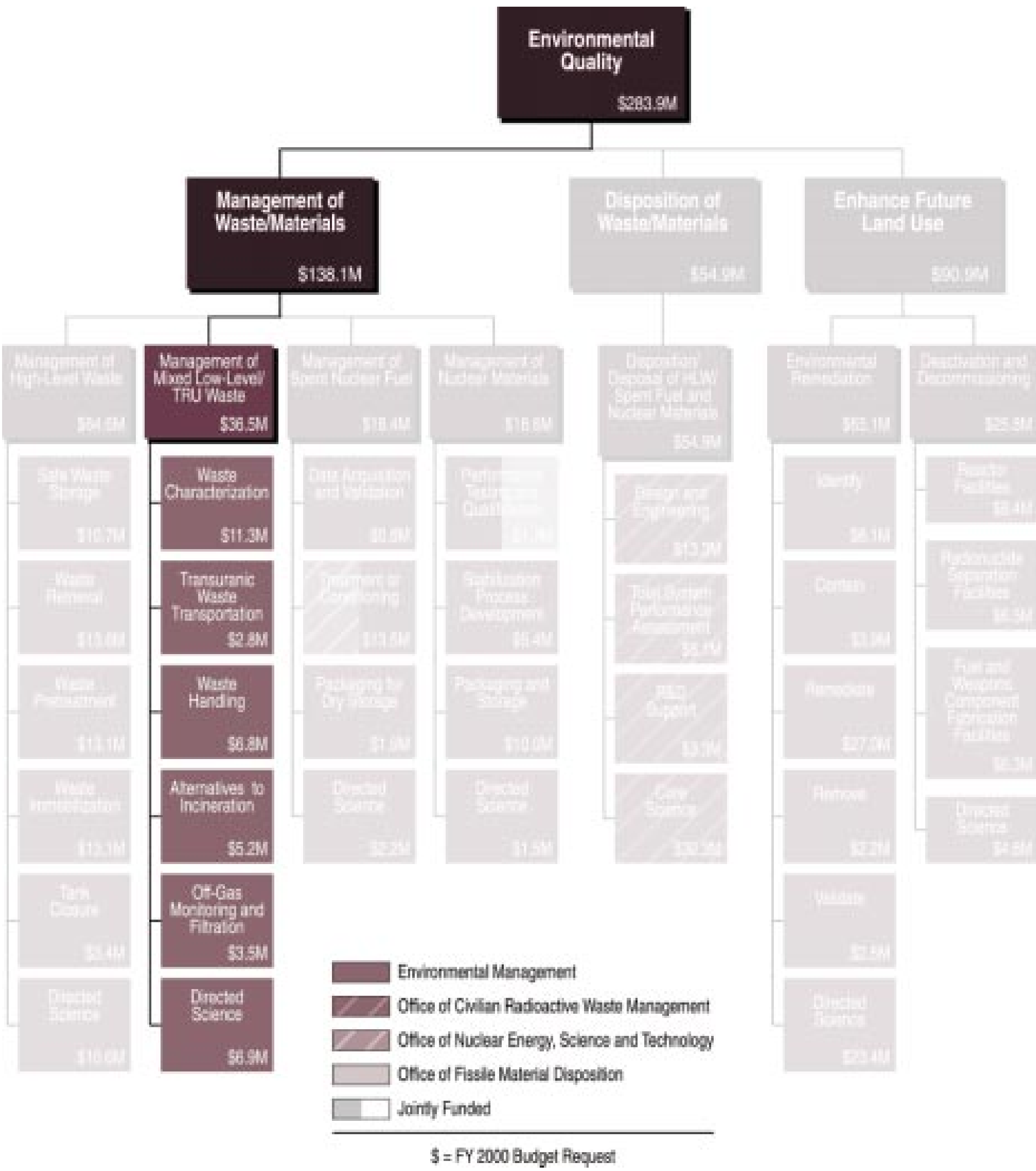
Chapter 4

Mixed/Low-Level/Transuranic Waste



Chapter 4
Mixed/Low-Level/Transuranic Waste

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Overview

Definition of Problem Area

Thirty-six DOE sites are storing about 165,000 m^3 of mixed low-level and transuranic waste. More than 2,300 waste streams comprise this inventory, which is heterogeneous both physically and chemically. About 60% of the total inventory is categorized as transuranic and is packaged in a variety of containers ranging from 55-gal drums to fairly large cargo containers. Most of the transuranic waste (TRU) is destined for disposal at the Waste Isolation Pilot Plant (WIPP). Treatments for most of the inventory's mixed low-level waste (MLLW) portion are prescribed in Consent Orders, which were established between the sites and their host states in compliance with the Federal Facilities Compliance Act (FFCA) of 1992.

The Department projects that an additional 45,000 m^3 of transuranic waste and 170,000 m^3 of MLLW will be generated over the next ten years, primarily from environmental restoration and decontamination and decommissioning activities. For planning purposes, DOE assumes that the wastes generated in the future will possess physical and chemical characteristics similar to those in the present inventory.

Most TRU waste is the result of the weapons production process, and contains plutonium. TRU waste from weapons production results almost exclusively from fabrication of plutonium weapons components, recycling plutonium from production scrap, residues, or retired weapons, and chemical separation of plutonium. Considerable amounts of TRU waste also contain hazardous constituents subject to regulation under the Resource Conservation and Recovery Act (RCRA) or the Toxic Substances Control Act (TSCA). Since 1970,[a] the Department has placed TRU waste in retrievable storage, typically in metal drums or boxes, either on above- or below-grade storage pads, in buildings or in tanks. TRU waste, including a relatively small amount of non-weapons-related TRU waste, is managed at 21 sites. The Department plans to dispose of stored post-1970 weapons-related TRU waste at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Final disposition of non-weapons-related TRU waste is still being determined, since, by current law, non-defense TRU waste cannot be disposed at WIPP.

Mixed low-level waste contains chemically hazardous as well as (non-transuranic) radioactive materials. As such it is subject to regulation under both RCRA and the Atomic Energy Act (AEC). The Department first started managing mixed low-level waste as a separate waste type in the 1980s. It is generated during a broad spectrum of processes and activities including equipment maintenance, materials production, cleaning, environmental restoration, facility decontamination and decommissioning (D&D), and the treatment or handling of low-level waste and other waste types.

The storage, treatment and disposal of MLLW are subject to state and Federal regulations. In response to the Federal Facilities Compliance Act, a 1992 Amendment to RCRA, each DOE site managing MLLW developed a "Site Treatment Plan" for these wastes. These plans formed the basis for consent orders, which were negotiated with the sites' host states. Within the provisions of the consent orders, the DOE sites are subject to various state-imposed penalties for missing

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[a] Prior to 1970, most TRU waste was routinely disposed in shallow pits and trenches. Pre-1970 disposed TRU waste is addressed as part of Environmental Remediation, discussed in Chapter 8.

mixed waste treatment and management milestones. Estimated costs for management and disposition of mixed, low-level, and TRU waste are shown in Figure 4-1.

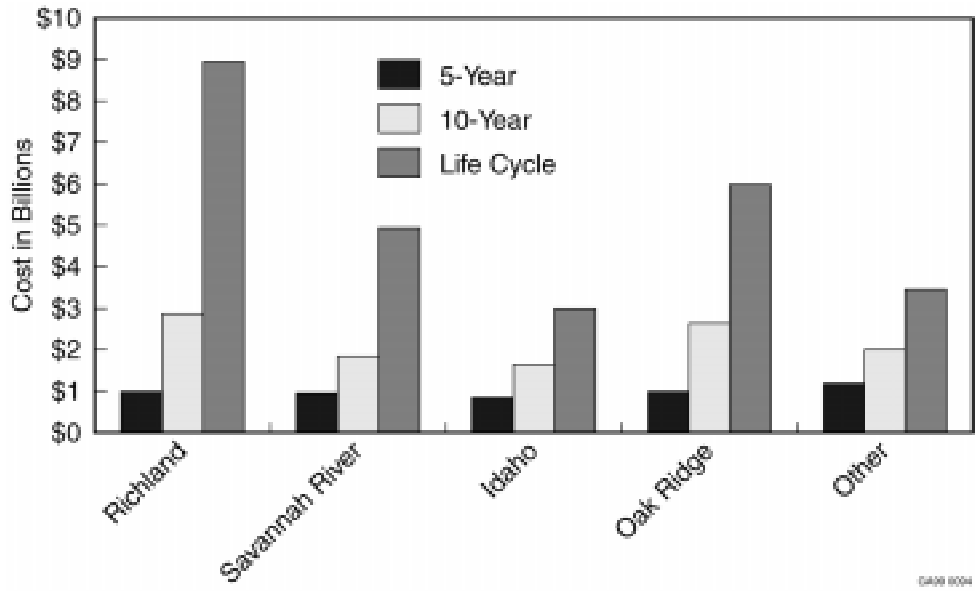

Figure 4-1. Costs for management and disposition of mixed, low-level, and transuranic waste.

National Context/Drivers and Federal Role

Currently, there are three principal drivers for the MLLW/TRU research and development portfolio: opening of the Waste Isolation Pilot Plant for TRU waste disposal; the consent orders in effect for MLLW; and the Environmental Protection Agency's promulgation of the rule, Maximum Achievable Control Technology for Waste Combustors (MACT).

The TRU waste to be shipped to WIPP must meet stringent waste acceptance criteria. The R&D portfolio is providing waste characterization and certification methods that are safer, more cost-effective, and quicker than currently available techniques. The portfolio also contains products that will improve the efficiency of the TRU waste shipping containers. If the technologies being developed fail to meet technical and schedule requirements, there will be significant impacts at several major DOE sites. Specific milestones in the Idaho settlement agreement and the Hanford Tri-Party Agreement will be jeopardized. Generally, less TRU waste will be shipped to WIPP and a greater number of shipments will be required for that which goes to WIPP. This will dramatically increase the total cost to DOE of shipping waste to WIPP and extend the timeframe for getting TRU waste out of storage and into safe disposal.

Missed consent order milestones cost money in fines and other penalties, and damage DOE's credibility with its host states. The MLLW/TRU R&D portfolio enhances DOE's ability to meet milestones and reduce the cost of compliance in several ways. The portfolio is providing safer, less expensive methods for characterizing the wastes' hazardous components and safer, more efficient methods to handle—especially--highly radioactive wastes in preparation for treatment. The presence of mercury adds greatly to the cost and complexity of MLLW treatment. Technologies to separate and stabilize the mercury are being demonstrated. The portfolio is providing techniques to address small quantity, highly problematic mixed waste streams, which exist at virtually all major DOE sites. Altogether they comprise 10-l5% of DOE's total MLLW inventory, and most have no clear path to disposition. Ceramics, polymers and other revolutionary waste stabilization materials are being made available to the sites to improve the environmental performance of final waste forms. These alternative technologies also increase waste loading efficiency, reducing waste volumes disposed, which, in turn, reduces disposal costs and conserves scarce disposal capacity.

The Environmental Protection Agency's (EPA) proposed MACT rule, expected to become effective in 1999, will potentially reduce, if not eliminate, DOE's ability to treat MLLW by incineration. The loss of incineration capacity will threaten several DOE sites' ability to meet compliance agreements, including sites that intend to use the facilities as well as the sites that operate the facilities. In recent trial burns DOE's three incinerators, which are located in Idaho, South Carolina and Tennessee, failed to meet at least one emission or monitoring requirement contained in the proposed rule. Specific problem areas include mercury, dioxins and furans. According to the EPA's current schedule, the facilities will have to be in compliance by January 1, 2002, or be shut down. The MLLW/TRU R&D portfolio is supporting development of emissions control and monitoring techniques that will allow the incinerators to comply with the new, more stringent regulatory requirements. Also, the portfolio contains alternatives to incineration (for some waste streams) for use at sites where incineration may not be possible due to state or local regulations, or stakeholder concerns.

The federal government, private sector, and universities all have roles in research and development for MLLW/TRU. Most of these wastes are managed within the DOE site operating system. For certain large volume, fairly homogeneous waste streams, where adequate profit potential exists, DOE has been able to engage the private sector in contracts that essentially privatize the waste treatment function. An example is the contract between DOE and British Nuclear Fuels Ltd Inc. (BNFL) to treat a large quantity of TRU waste prior to its shipment from the Idaho National Engineering and Environmental Laboratory (INEEL) to WIPP. The contract provides for some R&D by BNFL. The DOE is responsible for responding to technology needs identified by each of the major sites. The DOE's portfolio contains technologies from its laboratories, universities and the private sector. Technologies originally developed for application to strictly hazardous wastes often require only minor adaptation or demonstration for the wastes' radioactive component to broaden their applicability to mixed wastes.

Linkage to DOE Strategic Goals and Objectives

DOE delivers technical and engineering solutions necessary to ensure that MLLW/TRU program managers can resolve present and future needs identified in their accelerated path to closure. DOE is working to three key strategic objectives, which link directly to Environmental Quality goals and objectives. These objectives are to:

- Provide the science and technology needed to ensure safe, efficient characterization, certification, and transportation of TRU waste to the Waste Isolation Pilot Plant.
- Provide the science and technology needed to ensure DOE sites meet MLLW treatment consent orders in a timely, cost-effective manner.
- Provide the science and technology needed to maintain DOE's capability to treat MLLW by incineration in the face of increasingly stringent environmental regulations.

DOE invests in solutions that will be deployed and have a significant national impact. This is accomplished by an end-user-driven process that enables all steps from need identification through solution deployment, and is completed as an integrated part of the overall cleanup effort.

The portfolio's technologies help ensure safe, efficient characterization, certification, and transportation of TRU waste to the Waste Isolation Pilot Plant. These products directly support EQ Objective 3 to "safely and expeditiously dispose of waste generated by nuclear weapons and civilian nuclear research and development programs…" Other portfolio products help DOE sites meet MLLW treatment consent orders in a timely, cost-effective manner, and allow DOE to maintain the capability to incinerate MLLW in the face of increasingly stringent environmental regulations. These activities, too, are aimed at the EQ objective to make MLLW/TRU ready for safe and expeditious disposal. All the portfolio's activities are aimed at reducing the life-cycle costs of environmental cleanup by developing and deploying innovative technologies.

The level of impact and support the mixed/low-level/TRU waste activities provide to the Environmental Quality strategic objectives is indicated in Figure 4-2.

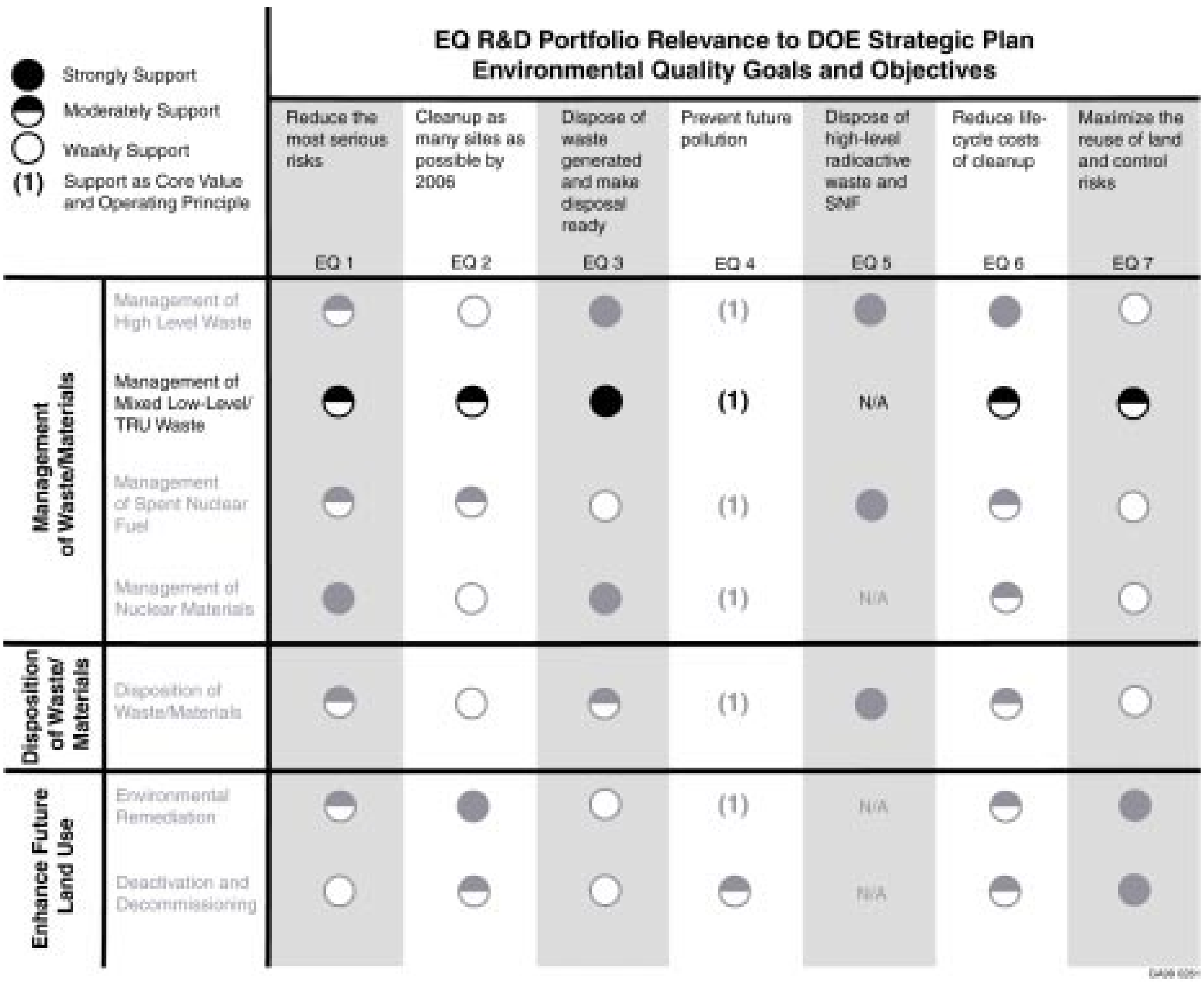

Figure 4-2. Relevance of mixed, low-level, and transuranic waste R&D investments to Environmental Quality goals and objectives.

Problem Area Uncertainties

This portfolio's most difficult technical challenges lie in the characterization of boxed and remote-handled TRU wastes. These waste streams present significant challenges to several current capabilities including adequate characterization, safe handling, adequate treatment to multiple requirements, and identification of available disposal facilities. High beta/gamma radiation fields create unique problems for non-destructive examination and assay techniques that may rely on less energetic radiation. Boxes are more problematic, because the magnitude of technical problems increases with container size. About half the TRU waste currently in storage is contained in the larger boxes, rather than drums.

Regulatory requirements affecting waste treatment facilities will continue to change. For example, the Environmental Protection Agency is considering replacing the toxicity characteristic leaching procedure (TCLP) with a suite of tests (that may or may not include TCLP) for hazardous waste characterization and compliance with Land Disposal Requirements treatment standards. Revision of the waste testing requirements could have a large impact on the volumes and types of waste categorized as mixed wastes. Such revisions could also impact requirements for mixed waste treatment and disposal and associated costs of the entire DOE mixed waste management system. An Advance Notice of Proposed Rulemaking is expected within the next year or two.

It is known that environmental restoration activities will generate additional quantities of MLLW/TRU. How much will be generated is not certain. An uncertainty with greater significance for science and technology resides in the specific MLLW/TRU waste streams that may be generated. Relatively large waste streams that are significantly different from those in the current inventory have the potential to present future "gaps" that will require new science and technologies.

R&D Investment Trends and Rationale

Figure 4-3 illustrates the current investment for mixed, low-level, and transuranic waste areas. The portfolio managers are undertaking the entire technology development process only in those cases where it is absolutely necessary. Over the past few years a series of Requests for Information (RFI) were issued in the Commerce Business Daily and other information media describing the problems to be addressed, and requesting responses from entities who believe they have a technology that might solve the problem. These RFIs successfully generated responses from universities, the private sector and DOE Laboratories. In many cases, the RFI process discovered technologies that need only minor adaptation or demonstration under specific conditions to be able to resolve certain MLLW/TRU problems.

Portfolio managers are investing the most significant share of their resources in the science and technology needed to certify and ship TRU waste to WIPP. Currently, these problem areas are the highest priority and the most difficult and expensive to resolve. Waste stabilization and waste form improvement to meet DOE's near-term needs are nearly complete, and emphasis is shifting to deployment.

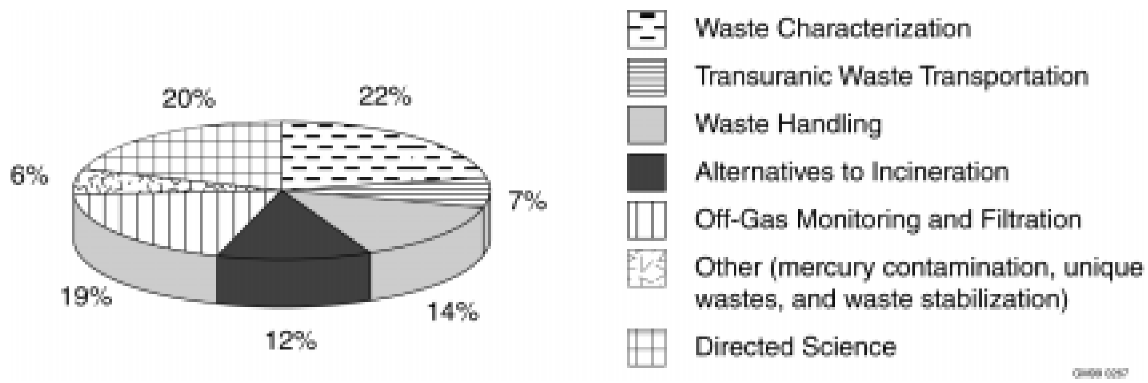

Figure 4-3. Cumulative investment in mixed, low-level, and transuranic waste areas over 3 years (FY 1998–FY 2000).

The sites' technology needs appear to be evolving beyond those that are similar or common among sites. Previously, allowing investment in a single technology, or suite of similar technologies, offered the possibility of solving several sites' problems. New and revised site needs, which were identified in the first quarter of FY 1999, are extremely heterogeneous; often, each need describes a unique problem specific to a particular site. Of the 136 site needs now applicable to this portfolio, about half are outside its current technical baseline capability. In the future, it may be more difficult for portfolio managers to find "big hitters"; that is, opportunities for single technology investments with a high potential for national impact and large cost savings or major project risk reduction.

Key R&D Accomplishments

DOE has made a great deal of progress in resolving the problems associated with managing its mixed low-level and TRU waste inventories. For current inventories of MLLW requiring stabilization, development of a suite of improved technologies is complete. Also complete are development and demonstration of technologies to treat mercury-contaminated mixed wastes. Often, these technologies are eliminating the sites' entire inventory of a mixed waste stream, finally putting an end to the life-cycle costs and risks associated with storing the wastes. Important, initial phases are complete in developing improved techniques for characterizing and certifying TRU waste for disposal at WIPP, as well as greater efficiency in shipping the waste to WIPP. Work on methods to remotely handle highly radioactive mixed wastes is getting under way.

DOE has completed development of a suite of waste stabilization technologies that collectively can address the entire Department's current mixed waste stabilization needs. With development complete, emphasis is shifting to deployment. Among the first completed, Polymer Macroencapsulation was deployed commercially in 1996 through a cooperative agreement that provided treatment and disposal of 520,000 lb of mixed waste lead and debris from 23 DOE sites. In several cases, the material processed was the site's entire waste stream. In one case, application of the technology eliminated a DOE site's entire mixed waste inventory. Three other DOE-developed stabilization technologies, two polymer microencapsulation methods and an advanced ceramic, are in the process of being commercially deployed and will be operational in

1999. Availability of this suite of technologies will allow treatment of 85–90% of the current DOE mixed waste streams requiring stabilization.

DOE and the private sector have successfully developed and demonstrated a suite of technologies for treating mercury-contaminated wastes. DOE sites are now acquiring the use of these technologies through contracts with the private sector, often allowing elimination of a site's entire mercury-contaminated mixed waste stream. Negotiations are under way to commercially deploy sulfur polymer cement, a DOE-developed technology proven to be very robust in treating mercury wastes. Collectively, this suite of technologies is able to process virtually all DOE's present mercury-contaminated mixed waste inventory.

DOE has completed all experimental and modeling activities aimed at increasing the amount of TRU waste that can be transported in the Transuranic Package Transporter, Model II (TRUPACT-II) shipping container. A significant portion of TRU waste destined for WIPP would require treatment or repackaging in order to be transportable. The portfolio's technical analysis and modeling results will be included in the shipping container's safety analysis report, which will allow up to 70% of the currently unqualified waste to be shipped without treatment or repackaging. Enabling these shipments will save DOE, and hence the taxpayers, $300 million.

DOE has successfully applied this portfolio's resources to unique mixed wastes, which are usually small-quantity, highly problematic mixed wastes that exist at many DOE sites. Two dozen projects have been initiated, resulting in elimination of more than 30 mixed waste streams at 14 DOE sites totaling over 538 cubic meters. At the Nevada Test Site (NTS), one such project eliminated a mixed waste stream that comprised 85% of the site's entire mixed waste inventory. The portfolio's alternative solution completed the job much quicker and at $1.25 M less than NTS's original estimate.

Work on improved nondestructive examination and assay techniques for contact-handled TRU waste drums is complete. The Active and Passive Computed Tomography technology is now providing mobile characterization services for TRU waste at the Nevada Test Site.

DOE has truncated its support of three high-temperature melters: the DC Arc, Plasma Hearth Process, and Transportable Vitrification System. The melters were originally envisioned as high capacity, "omnivorous" technologies, capable of converting a wide band of extremely heterogeneous waste streams into durable glass waste forms. Had these technologies been entirely successful, a few large systems could have treated most of DOE's MLLW inventory with need for relatively little pre-treatment handling and characterization. Vitrification technologies have proven to be extremely useful for treating high level wastes, which are well characterized and homogeneous in comparison with mixed low-level wastes. However, the melters were unable to entirely live up to their early promise for treating MLLW. Developers found that, for a variety of reasons, pre-treatment handling and characterization continued to be required, which greatly reduced melters' cost-effectiveness. It is likely that melters will ultimately occupy a niche in mixed low-level waste treatment, but not as large a one as originally envisioned. A commercially designed and built high-temperature melter, which is based on the DOE development work, is being deployed at Hanford. The melters' limited success in treating MLLW has required the portfolio managers to continue their investments in improved waste characterization technologies, as well as simpler, low-temperature waste stabilization technologies.

Important work has recently commenced to provide sites with the capability to remotely handle highly radioactive wastes for sorting, repackaging, and transport to treatment. HANDS-55, targeted initially for use at the Savannah River Site and then to be modified for use at other sites, will save $100 million in waste packaging and transportation costs at Savannah River alone.

Key R&D Issues

A report issued recently by the National Research Council identifies a number of key research and development issues, particularly for mixed low-level waste. (National Research Council. 1999. *The state of development of waste forms for mixed wastes*. Washington, DC: National Academy Press)

A major finding of the report is that no new classes of waste forms are required. Recognizing that no single waste form is appropriate for all wastes, the Council notes it is "unlikely that any totally new class of waste forms will be necessary to complete EM's planned cleanup program." (p. 98) As noted above, the portfolio managers have essentially completed development work on waste forms and are focusing on technical assistance to DOE sites for implementation and deployment (another aspect of the Council's recommendation). Funding reductions are restricting assistance available, however, leaving much of implementation and deployment to site operations and the private sector.

Another recommendation is for the portfolio managers to continue to respond to technology deficiencies (needs). As noted above these needs have tended to concentrate in three primary driver areas associated with the cleanup: characterizing and preparing TRU waste to be shipped to WIPP; assisting sites in meeting Consent Order milestones; and new or improved monitoring and off-gas filtration technologies to allow DOE to continue incineration in the face of new, more stringent air emissions requirements. The nature of these drivers require action in the relatively near term—prior to 2006. The dedication of diminished resources to the near-term problems, however, allow little or no analysis to anticipate needs and deficiencies that may arise in the future.

New needs identified early in 1999 indicate sites' attention is shifting to small quantity, highly problematic waste streams. These technology needs often require highly individualized solutions, applied to small waste streams. Because of the higher funding priority attached to technologies with broad application and large potential cost savings, portfolio managers have difficulty securing the funds to meet these technology needs.

Some longer-term challenges, which are extensions of the on-going work, can be identified. The portfolio managers, as well as the National Research Council, recognize the need for non-destructive characterization of hazardous substances in containerized wastes—heavy metals and organics in particular. Regulatory requirements affecting waste treatment facilities will continue to change. More restrictive requirements on facility effluents other than air—waste water, for example—can be anticipated. Preparing to meet more restrictive effluent emissions requirements with new or improved technologies presents a longer-term challenge.

A key research and development issue for this portfolio is the uncertainty discussed earlier regarding waste that will be generated by environmental restoration activities. While waste volumes have been tentatively predicted, less is presently known about the physical and chemical characteristics of the wastes. A fundamental assumption underlying management of the research and development portfolio is that the wastes generated in future cleanup activities will fit within the capability envelope of the technologies being implemented in the near term.

Problem Area R&D Program

Budget: FY98-$56.3M, FY99-$34.8M, FY00-$36.5M

Program Description

The MLLW/TRU portfolio of science and technology investments addresses all the major functions involved in managing these wastes. The portfolio's technical scope includes characterization, handling and repackaging, pretreatment and treatment, transportation, and disposal. The portfolio's solutions are applicable to legacy MLLW/TRU, which is currently stored at many DOE sites, as well as wastes being generated now and in the future as a result of on-going operations and environmental restoration activities.

Through analysis of the sites' submitted needs, DOE has identified eight major problem areas for the management of DOE's mixed low-level and transuranic waste inventory: waste characterization; transuranic waste transportation; waste handling; alternatives to incineration; off-gas monitoring and filtration; mercury contamination; unique wastes; and waste stabilization.

In the following sections, the problem areas are summarized along with the activities aimed at resolving them. The activities described in this section are present or planned for the near-term, and do not necessarily address the longer-term challenges and issues discussed above.

Waste Characterization

Budget: FY98-$10.2M, FY99-$6.9M, FY00-$11.3M

Description. Various regulatory drivers and management needs, as well as stringent WIPP waste acceptance criteria for the transuranic waste portion, require detailed characterization of the mixed waste inventory's radioactive and hazardous components. In situations where destructive analysis is necessary, the techniques that are presently available require opening and drawing multiple samples from each waste container. These techniques increase the risk to workers and the environment. They are slow, extremely expensive, and generate secondary mixed waste streams. Available nondestructive examination and assay techniques for both contact- and remote-handled wastes alleviate some of these problems, but need improved reliability to meet increasingly demanding characterization requirements.

Objective. Improve end-users' capability to nondestructively examine and assay containerized waste for radioactive and hazardous components.

Strategy. The strategy to resolve waste characterization problems is based upon logical groupings of the problems areas identified. Three major categories have been created: determination of hazardous constituents, determination of radioactive constituents, and support programs.

Hazardous contaminant characterization identifies and quantifies RCRA constituents, process operating parameters, and the other physical and chemical properties that affect the system. It has been further divided into debris and sludges. This additional level of characterization is needed to address the differences in requirements and approach. Requirements for debris characterization are driven by the DOE incinerator criteria and sludge characterization is driven by WIPP criteria. Additionally, it is possible to obtain representative samples of sludge waste.

Radioactive contaminant characterization is divided into contact-handled and remote-handled wastes due to the unique problems associated with remote-handled waste. These problems arise from the high beta/gamma and neutron backgrounds associated with the waste. Each category is further divided based upon the size of the waste package, because the magnitude of the problems identified earlier increases with package size. This allows for subsets of the problem to be resolved independently. In this strategy, contact-handled waste is given a higher priority than remote-handled waste and small packages are given a higher priority than large ones.

There are several reasons for this: it is easier to resolve the problems on contact-handled waste, and it is easier to resolve small package problems; there are more drums than boxes (although the volumes are approximately equal); and WIPP and site disposal schedules.

Support programs provide additional technical support and materials for the deployment and implementation of nondestructive assay technologies. Materials, including certified radionuclide standards and surrogate wastes, are needed to assess technology performance.

R&D Activities:

Hazardous Contaminant Characterization—Solutions to determine hazardous contaminants will be based on non-destructive technologies. These will primarily rely on the interrogation of the waste container with a neutron source and subsequent detection of gamma rays. The detected gamma rays are the result of neutron reactions with hazardous contaminants that result in the emission of gamma rays. Other non-destructive technologies that employ x-rays as the interrogating radiation will be examined. The criteria and requirements that must be satisfied will be established by the waste acceptance criteria that are associated with the DOE incineration facilities. DOE will also address problems associated with conventional (that is, destructive) RCRA contaminant analysis.

Contact-Handled Wastes—To date the program has focused on developing solutions for the wastes contained in 55-gal and 83-gal drums. Advanced systems have been developed based on tomographic active and passive gamma-ray spectroscopy and active neutron measurements using thermal and epithermal neutrons. These systems have been shown to more effectively handle the identified problems and yield results with lower total measurement uncertainty. Additionally, a comparative demonstration of commercially available technologies was conducted. The results of this demonstration will be used to determine if additional technology development is required. Future activities will include the deployment of advanced neutron and gamma systems.

Box assay development activities will be identified and initiated in 1999. A baseline report documenting the need (waste types, quantities, radionuclides) and capabilities of current technologies has been completed. It is anticipated that the box assay systems will use all of the technology developed for drums to address the identified problems. It is anticipated that the box systems will be based on active and passive neutron counting as well as active and passive gamma ray spectroscopy.

Remote-Handled Wastes—Potential solutions to address nondestructive assay of remote-handled wastes were identified in 1998. Each technology under evaluation addresses the effects of high background radiation, both neutron and gamma, uses different approaches to deal with the background radiation, and was previously funded or evaluated by other DOE programs. The purpose of the present evaluation is to assess their potential to assay remote-handled transuranic wastes. The successful technologies will be further developed using commercial vendors with assistance from national laboratories directed by the vendor. Implementation will be led by the vendor and will be supported by DOE.

Support Programs—DOE is funding the development of surrogate waste drums and crates and standards to support testing of developmental and commercially available systems. These standards will contain radionuclides and RCRA hazardous materials.

Accomplishments. During 1997, an active and passive computed tomography system (A&PCT), developed at Lawrence Livermore Laboratory, was demonstrated at the INEEL as part of the Rapid Commercialization Initiative. DOE deployed the technology in 1998 at NTS. The Combined Thermal and Epithermal Neutron Assay System (CTEN) was also readied for implementation during 1998. The expert radiological data validation system was demonstrated and readied for deployment in 1999 at the INEEL.

Transuranic Waste Transportation

Budget: FY98-$2.1M, FY99-$3.5M, FY00-$2.8M

Description. The TRUPACT-II is the certified container for shipping contact-handled transuranic waste to WIPP for disposal. Strict limits are in effect for certain constituents in each waste package due to the potential for hydrogen gas generation during shipment. As a result, 20–40% of the transuranic waste currently stored at 34 DOE and non-DOE sites is not transportable in its current package configuration. The options available for solving this problem are to pierce the waste containment bags inside the packages or to redistribute the waste in smaller quantities over more packages. These options would increase risk to workers during waste handling, increase transportation risks by increasing the number of shipments, and would increase waste handling and transportation costs dramatically. Techniques are needed for in situ, realistic and real-time characterization of gas generation.

Objective. Increase the container payload efficiency of transuranic waste shipments for treatment and disposal.

Strategy. DOE has developed a strategy (the TRUPACT-II Payload Expansion Plan) to address the flammable gas impact on transuranic waste transportation. This strategy is designed to expand the TRUPACT-II waste envelope and minimize impact on remote-handled transuranic waste. This strategy defines the hydrogen gas generation problem according to the following situations:

- Predicted to exceed 5% hydrogen gas concentration when actual hydrogen gas concentration is less than 5%.
- Exceeds the 5% hydrogen gas concentration limit.

These problem areas exist in both contact- and remote-handled transuranic waste. DOE assumes that solutions developed for contact-handled waste will be generally applicable to the remote-handled portion. Under this strategy, DOE is funding the collection of data that will be used in revising the TRUPACT-II Safety Analysis Report for Repackaging and the 72B Cask Safety Analysis Report for Repackaging.

DOE-funded programs will provide transportation relief for approximately 90% of the current TRUPACT-II hydrogen-gas-related drum rejections at the Idaho, Los Alamos and Rocky Flats Sites. The amount of relief anticipated for the higher Curie loading plutonium-238 waste stored at SRS has not been estimated due to a lack of inventory assay data.

R&D Activities:

Contact-handled Transuranic Waste—DOE is funding activities to address situations in which the contact-handled waste package is predicted to be greater than 5% hydrogen, when it is actually less than 5% hydrogen. These activities are directed at collecting gas generation data that are more representative of actual contact-handled transuranic waste and developing alternative methods of compliance with the hydrogen gas generation rate requirement. The activities to address the situation in which the hydrogen gas concentration is greater than 5% are directed at technologies that remove hydrogen gas from the TRUPACT-II payload.

Remote-Handled Transuranic Waste—DOE will support activities to address situations in which the remote-handled waste package is predicted to be more than 5% hydrogen, when it is actually less than 5% hydrogen. Currently funded activities are directed at collecting gas generation data that are more representative of actual remote-handled transuranic waste. Future work will include developing alternative methods of compliance with the hydrogen gas generation rate requirement. DOE will develop technologies that remove hydrogen gas from the 72B Cask payload for those situations in which the hydrogen gas concentration is greater than 5%.

Accomplishments. In 1998, DOE completed all experimental and modeling activities centered on increasing the amount of TRU waste that can be transported in the TRUPACT-II shipping container. Of such TRU waste that is currently not transportable to the Waste Isolation Pilot Plant, up to 70% will be transportable once DOE's results are implemented in the shipping container's safety analysis report.

Waste Handling

Budget: FY98-$6.8M, FY99-$4.1M, FY00-$6.8M

Description. Several DOE sites have expressed the need for improved handling techniques for several significant waste streams within the mixed waste inventory, especially those designated as remote-handled. Planned treatment and disposal methods demand new or improved technologies for repackaging or sizing wastes, and moving or handling wastes at the treatment or disposal facility. Commercially available technologies can be used for wastes designated as contact-handled, but these require some adaptation to reduce worker exposure. Technologies applied to remote-handled wastes are much more complicated to operate and maintain, requiring separation of the workers by containment. A significant portion of DOE's mixed waste inventory simply cannot be prepared for and moved to treatment and disposal without these technologies.

Objective. Provide the capability to remotely handle highly radioactive waste streams for sizing, repackaging, and transport.

Strategy. The strategy for resolving this problem centers on the three key functions of waste handling: repackaging, volume reduction and transportation to treatment.

The focal point of the present strategy is to provide technology that will meet repackaging needs to transfer waste to WIPP. The repackaging technology will be demonstrated using contact-handled waste that requires containment for alpha contamination. This technology is being designed in a remote modular format for ease in adapting it to a mobile platform for small generator sites, or fully automated for remote-handled waste. Another development area is sizing or volume reduction of remote-handled wastes. Many sites have large pieces of remote-handled waste that must be size-reduced to meet disposal criteria, volume reduction by segregating, or to prepare the waste for the designated treatment method. This work will focus on adapting commercially available sizing technology rather than development. Treatment methods for mixed wastes, both contact-handled and remote-handled are ready for deployment; therefore, the issues associated with transporting waste to treatment must be addressed.

R&D Activities:

This investment addresses solutions in the following technical areas:

- Repackaging drummed waste to meet WIPP acceptance criteria.
- Working with industry to adapt commercially available sizing technology.
- Transporting waste to treatment technologies.

DOE is developing a system (HANDSS-55) to prepare drummed transuranic and transuranic mixed wastes that are stored at SRS for transport to WIPP. This semi-remote system will open drums and liners, remove non-compliant items, and repackage the waste into WIPP approved storage containers. The SRS has approximately 30,000 drums that need this form of preparation and verification to meet WIPP acceptance criteria. But other sites, such as Idaho and Albuquerque, have also listed repackaging for WIPP as a high priority need. HANDSS-55 is being designed in a modular format to adapt the system to be a mobile platform, to meet the needs of the small generators (Mound and Battelle Columbus), or to allow the system to be made fully remote for future use on remote-handled waste.

The National Transuranic Program has listed developing robust sizing technology for remote-handled waste as their third-highest priority technology development area. This investment will adapt commercially available technology to meet the remote sizing needs at Richland and SRS.

This investment also addresses the transportation issues associated with moving non-homogenous wastes to treatment methods. Currently this investment provides a solution to a fly-ash transport problem for the Idaho Ash Demonstration. Using this commercially available technology in an innovative way will help increase process reliability and reduce worker exposure to hazardous and radioactive constituents. The SRS has also listed a reliable transport and ash stabilization process as a need.

Accomplishments. This was a new investment in 1998. Activities involved defining the work scope, detailed end-user requirements, and starting the design and implementation of four subsystems that will make up a remote-handling and repacking system for Pu-238 and Pu-233 job control waste at Savannah River.

Alternatives to Incineration

Budget: FY98-$6.6M, FY99-$3.8M, FY00-$5.2M

Description. A portion of DOE's mixed waste inventory containing organic materials is difficult to stabilize; therefore, oxidizing or destroying the hazardous organic materials is preferred before final treatment for stabilization. The presence of certain nonorganic substances (for example, mercury) in the waste can eliminate incineration as a choice for organic destruction. Incinerators are becoming more complex, difficult, and expensive to permit and operate in both the DOE complex and the private sector. These combined technical and stakeholder considerations drive needs for alternative methods to oxidize organic materials in the waste. Alternatives to incineration can substantially reduce offgas emission volumes and eliminate the discharge of hazardous volatiles to the environment.

Objective. Provide non-flame alternatives (which can be thermal or nonthermal) to incineration for organic waste destruction.

Strategy. The strategy to resolve these problems involves two areas: solution development and solution deployments. *Solution Development*—DOE has supported several alternative oxidation technologies as either developmental projects, or quick wins dedicated to rapidly deploying a technology on a small scale while eliminating one or more problematic waste streams. Examples of these technologies include Acid Digestion, Direct Chemical Oxidation, Catalytic Chemical Oxidation, Delphi Detox, and steam reforming. Although the development stage among these selected technologies varies greatly, several candidates are now at a level requiring a significant infusion of capital to attain the next level, namely a semi-scale or full-scale demonstration facility.

Solution Deployment—The strategy is to deploy one or several of these technologies at a given site to address a particular need. This strategy focuses on a competitive bid process to select and demonstrate a technology for treating plutonium-238 contaminated debris at SRS.

R&D Activities. The SRS has a need for a process to destroy the organic component of a combustible debris mixed waste stream known as job control wastes. This waste stream includes personal protective equipment, rags, plastics, and wood. This material is also contaminated with sub-micron plutonium-238 particles. Shipping waste to WIPP requires destroying the organic fraction to minimize or eliminate the radiolytic generation of hydrogen, or repackaging, which would be prohibitively expensive. Responding to this need is an ideal opportunity for the Alternative Oxidation Technologies, with the potential to reduce costs substantially, while demonstrating a technology that may be useful at many other sites needing non-incineration options. DOE is working to define technical performance requirements, selection criteria, and specific work activities. The project is estimated to take four years to successfully demonstrate technology that could then be deployed at other sites, and may be useful in the unique wastes requiring oxidation without incineration.

Accomplishments. During 1998, DOE completed development of two alternative oxidation technologies, Direct Chemical Oxidation (DCO) and Acid Digestion. Both technologies have been commercialized. In addition, a catalytic chemical oxidation system was deployed at Lawrence Berkeley Laboratory to treat aqueous waste containing tritium.

Off-Gas Monitoring and Filtration

Budget: FY98-$14.0M, FY99-$6.8M, FY00-$3.5M

Description. In recent trial burns, the DOE's three incinerators, located in Idaho, South Carolina, and Tennessee, and Idaho's high-level liquid waste calcining facility, failed to meet at least one emission or monitoring requirement in the EPA's proposed rule for Maximum Achievable Control Technology for Hazardous Waste Combustors. Specific problem areas include dioxins and furans, multi-metals, mercury, and other substances (e.g., chlorine). According to EPA's current schedule, the facilities will have to be in compliance by January 1, 2002. If the facilities cannot meet the new requirements, they will be forced to shut down, which will threaten several sites' ability to meet compliance agreements. The loss of incineration capability would affect not only the site that operates the facilities, but also others that intend to use the facilities to treat their wastes.

Objective. Improve off-gas monitoring and environmental performance of the DOE's waste incinerators to meet new regulatory requirements.

Strategy. The strategy to resolve the problems associated with monitoring and controlling emissions is based upon logical groupings of problems: emission monitoring and emission control. The strategy consists of two primary thrusts: (1) working with regulators to understand the content and intent of newly proposed and forthcoming regulations, and to help ensure that those regulations are achievable, and (2) to work with facility operators to understand how regulations will affect them and to develop technological solutions for those facilities that may be unable to meet some aspect of a new regulation.

Emission Monitoring:

Dioxins and Furans Monitors—Monitors will be developed, through laboratory and commercial solicitation, to measure dioxins or indicator species which may be easier to detect. Correlations will be developed relating indicator or precursor species to the dioxin/furan toxicity equivalence.

Mercury Monitors—Commercially available mercury monitors will be tested at DOE facilities to determine their effectiveness in off-gas systems that remove particulate and acid gas. Innovative mercury continuous emissions monitors will be developed and tested.

Multi-metals Monitors—Multi-metals continuous emissions monitors will be developed and tested using laboratory or commercial entities.

Other Monitors—Chlorine and hydrogen chloride continuous emissions monitors will be tested.

Emission Control:

Dioxins and Furans Control—In conjunction with the dioxin and furan continuous emissions monitors development effort, DOE's incinerator off-gas will be analyzed to determine the primary source of dioxin and furan emissions. Prevention and control measures will be developed and tested when the source of dioxins is better understood.

Mercury Control—Novel and commercially available mercury control technologies, such as gold filters and sulfur-impregnated carbon, will be tested to determine their effectiveness. Technologies for removing mercury from aqueous scrub solutions will be tested in coordination with work being undertaken by the mercury control product line.

Other Emissions Control—Technologies that remove high-levels of nitrogen oxides will be demonstrated. Techniques, including feed additives and control equipment, for controlling chlorine and hydrogen chloride emissions will be demonstrated.

R&D Activities:

Discussion involving DOE, EPA, and representatives from major sites having incinerators are now defining a solution set for future investigation.

Evaluation of Off-Gas Components—Demonstrating commercially available off-gas control components for their applicability to DOE waste treatment systems, Mississippi State University's Diagnostic Instrumentation and Analysis Laboratory (DIAL) has conducted development of continuous emissions monitors and is evaluating off-gas control components for DOE.

Accomplishments. In 1998, DOE completed the development of three high-temperature melters, the Plasma Hearth Process, Transportable Vitrification System, and the DC Arc Project, and made them ready for implementation. The Oak Ridge Site successfully applied the Transportable Vitrification System to a waste stream the site was required to treat under its consent order with the State of Tennessee.

Advanced Technologies Group (ATG) announced that the company will deploy a high temperature melter as part of its Hanford mixed waste treatment contract. The melter, designed and built by Integrated Environmental Technologies, is based on the DOE-funded DC Arc Project and other DOE high-temperature melter development programs.

Mercury Contamination

Budget: FY98-$4.8M, FY99-$0.9M, FY00-$0.0M

Description. Mercury is present in a broad range of concentrations in several of the DOE's mixed waste streams, including large volumes of soil and debris, and several types of process residues. Because it is highly mobile and easily vaporized, the presence of mercury complicates the design of off-gas systems, the stabilization of treatment residues, and the monitoring of all effluents. Removing mercury before treatment would significantly simplify downstream treatment operations, thereby reducing the cost of treatment facility design, construction, and operation, as well as the risk of operation. After its removal, the mercury must be amalgamated, or otherwise stabilized, for disposal as a separate waste stream.

Objective. Improve DOE's efficiency in managing mercury as a mixed waste contaminant.

Strategy. The strategy to resolve the problems associated with mercury waste streams is based upon logical groupings of the problems: mercury amalgamation, mercury stabilization, and mercury separation and removal. The strategy for addressing the mercury-contaminated waste problem started with forming the Mercury Working Group, comprising site end users responsible for treating mercury waste streams. The Mercury Working Group was asked to define the mercury mixed waste inventory and provide direction in selecting or developing technologies to address the problem. DOE issued a request for information through the Commerce Business daily to determine the current capabilities of the commercial sector. An analysis of the responses to the request for information, coupled with available waste inventory information and EPA treatment requirements, indicated that the mercury treatment technology selection and development strategy should be divided into three areas: amalgamation, stabilization, and separation.

Mercury Amalgamation—DOE issued a request for proposal from industry to demonstrate commercial processes on a larger scale using actual mixed waste streams. The request for information results indicated that industrial technologies were mature enough that, with a little more work, commercial processes would be available to treat DOE's wastes. Funding commercial demonstrations would provide the impetus for industry to put sufficient effort into their technologies to have them available. Also, because of the small quantities of waste at most sites, DOE needs to ensure that a vehicle is available for sites to combine their waste streams for treatment.

Mercury Stabilization—For the mercury stabilization area, a strategy similar to that employed for amalgamation was adopted for wastes contaminated with less than 260 parts per million mercury. In addition, efforts have been combined with EPA to investigate the possibilities of extending stabilization as a means of treating wastes contaminated with greater than 260 parts per million mercury. Demonstrations would be required to produce data to support that change.

Mercury Separation and Removal—For mercury separation, the request for information indicated that, other than retorting or roasting, technologies for removing mercury from contaminated matrices are not available. DOE turned to its laboratories to develop non-thermal methods for extracting mercury and has pursued commercial vendors to develop non-thermal treatment systems.

R&D Activities:

Mercury Amalgamation—Contracts were awarded to ADA Technologies, Inc., and to Nuclear Fuel Services. Quantities of radioactively contaminated elemental mercury were shipped to these vendors for treatment. In addition, the Mercury Working Group facilitated the issuance of a nationwide contract for mercury amalgamation of small quantity waste streams from multiple sites.

Mercury Stabilization—Contracts were placed with International Technologies, Duratek, Allied Technologies Group, and Nuclear Fuel Services to perform a variety of tests to demonstrate the capabilities of the commercial sector. These tests on less that 260 parts per million mercury matrices included bench-scale surrogate work with selected species of mercury and large-scale demonstrations on actual mixed wastes. National contracts will be made available to treat and dispose of less than 260 parts per million mercury wastes. Additional stabilization tests are planned for matrices with greater than 260 parts per million mercury. DOE is working closely with EPA to ensure that the data gathered in the tests will satisfy EPA's needs for evaluating proposed modifications to treatment requirements. As part of this testing, new EPA waste-form-evaluation protocols will be investigated.

Mercury Separation and Removal—Both DOE and commercial groups are developing and demonstrating mercury separation technologies. The technologies target industrial mercury in wastewater and in matrices destined for incineration, including soft debris and organic liquids.

In 1997, the sulfur polymer cement stabilization was demonstrated at Brookhaven National Laboratory to treat elemental mercury mixed waste. The entire inventory of elemental mercury mixed waste stored at Brookhaven, approximately 24 kilograms was treated and subsequently disposed of as low-level waste.

In 1998, in partnership with ADA Technologies, Duratek, and Nuclear Fuel Services at the Oak Ridge Site, DOE successfully demonstrated four commercially available technologies to be capable of amalgamating or stabilizing mercury in a radioactive environment. DOE issued reports on the ADA Technologies' stabilization process and Nuclear Fuel Services' amalgamation process, and made them ready for implementation.

Accomplishments. In 1998, DOE completed the development and demonstration of two mercury amalgamation processes at the Oak Ridge site. The demonstrations were performed in conjunction with two industrial partners, ADA Technologies and Nuclear Fuels Services.

Unique Wastes

Budget: FY98-$0.1M, FY99-$0.0M, FY00-$0.0M

Description. Approximately 10–15% of DOE's mixed waste inventory cannot be prepared for disposal using existing capabilities. Reasons for this include the nature of the hazardous contaminants, radioactive isotopes present and/or their concentrations, regulatory requirements, stakeholder concerns, and resource limitations. These problematic wastes include organic or highly energetic waste streams, radioactive sources, and other miscellaneous, problematic streams. Because their disposition requires highly specialized solutions, they are not typically being included in the scope of privatized treatment contracts. Their usually low volumes and special problems have kept them in relatively low priority for disposition at most sites. However, at 10–15% of the total, they represent a significant proportion of DOE's mixed waste inventory. The potential accumulated costs of maintaining safe storage for these wastes warrants DOE's efforts to find solutions for their disposition.

Objective. Provide specialized solutions for small-quantity, problematic mixed waste streams.

Strategy. The strategy to resolve the problems associated with the small quantity, problematic waste streams is based upon logical groupings of the problems: organic waste streams, high energetic waste streams, radioactive sources and problematic waste streams. While this strategy was established in FY-1998 to identify funding for the ensuing years, the necessary funding has not been secured. It is described here assuming all the necessary funds can be secured.

Organic Waste Streams—DOE will provide end users with the necessary information to select those technology solutions potentially suited for their organic waste streams. In addition to needs identified by the sites, DOE has used site visits, workshops, and teleconferences to collect and clarify the needs associated with these waste streams and to define the requirement sets for the solution. Identifying these waste streams is scheduled to start in 1999, with the work continuing through 2003.

Highly Energetic Waste Streams, Radioactive Sources, and Problematic Waste Streams—DOE will develop national strategies for each element (using national initiatives, case-by-case resolution, and multiple-site coordination), to establish a National Initiative to address water reactive wastes. Developing the Highly Energetic Waste Stream Strategy is scheduled to start in 1999, and continue through 2002. Developing the Radioactive Sources Strategy is scheduled to start in 2000 and continue through 2002 and developing the Problematic Waste Stream Strategy is scheduled to start in 2000 and continue through 2004.

R&D Activities:

DOE will start to identify the organic waste streams and develop the Highly Energetic Waste Disposition Strategy in 1999.

Accomplishments. DOE developed the strategy, technical objectives, and work package in 1998, based on an analysis of similar small-quantity waste streams present at nearly all the major DOE sites. The solution-development process will begin in 1999 and 2000.

Waste Stabilization

Budget: FY98-$2.1M, FY99-$0.1M, FY00-$0.0M

Description. Portland cement is the baseline stabilization technology used for much of the sludge, soils, and homogeneous solids that comprise DOE's MLLW inventory. But waste streams produced as fly ash or scrubber blowdown residue from the DOE's incinerators present unique problems because they contain salts or heavy metals. These materials in sufficient quantities can prematurely degrade the waste form. This problem is currently resolved by mixing very low proportions of the waste material with the Portland Cement. This practice significantly increases waste volume, which then increases waste handling and transportation costs, and consumes scarce disposal capacity. Alternative stabilization technologies are needed that can maintain waste form integrity at higher waste loading.

Objective. Increase the efficiency of waste stabilization processes, and improve the environmental performance of the resulting waste form.

Strategy. The strategy to resolve the problems associated with stabilizing high salt content and ash waste streams is based upon logical groupings of the problems: salt waste streams and ash waste streams. DOE will provide end users and waste managers across the complex with the necessary information to select those technology solutions potentially suited for their specific salt, ash, and/or problematic waste streams. DOE has developed and demonstrated new stabilization materials based on innovative chemistries (such as ceramics and polymers) to increase waste loading and improve final waste form performance for salt and ash waste streams.

DOE will complete the follow-up development efforts and demonstrations necessary to deploy the end-user chosen technology. However, no new classes of waste forms will be developed.

R&D Activities:

Salt—Five processes were tested using the same high salt waste surrogate composition: phosphate bonded ceramic stabilization, polyester stabilization, enhanced concrete, polysiloxane stabilization, and sol gel stabilization. The data from these tests, when published in the near future, will provide DOE with performance data on potential solutions to their high salt content waste streams.

Ash—Three processes were tested using the same incinerator mixed waste fly ash stream: phosphate bonded ceramic stabilization, sintered aggregate ceramic stabilization, and sintered monolith ceramic stabilization. The data from these tests, when published in the near future, will provide DOE with performance data on potential solutions to their ash waste streams.

Deployment—The SRS is conducting treatability studies on two processes to validate an efficient stabilization process for both the fly ash and the salt blowdown from their Consolidated Incineration Facility. The project started in 1998, and work will continue through 2000.

Disposal Criteria—If the new Environmental Protection Criteria are issued in 1999, testing waste forms to meet this criteria is scheduled to start later the same year.

Accomplishments. In 1997, Chemically Bonded Phosphate Ceramic, a mixed waste stabilization technology developed by Argonne National Laboratory East, won an R&D 100 Award.

In 1998, DOE completed technology transfer and full-scale version deployment of Chemically Bonded Phosphate Ceramic and the Kinetic Mixer Polymer Microencapsulation Process to Envirocare of Utah, Inc. DOE also issued reports on the Sol-Gel Process, Polysiloxane, and Clemson's sintering process, making them ready for implementation.

Directed Science

Budget: FY98-$9.7M, FY99-$8.6M, FY00-$6.9M

Within the MLLW/TRU investment portfolio, DOE funds research that advances science to solve environmental problems associated with very limited treatment options and disposal capacities. Seven subcategories of needs were identified in the area of MLLW/TRU:

- Non-intrusive, nondestructive characterization, monitoring, and measurement.
- Reduction of waste volumes from remediation, decommissioning, and separations processes.
- Waste treatments for heavy metal, dioxin, organics, and radionuclide contamination.
- Shipping and storage of wastes, including hazardous and radioactive materials.
- Materials stabilization, including improved methods for predicting partitioning performance of vitrification techniques.
- Development of waste forms having long-term durability.
- Long-term behavior of different waste disposal forms and containment media.

The MLLW/TRU directed research portfolio is concentrated in 10 scientific areas (below). In 1999, the portfolio managers are reviewing the applicability of the projects presently identified in light of changing priorities and needs. Some of the projects listed here may no longer be applicable, while other science needs have arisen that are not yet being addressed.

- *Actinide Chemistry:* The objective of this research addresses the synthesis of new materials, the physical characterization and evaluation of those materials, and the evaluation (and subsequent improvement) of these materials for interface to applied separation technologies.
- *Analytical Chemistry and Instrumentation:* Focus is on mass spectrometry, and sensors and techniques. Develop sensors or waste treatment techniques that will assist with: monitoring of effluents; nondestructive characterization methods; development of inorganic processes to treat radionuclide-bearing wastes; characterizing metal/water interactions; molecular recognition strategies for toxic metals and organics, (i.e., lead, uranium, plutonium); and, development of a new class of chemical sensing technology for remote diagnostics of chemical species in hazardous gas, liquid and semi-solid phases.

- *Engineering Science:* Research projects will provide knowledge in the areas of bubble mechanics and sonification, and design, process and modeling for the handling, characterization, and treatment of TRU and mixed low-level wastes. Projects range from developing an understanding of reactions of organic compounds in the presence of high intensity ultrasound, to providing accurate predictive models for hazardous chemical and mixed waste properties.

- *Inorganic Chemistry:* Focus is on hydrothermal oxidation, multiphase/gaseous chemistry, and solid/solution chemistry. Applications for this work include knowledge that can be used to directly give reasonable estimates of explosive or flammability hazards in the storage or transport of transuranic wastes; reducing the volume of waste requiring vitrification and long term storage; quantifying and monitoring the presence of alkali metals and other elements in waste liquids; and, interpreting and predicting pathways (stoichiometric and catalytic), for the safe destruction of halocarbon pollutants.

- *Materials Science:* Focus is on two topics, they are chemical and structural properties of storage materials, and surface chemistry. Projects include use of solar energy to oxidize organic chemicals to carbon dioxide and dilute mineral acids, thus reducing toxic pollutants with a very energy efficient detoxification method; and structure-property relationships for iron phosphate glasses that are of critical importance to cost-effective nuclear waste disposal.

- *Microbial Science:* Microbial genetics and instrumentation research can potentially aid in the bioremediation of waste streams. Develop a set of D. radiodurans gene strains specifically designed with biodegradative functions, and to survive in the toxic conditions found in DOE mixed waste streams.

- *Separations Chemistry:* Directed research is being conducted in catalyst chemistry and waste treatment, and ligand design and ion exchange. Investments will help meet challenges in MLLW/TRU material handling and characterization, and waste separation and treatment. Projects include removal of tritium from water, based on effects in the catalytic redox processes; development of electrochemical filtration and collection devices to be used for removal of heavy metals, radionuclides and transuranic elements from liquid phase streams; use ligands in the service of separations science; and, the solubility and stability of metal chelates in supercritical CO2 and use that understanding to model and compute phase behavior.

The next three research areas are applicable to several waste types, including waste types discussed in other chapters. The research is described here due to its high degree of applicability to the waste types discussed in this chapter.

- *Transport Aspects of Selective Mass Transport Agents:* The ability to separate radioactive and/or hazardous waste components from bulk matrices is a critical need in the efforts to cost effectively treat and process the wide variety of wastes for which DOE EM is responsible. The critical issues are 1) the physical characteristics of the separation media and 2) the inter- and intra-molecular interactions involved in the transport/retention mechanisms. Better understanding of these two areas will provide the basis for the development of new separation tools for DOE use. This effort consists of three research tasks.

- Selective Mass Transport in Polymers. Studies of selective mass transport in polymers will be conducted including (1) Synthesis of polymer materials utilizing group contribution theory to predict desired material properties; (2) Physical property characterization of the synthesized polymers will be conducted and will include determination of glass transition temperatures, melting/degradation characteristics and other fundamental physical properties; and (3) Evaluation of interactions leading to transport of molecules in polymer matrices. Based on these activities a feedback loop will be provided that allows the optimization of the mass transport properties based upon understanding of the separation mechanisms. Polymers were chosen as the media of interest due to their potential use in encapsulents, liners, barriers, membranes, solid phase extractants, and other separation media. Targeted areas of study include application of positron annihilation spectroscopy (PALS), nuclear magnetic resonance (NMR) spectroscopy, electronic impedance spectroscopy (EIS), gas sorption and transport studies, and other standard polymer characterization techniques to understand the fundamentals of molecular interactions in the selected systems.

- Pore Size and Morphology Control for Solid and Polymer Matrices. Understand methods for generating controlled pore sizes in polymers and in solid matrices such as silicates and aluminates. The ability to understand mechanisms of controlled pore size generation will permit the design of selective separation media engineered to accomplish specific separations of importance to DOE EM. Studies will be conducted with glassy polymers and micellular-forming materials to generate controlled pores. These studies include the development of molecular composites (i.e. polymer silicate) that will have specific molecular recognition and stability properties that could find applications in a number of separations areas. A variety of materials will be examined. Chemical templating methods will also be explored relative to production of controlled pores in the solid phase materials.

- Adsorption and Absorption Materials for Molecular Separations. Development of new adsorption and absorption materials that possess enhanced selectivity for gas and liquid separations compared to currently available materials. Activities focus on specific surface and pore modifications to provide hydrophilicity or hydrophobicity plus molecular recognition. Materials of interest of these studies include sorbents specifically designed to absorb acid gasses (H_2S, SO_2, CO, CO_2), metal vapors (Hg), and water vapors.

▪ *Characterization Science:* Characterization methods are critical in waste remediation, handing, and processing activities. The program focuses on five areas: 1) intelligent nonintrusive methods, 2) adaptive sensors, 3) integrated sensors for in situ chemical measurement, 4) nondestructive assay, and 5) nuclear structure.

- Intelligent Nonintrusive Methods. Characterization of nuclear material and containers is critical to the success of retrieval, processing, transporting, interim storage, and ultimate disposal of that material. The goal of this task is to provide sufficient understanding of the physical measurements to develop methods for processing and integrating information in order to automate decision making with respect to each characterization step (retrieve, process, transport, treat, store, dispose).

- Adaptive Sensors. Substantially improve in situ measurement capability by exploitation of a new sensing technique based on nonlinear optics. The potential gain is a new class of noncontacting sensors that are self-adaptive, self-processing and provide quantitative images in situations where only point measurements are now available. Optical characterization has historically provided high quality characterization in the laboratory, but the need for sample preparation and other control has limited in situ application.

- Integrated Sensors for In Situ Chemical Measurements. The ability to fabricate low-cost, integrated sensor packages, using techniques currently applied to integrated circuit fabrication, will lead to a wide variety of inexpensive chemical and physical property sensors. Using this information and additional technical assessment, a research effort will be initiated to begin development of the underlying and enabling techniques for integrated sensors.

- Non Destructive Assay (NDA). Radio-assay signatures for elemental identification and quantification. In particular, processes that are germane to complex wide NDA issues; i.e., actinide, fission product, and activation product identification and quantification.

- Nuclear Structure. Perform nuclear structure research that build and expand current nuclear physics expertise. Four related research areas will be explored. All four address the need to improve the known nuclear data to either (1) verify and validate our present understanding of nuclear structure and the interactions of radiation with matter, or (2) to provide a foundation to be used to improve our current understanding of and ability to predict nuclear parameters such as energy levels, transition probabilities, etc.

▪ *Computational Simulation of Mechanical and Chemical Systems:* Delivery of computational modeling capability and results for chemical and physical processes that occur in the wide range of systems of importance to DOE EM.

- Computational Infrastructure. Provide computing infrastructure technologies for the efficient simulation and modeling of the computational components of environmental problems. These shall include support for all the elements of the computational work including physical and process simulation, data analysis and archiving, and the appropriate visualization and communication tools. This effort will develop multi-processing computing capability.

– Computational Simulation. Focus on providing computational science capabilities to the various experimental research activities included in the Core Capabilities/Technical Enhancement tasks.

Budget Summary Table

(Dollars in thousands)

Research Areas	FY 1998 Appropriated	FY 1999 Appropriated	FY 2000 Request
Waste Characterization	10,217	6,895	11,345
Transuranic Waste Transportation	2,095	3,510	2,805
Waste Handling	6,795	4,147	6,759
Alternatives to Incineration	6,574	3,836	5,195
Off-Gas Monitoring and Filtration	13,989	6,761	3,500
Mercury Contamination	4,802	931	0
Unique Wastes	53	0	0
Waste Stabilization	2,109	110	0
Directed Science	9,700	8,631	6,865
Total	**56,334**	**34,821**	**36,469**