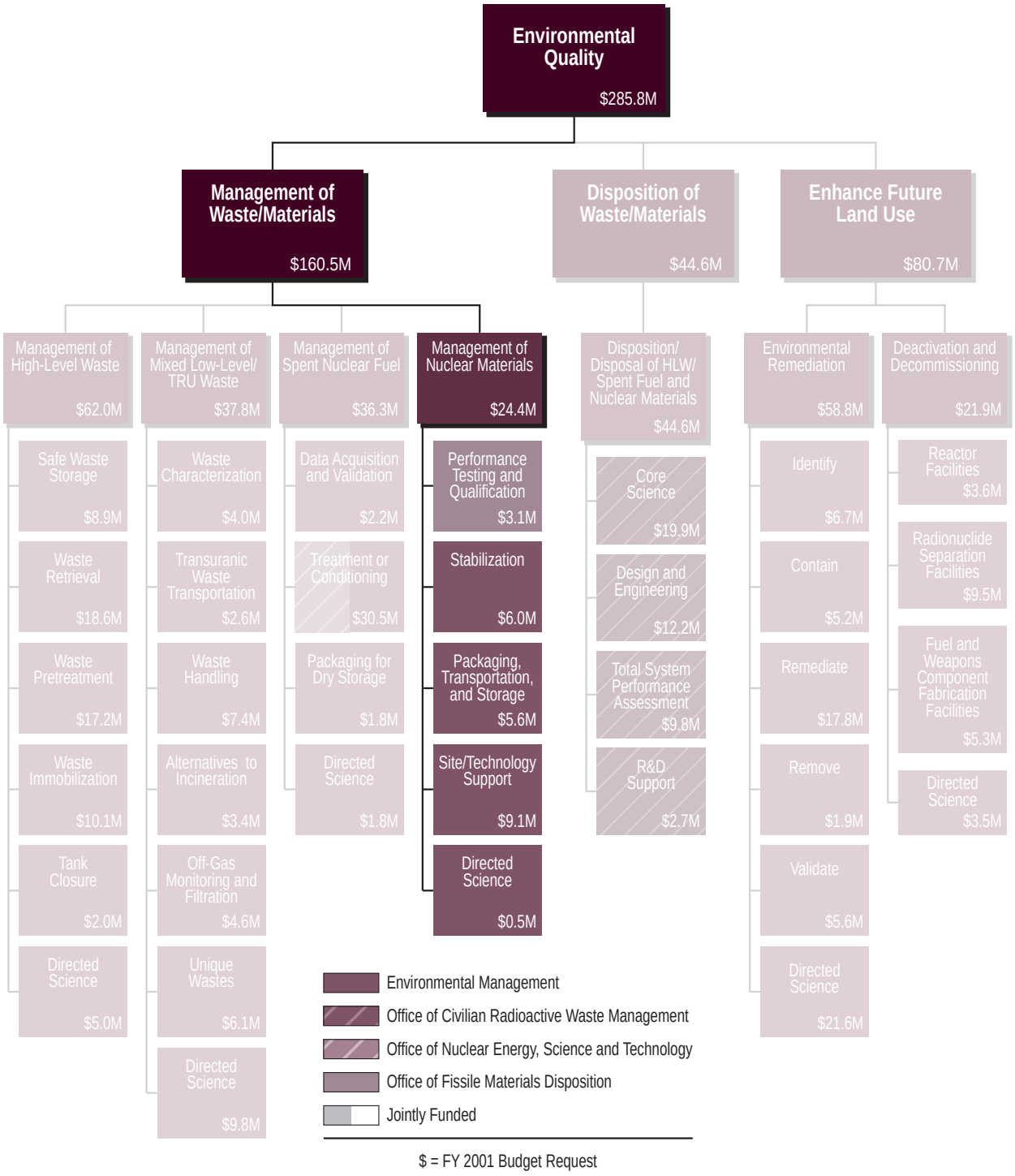
# Chapter 6
# Nuclear Materials



# Chapter 6
# Nuclear Materials

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## Overview

### *Definition of Problem Area*

A primary mission of the Department of Energy (DOE) and its predecessors has been the national security of the United States. Since the Manhattan Project, the DOE and its predecessors have produced special nuclear materials and manufactured nuclear weapons. This historical emphasis underwent a significant change beginning in 1989. The Cold War ended and the START series of treaties dramatically decreased the needed inventory of nuclear weapons. As a consequence, considerable quantities of nuclear materials that had previously been deployed around the world as nuclear weapons components were returned to the Department. The reduced threat to the nation and the treaties into which the nation entered caused a large portion of these materials to become surplus to needs for the national defense, and DOE initiated a major program to disposition these materials in a way that would be non-proliferant. Also, the significant reduction in the nuclear weapons stockpile, and the corresponding reduction in requisite weapons production capacity, presented DOE with an opportunity to downsize its weapons complex and to close a number of facilities and sites.

Approximately 200 metric tons of U.S. weapons usable fissile materials have been determined to be surplus. The DOE Office of Fissile Materials Disposition (MD) is responsible for the disposition of this material, which will be accomplished either by burning the material in electricity-producing commercial reactors to produce spent fuel, or immobilizing the material with high-level waste for disposal. All EM weapons-usable materials not disposed of as waste will be transferred to MD at a point in time yet to be determined. The buildings currently housing this material cannot be decommissioned while the materials are present. Hence, the removal of the materials is on the critical path for closure of facilities and sites such as Mound and Rocky Flats.

Growing concerns about safety and environmental problems caused the Department to temporarily suspend various operations throughout the weapons complex in the late 1980s and early 1990s. Many of these shutdowns became permanent with the end of the Cold War and the collapse of the Soviet Union. However, because the shutdowns were viewed as temporary at the time, the Department did not make long-term storage or disposition plans for surplus materials prior to suspending operations. For the same reason, the halt in weapons production that began in 1989 “froze” the manufacturing pipeline, leaving it in a state that posed significant risks. These risks were identified in three vulnerability assessments (spent nuclear fuel, plutonium, and highly enriched uranium) undertaken by DOE and in DNFSB Recommendations 94-1, 97-1 and 2000-1, dealing with high risk forms of special nuclear material. Subsequently, DOE has established implementation plans to eliminate or reduce these risks. Also, DOE has entered into a variety of stakeholder agreements governing on-site inventories of radioactive materials, schedules for facility and site closure and related matters.

Another material of concern to the Department is depleted uranium hexafluoride. Comprising over 700,000 metric tons, this inventory is the focus of a program to convert the material to a more stable form. The program’s research and development activities are focused on development of beneficial uses and assuring paths to disposal, as required. Detailed information

concerning this program's research activities will be provided in the next revision of this portfolio.

The estimated costs for management and disposition of DOE's nuclear materials are shown in Figure 6-1.

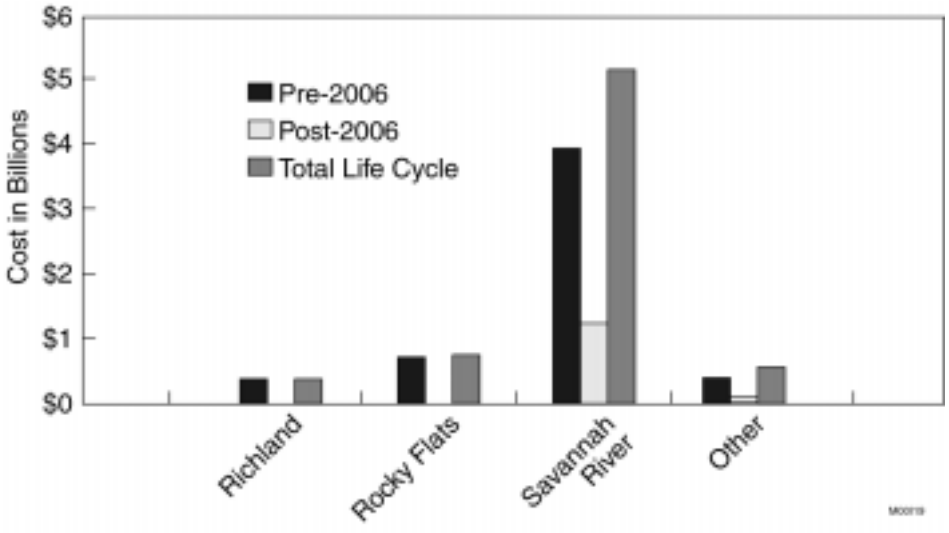


*Figure 6-1. Through 2006, Post-2006, and Life Cycle costs for managing nuclear materials.*

***National Context/Drivers and Federal Role***

The nuclear material inventories around the country are viewed as a safety and environmental problem. The safety issues have been identified in various DOE assessments and DNFSB recommendations. The safety issues arise primarily from the relatively unstable form in which the nuclear materials have been kept. Stabilization of these materials is required for safe storage. It is also required before inventories can be removed from buildings to be decommissioned and, ultimately, transferred from the sites.

Further, U.S. surplus inventories have been offered for International Atomic Energy Agency (IAEA) safeguards. Some surplus materials at RFETS and Hanford are already under IAEA Safeguards. Stabilization of much of the surplus inventory is required to put them in a form that allows such safeguards to be put in place.

The United States has determined that excess weapons-usable fissile materials in the U.S. and in Russia pose a threat to national and international security due to the potential for global proliferation. Conversion of these materials to a form that makes them difficult to divert and/or use in nuclear weapons is essential for reducing these risks. The U.S. and Russia are currently negotiating disposition agreements.

***Linkage to DOE Strategic Goals and Objectives***

Nuclear materials R&D initiatives strongly support several DOE Strategic Plan Environmental Quality Goals and Objectives, as shown in Figure 6-2. Stabilization of the various forms of

material into forms suitable for storage supports EQ1 (Reduce the most serious risks). It is also essential for accomplishing the removal of nuclear materials from RFETS, which is on the critical path for site closure (EQ2 - Clean up as many sites as possible by 2006), as well as EQ3 (dispose of waste generated and make disposal ready). The R&D also has a role in reducing life-cycle costs of cleanup (EQ6), because delays in addressing nuclear materials requirements will delay cleanup activities.

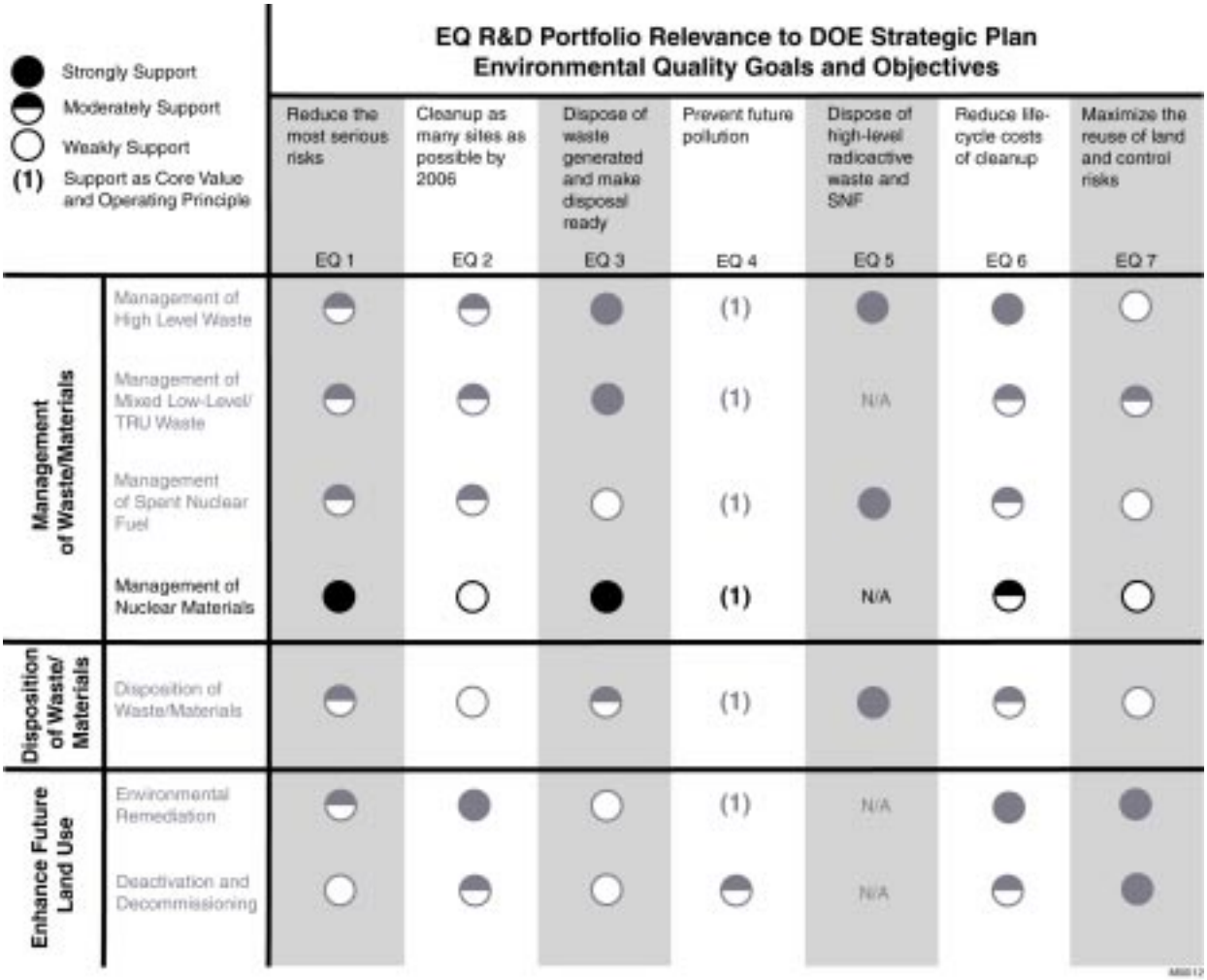


*Figure 6-2. Relevance of nuclear materials R&D investments to Environmental Quality goals and objectives.*

### *Problem Area Uncertainties*

A significant uncertainty in this Problem Area is the limited knowledge of the specific characteristics of the items that comprise the nuclear material inventory. There has been some characterization of higher-risk items around the complex; however, many items will never be completely characterized. Historical databases have detailed information on nuclear material content, but little information on other constituents in the items. This imposes uncertainties in how these items need to be treated to achieve a stable product that can safely be stored for up to 50 years.

Another area of uncertainty results from the complex, interconnected strategies and plans for managing materials at DOE sites. Changes in plans, or unanticipated events at one site, with other DOE programs or in transportation can seriously impact requirements at another site, requiring changes in technical approaches for dealing with these materials. This requires Nuclear Materials R&D personnel to be acutely aware of the coordination of national strategies.

***R&D Investment Trends and Rationale***

Figure 6-3 illustrates the current R&D investments for nuclear materials management.

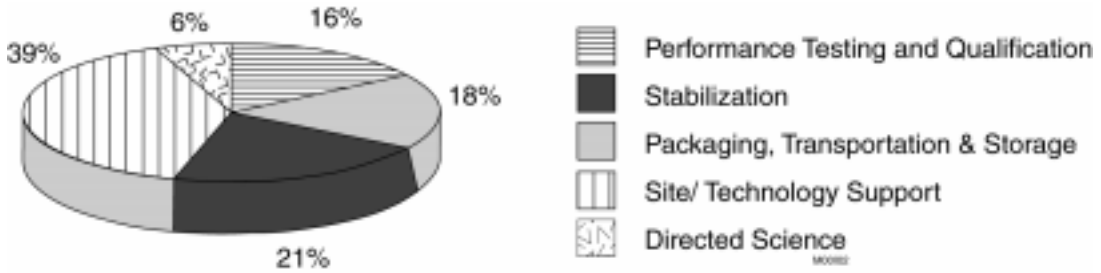


*Figure 6-3. Cumulative investment in nuclear materials areas over 3 years (FY 1999–FY 2001).*

Trends in technology development funding follow generally the perceived needs, confirming that funds are being spent on the most important issues. To date, stabilization has been a major element for the program. However, that funding is projected to decrease over the next few years as materials are stabilized, or as low risk disposition paths are identified. Site technology support will become more important, reflecting the increased concern over storage, surveillance, and removal of radioactive sources from the closure sites.

***Key R&D Accomplishments***

Key accomplishments have involved developing stabilization technologies, characterizing materials, expanding the technology base for safe storage, and developing surveillance and monitoring approaches. Specific accomplishments are outlined below:

- Developed technologies for the stabilization of plutonium pyrochemical salt process residues.
- Developed technologies for combustible residue stabilization.
- Developed vitrification techniques for ash, graphite, and sand, slag & crucible residues.
- Characterized and stabilized representative Rocky Flats and Hanford plutonium items.
- Developed moisture measurement methods to certify material stability after processing.

- Solidified the technical basis for storage of impure plutonium oxides.

***Key R&D Issues***

The most important R&D issues are ensuring that the efforts are as relevant as possible to evolving site needs, requirements, and constraints, and that R&D priorities adequately reflect site schedule drivers. The strategy for developing technology is to identify needs, solicit technology alternatives, recommend acceptable technology choices and monitor performance and progress. Programmatic risk assessments of baseline and competitive alternative technologies based on technical maturity and need date provide the basic elements for prioritization.

## Problem Area R&D Program

Budget: FY99-$25.3M, FY00-$22.2M, FY01-$24.4M

***Program Description***

The scope of DOE activities includes surplus plutonium materials, special isotopes, and other fissile materials. DOE is working on solutions to site-specific and complex-wide technology issues associated with nuclear material risk reduction, stabilization, and preparation for disposition to:

- Expedite complex-wide progress toward cleanup and site closure.
- Standardize resolutions, practices, and equipment systems.
- Promote integration to meet established requirements.
- Produce more cost-effective programmatic results.

Currently, the EM technology development projects are derived in the Nuclear Materials Focus Area FY2000-FY2004 Multi-Year Program Plan, November 1999, DOE/ID-10728, and the technology needs identified by field offices. This plan identifies gaps in technology that may pose significant worker and public safety risk and/or programmatic risk to timely nuclear materials disposition and, hence, site closure. This program plan recommends projects intended to enhance and expand existing scientific data to handle, process, store, and safely disposition nuclear materials by resolving gaps in existing technology. Most of the focus in the past has been on plutonium. That approach is being broadened to systematically evaluate disposition paths of other nuclear materials as well. The nuclear material program also provides technical support to field offices, develops and maintains core competencies, and provides technical support for short-term critical issues associated with site de-inventory, cleanup and shutdown.

### Performance Testing and Qualification for Repository Disposal

Budget: FY99-$4.4M, FY00-$4.2M, FY01-$3.1M

**Description.** The Department plans to disposition surplus weapons-usable plutonium by transforming this material to forms not readily accessible for use in nuclear weapons, i.e., the spent fuel standard. Two forms are under consideration: the mixed-oxide spent fuel and an immobilized plutonium form encapsulated in high-level waste canisters. To support current Departmental plans to dispose of these forms in a federal geologic repository, two distinct and parallel efforts are underway: Performance Testing and Form Qualification. The Performance testing effort is designed to support analyses for the Repository License Application. The purpose of the Form Qualification effort is to demonstrate that the plutonium forms meet deep geologic disposal requirements. Lawrence Livermore National Laboratory is responsible for providing thermochemical and physical property data, and a long-term dissolution model of the ceramic form. Argonne National Laboratory is responsible for conducting both short-term and long-term tests to study the dynamic behavior of the ceramic material. Pacific Northwest National Laboratory is responsible for examining

the effects of radiation damage on the physical and chemical properties of the ceramic form and for providing thermochemical data on various complex chemical systems.

**R&D Challenges:**

The R&D effort establishes tests required to support the development of models that completely characterize the behavior of a new high-performance ceramic form containing plutonium under the potentially challenging environment of a geologic repository. These tests are difficult to perform because most of the elements of concern are below measurement detection limits. Another technical challenge is the development of a long-term dissolution model that can adequately predict the dissolution rate of the ceramic form in such a complex environment as that of the repository, coupled with the many uncertainties that exist regarding unanticipated future events. Other challenges also include the lack of important thermochemical data associated with key chemical elements that are unique to the plutonium form. Significant data gaps identified in the solubility database of materials will need to be filled in. These specifically relate to the likelihood of solid phases forming in repository water chemistries that have not been previously observed or characterized.

**R&D Activities:**

A series of short-term (a few days) and long-term (years) dissolution tests designed to characterize the degradation behavior of the high-performance ceramic forms are being conducted. Short-term tests are designed to provide an estimate of the forward dissolution rate and serve as a comparative test between samples. Long-term tests are designed to characterize the corrosion behavior of the ceramic form. These tests will also provide information on the interactive effects of the ceramic with the high-level radioactive borosilicate glass, colloids formation, and the effects of temperature and pH on the dissolution rate. Radiation damage due to alpha decay of plutonium is also being studied. Test results will then be used to synthesize a consistent model to identify the rate-limiting process. These data will also be used to support criticality analyses, and performance assessments of the geologic repository.

In addition to the short-term and long-term dissolution tests, a number of other tests are also being conducted to obtain thermochemical data of different phases comprising the ceramic formulation, and other complex chemical systems, including gadolinium, hafnium, uranium phosphates, plutonium phosphates, and titanium oxide.

To demonstrate that the plutonium form qualifies for the repository, the Form Qualification effort will develop the acceptance specifications for the plutonium product, show how compliance with these specifications will be met, and demonstrate compliance through tests. A significant effort in the qualification process will be the development of the Product Control Model. This Model will quantitatively relate the mineralogical composition of the form as a function of input composition and processing conditions.

**Accomplishments:**

- Completed Ion Irradiation Study.

- Completed Fabrication of Pu238 doped ceramic for radiation damage study.
- Completed report on solubility of titanium dioxide
- Completed report on Pu phosphate solubility.

**Stabilization Process Development**

Budget: FY99-$5.2M, FY00-$4.1M, FY01-$6.0M

**Description.** Stabilization to rather stringent specifications is required for plutonium and other nuclear materials that are to be placed in long term storage. It is also often required prior to shipment to other sites. Residues generally need not meet such stringent stabilization criteria, but still must be stabilized to the extent that they may be safely dispositioned either for fissile material recovery, or may be emplaced in a waste repository (i.e., they must meet the repository waste acceptance criteria).

The term “stabilization” can also include any mechanism that will effect a change in the character of the materials being processed. This includes conversion of weapons components to unclassified forms, removal of surface plutonium contamination, separation of elements (such as plutonium and uranium), conversion (such as conversion from a metal to an oxide), and various aqueous and pyrochemical processes that may be used to handle materials such as radioactive sources and high fissile content residues. The research efforts associated with this “expansive” interpretation span a wide variety of technologies but are all directed at placing materials into a form that will support satisfying closure site requirements.

This work package includes international coordination initiatives that are primarily concerned with identification, development, demonstration and deployment of promising technologies that have application in foreign countries, particularly the Former Soviet Union. Of special interest nuclear materials R&D are techniques for stabilizing problematic actinide residues and waste solutions. Russian collaborative research projects are funded by the U.S./Russian Joint Coordination Committee for Environmental Management (JCCEM). Current coordination efforts involve the development of a Russian technology that provides an alternative to the vitrification process for stabilizing problematic liquid waste. The final waste form is a stable ceramic material, suitable for safe transportation and treatment or long-term storage. Verification testing, first with surrogate materials and finally with solutions in inventory, will provide the basis for processing, cost and schedule comparisons.

**R&D Challenges:**

The major challenge in the area of stabilization is the lack of specific knowledge about the non-SNM constituents of the materials to be stabilized. This lack of knowledge imposes a requirement for stabilization processes that are forgiving of a wide range of constituents. A second challenge is the fact that site baselines change with time, causing R&D needs to change accordingly. In some cases complete disposition paths either have not been identified, or the paths selected continue to have significant technical risk. In many cases the development of alternatives to the traditional methods of material processing is required due to facility closure or by stakeholder agreements. In any case, R&D must be applied to

facilitate selection of a disposition path and to minimize the risk associated with the paths selected.

**R&D Activities:**

*Actinide Solution Stabilization Technologies*: Liquid actinide solutions have posed some of the most serious risks. Techniques for precipitation of plutonium solutions largely have been developed and implemented. Technologies for vitrification of americium and curium in solutions are currently being developed.

*Plutonium Residue Stabilization Technologies* : Stabilization technology development efforts have been initiated for treating pyrochemical salt residues, ash residues, graphite fines, crucibles, combustibles, and fluorides. Several approaches were suspended based on trade study recommendations and determination that some materials could be directly discarded. Some other approaches are entering a deployment phase. R&D efforts are being brought to conclusion for the majority of the residue inventories. There will likely be additional technology needs established as the remainder of the residue inventories are evaluated and characterized.

*Characterization of PFP, RFETS, SRS, LLNL, and LANL Materials*: Lack of chemistry and physical characterization of site materials limits the identification of effective stabilization processes and the understanding of the performance of each item in a storage container after stabilization and packaging. Characterization and stabilization parameters investigation for materials from each of the sites continues.

*U-233 Stabilization Technologies*: The execution of DOE's Implementation Plan for DNFSB Recommendation 97-1, "Safe Storage of Uranium-233," has accelerated the inspection, chemical stabilization, and repackaging of selected 233U materials.

*Aqueous Processing:* In the area of aqueous processing, research will address the special problems of processing certain Rocky Flats residues in the Savannah River canyons as well as alternatives to canyon processing to separate uranium from plutonium.

*Decontamination:* Technology will be developed to remove plutonium surface contamination, primarily from uranium parts, so that the uranium can be reused by other programs.

*Declassification:* Other research will develop technologies to remove the classified characteristics of components remaining at the Rocky Flats within the operational constraints of the site

**Accomplishments:**

*Salt Oxidation:* Salt oxidation has been developed and deployed at RFETS. The process oxidizes constituents that could exhibit pyrophoric behavior and generate hydrogen in storage.

*Salt Distillation:* Partway through development, it was determined that a separation step was not necessary for disposal of RFETS salt residues. However, the technology is being deployed at Los Alamos for recycling salt in ongoing pyrochemical operations, thereby eliminating a significant waste stream.

*Vitrification:* This approach was tested for treatment of sand, slag, and crucible residues, graphite fines, and incinerator ash. The primary application was suspended because these items could be discarded to WIPP without further treatment. However, vitrification is being deployed at LANL as a replacement for cementation in waste operations in order to increase the loading of waste containers.

*Phosphate Bonded Ceramics*: Chemically-Bonded Phosphate Ceramics have been demonstrated as a highly stable, leach-resistant means of immobilizing Pu-bearing ash and ash heel. This technology is also expected to prove useful for many other DOE complex wastes.

*Polycube Pyrolysis*: Pyrolysis uses a high-temperature inert environment to break down and volatilize polymeric materials. A pyrolysis furnace and off-gas treatment apparatus have been successfully demonstrated Deployment at Hanford is being deferred while approaches that use existing Hanford equipment are being evaluated. A pyrolysis unit is being deployed at LANL to treat combustible materials.

*Characterization of PFP, RFETS and LANL Oxides:* Pre- and post-stabilization samples of materials expected to be packaged for long-term storage have been characterized to verify the efficacy of the stabilization process. Additional materials from RFETS and SRS are being sent to LANL for evaluation.

*RFETS Residue Stabilization:* Process development is complete in the Borax/$PuF_4$ shake test, the $CCL_4$/HCl uptake on granulated activated carbon, aqueous fluoride precipitation, and fluoride cementation.

*Electrolytic Decontamination:* Developed and implemented electrolytic decontamination of gloveboxes, nuclear materials containers and HEU at Rocky Flats and Richland.

**Packaging, Transportation and Storage**

Budget: FY99-$4.0M, FY00-$3.1M, FY01-$5.6M

**Description.** The primary activities in packaging and transportation are developing the technology base for DOE storage standards and resolving shipping container certification issues. The most pressing current issue in packaging, transportation and storage of nuclear materials is bounding the generation of gas, particularly hydrogen gas, within the nuclear materials package. The gas generation rate must be estimated to properly assess safety issues during transportation and storage. Alternatively, some means must be found to mitigate the effects of gas generation. In the future, ALARA-based techniques, such as glovebox automation technologies and new systems for repackaging nuclear materials may become a part of this work scope.

Long term safe storage of nuclear materials is an essential element of the Department's nuclear material management strategy. Long-term storage is differentiated from shorter term storage by the length of time the material is in storage (typically, up to 50 years or longer) and by the desire to minimize personnel exposure from surveillance during the storage period. LANL and SRS are collaborating to develop an integrated surveillance plan to identify the activities to monitor a statistical sampling of the 3013 packages produced at DOE sites.

**R&D Challenges:**

The diversity and limited characterization of impure materials makes it challenging to develop a comprehensive technical basis for safe storage criteria. In addition, there are limitations in the understanding of detailed phenomena and processes that occur in long-term storage packaging systems.

Effective surveillance is a balance between the scope of package examination, together with the number of packages examined, and the cost of that surveillance in terms of financial resources and personnel exposure. A major challenge will be the establishment of an effective program while minimizing the associated costs. Storage of radioactive materials and their reactive impurities at elevated temperatures for such long periods presents a number of technical challenges. These include the difficulty in adequately simulating the temperature environment (to assess temperature dependent effects) and the fact that some forms of corrosion (such as stress corrosion cracking) exhibit a different time dependence than "ordinary" corrosion. Technologies to permit the monitoring and interrogation of storage containers without violating the integrity of the package are limited. Surveillance and monitoring equipment and systems may be complicated by the need to allow for IAEA inspection of excess materials.

**R&D Activities:**

R&D activities are supporting the development of DOE Standards for nuclear material storage including testing representative samples of the inventory to assure that stability requirements can be met, and developing technologies to certify that stability has been achieved.

This effort also involves accumulating an inventory of representative materials to monitor in a shelf-life program, and developing a complex-wide resource for testing of sensor, measurement, and integration technologies for monitoring and surveillance of materials in storage. In addition, this effort will perform detailed investigations of the potential corrosion problems and other phenomena in this environment. Accelerated aging studies will be used to anticipate material chemical and physical changes under appropriate storage conditions. Efforts will begin to develop a predictive model to identify potential storage problems and determine ultimate storage limitations.

**Accomplishments:**

*Materials Identification and Surveillance:* Representative samples of inventories around the country have been accumulated and tested to verify that stability requirements can be met. It was determined that ~80% of the materials to be stabilized could not be certified with the baseline approach for moisture measurement, prompting the development of alternative certification approaches.

*Moisture Measurement:* Two additional techniques for moisture measurement in nuclear materials have been evaluated as an alternative to loss on ignition (LOI) testing. The super-critical fluid extraction method is fully developed and is being deployed at LANL, RFETS and Hanford. Development work continues on a neutron moderation method.

*Storage Container Pressurization*: Mechanisms for generating pressures in the sealed storage containers were evaluated and tested to confirm the adequacy of the DOE storage standard.

*Gas Generation:* A workshop on gas generation and mitigation in nuclear materials ranging from plutonium oxide to TRU waste and mixed waste has been established as a means of sharing available information and focusing future research.

*Container Corrosion:* The severity of corrosion as a threat to container systems has been evaluated to support the storage standard development and clarify surveillance requirements.

*Update of DOE-STD-3013:* The technical basis for storage of plutonium metal and oxide was expanded to include the ability to store impure items. The DOE Standard was updated accordingly.

*Plutonium/Container Interactions:* Experiments and associated finite element analyses have been completed, showing that phase transitions in the plutonium and plutonium-stainless steel interactions do not threaten the container integrity.

*Surveillance of 3013-94 oxides and Metals:* Oxides and Metals were sealed in 3013-94 type containers with bellows to monitor pressure changes. These containers have been monitored for over 2 years with no significant pressure change indicated.

*Surveillance of 10-g items:* Representative samples from RFETS and Hanford plutonium holdings have been stabilized and placed in instrumented containers. These containers have been monitored for over 2 years with no significant pressure change indicated.

**Site Technology Support**

Budget: FY99-$9.5M, FY00-$9.1M, FY00-$9.1M

**Description.** This work package consists of two interdependent activity areas, Core Technology and Site Technical Support. Core Technology addresses the need to understand the science underlying nuclear materials stabilization, packaging, transportation and storage. It provides basic research on the wide variety of nuclear materials and their interactions with other materials, particularly storage and transportation container materials, processing facility materials of construction, and so forth. The objective is to improve the

understanding of observed phenomena and to increase the ability to anticipate problems. In addition, personnel involved in Core Technology efforts comprise a cadre of expert personnel available to deal with urgent site issues associated with development, demonstration and deployment of evolving technologies.

It is anticipated that during implementation of materials stabilization, packaging, shipping, and subsequent facility clean-up, and extending until all nuclear materials have been transferred to some other Program, EM sites and programs will have nuclear materials management activities that require routine technical support. Site Technology Support provides the expertise, coordination, and leadership to address these issues.

**R&D Challenges:**

The major challenge is to anticipate the site technical issues so that expert personnel and timely results are available to address their concerns. At the present, major areas of interest are related to issues that are expected to be important to storage and transportation of nuclear materials, as these are the areas that have the highest likelihood of causing delays in site closures.

Another key challenge is the result of the complexity and diversity of the nuclear material inventories, and the lack of comprehensive plans for managing all the materials that exist at DOE sites. One example is the handling of sealed sources. The issues involve the numbers of types of sources, their possible reuse, the advisability of recovering the contained SNM, etc.

**R&D Activities:**

A major element of this area is likely to be supporting implementation of stabilization approaches and support for de-inventory initiatives. Core Technology support includes the following areas for plutonium materials: actinide thermochemistry and phase behavior, actinide surface chemistry, corrosion, radiation chemistry and microdosimetry on impurities, plutonium-stainless steel interactions, and water interactions with U/Pu surfaces.. Another major element is expected to be a complex-wide approach to removing and dispositioning the wide variety of sealed sources at the closure sites. This might be extended to consider excess sealed sources at other sites, as well.

**Accomplishments:**

*Stress Corrosion Cracking:* Evaluated stress corrosion cracking (SCC) potential in a stainless steel container with chloride-containing oxide materials stabilized to the 3013 standard. Determined that moisture content is the critical parameter and that SCC should not threaten the 3013 container.

*Plutonium-Stainless Steel Interactions:* Evaluated the likelihood of eutectics or intermetallics occurring during 50 years of storage at expected 3013 storage temperatures. Determined there was no threat to the container.

*Pressurization Mechanisms:* In support of the DOE-STD-3013 revision, a kinetic model of the 3013 system was developed to explore phenomena that could contribute to pressurization.

*Technical Basis for DOE-STD-3013:* Many topical peer-reviewed reports have been generated to formalize the technical basis for the plutonium storage standard.

*Site Support:* Short-term support has been provided to RFETS to support disposition of residue items to WIPP and address problems with corrosion of drum vent filters.

*Sealed Sources:* Efforts to establish a coordination center for sealed sources have been initiated, and effort expended to resolve source-related issues at Mound and Fernald.

**Directed Science**

Budget: FY99-$2.1M, FY00-$1.8M, FY01-$0.5M

Within the Nuclear Materials investment portfolio, DOE funds research that advances science to solve environmental problems associated with unstable materials, such as plutonium metals and oxides, highly enriched uranium and nuclides of other actinide elements, and their long-term storage. Five subcategories of needs were identified in the area of nuclear materials:

- Nuclear materials stabilization, including forms for long-term disposal.
- Treatment methods for fissile materials.
- Characterization of fissile materials behavior; thermodynamics and kinetics; interactions with organometallics, surfaces and organic residues; stabilization and storage.
- Development of methods to verify integrity of storage containers, detect and/or prevent hydrogen buildup.
- Development and maintenance of robotic technology to minimize personnel exposure and handling of storage containers.

Between 1998 and 2000, eight research projects will be funded for a total amount of $5.5 million. The nuclear materials directed research portfolio is concentrated in the scientific areas of actinide chemistry, analytical chemistry and instrumentation, engineering science and materials science.

- *Actinide Chemistry:* Challenge of nuclear materials stabilization, as well as efforts directed at waste minimization/pollution prevention associated with continued actinide processing activities and waste-form and spent fuel stabilization assessment. A second study of actinide chemistry research is to develop a basic scientific (thermodynamic) understanding of actinide volatilization and partitioning/speciation behavior in the thermal processes that are central to DOE/EM's mixed waste treatment program.

- *Analytical Chemistry and Instrumentation:* Developing a new analytical instrument based on the principle of nuclear magnetic resonance (NMR) for in situ, in-field and in-process characterization and monitoring of various substances and chemical processes. Its development will involve application of the most recent advances in the fields of micromachining and microfabrication, permanent magnet materials and design, and microelectronics and signal processing.

- *Engineering Science:* Engineering science research in this area is specific to design, process and modeling to address criticality safety issues of interest in ongoing activities to dispose of DOE-owned spent nuclear fuel, and to assure criticality safety of fissile materials during facility remediation. Specifically, the research includes the utilization of novel computational techniques, improved nuclear data, and new analytical methods.

- *Materials Science:* Chemical and structural properties of storage materials, and radiation effects on storage materials. Research projects include physical and chemical properties of monazite, pyrochlore, zircon, and zirconolite as ceramic waste forms; distributions, solubilities, and releases of radionuclides and neutron absorbers in waste forms; and characterizing the effects of transmutation in a candidate waste form for cesium-137 by investigating samples of a cesium aluminosilicate mineral.

## Budget Summary Table

(Dollars in thousands)

| Program Activity | FY-1999 | FY-2000 | FY-2001 |
|---|---|---|---|
| Performance Testing & Qualification | 4,410 | 4,153 | 3,127 |
| Stabilization | 5,246 | 4,085 | 6,036 |
| Packaging, Transportation & Storage | 3,958 | 3,082 | 5,630 |
| Site/Technology Support | 9,509 | 9,100 | 9,079 |
| Directed Science | 2,141 | 1,780 | 526 |
| **Total** | **25,264** | **22,201** | **24,399** |