U.S. Department of Energy
Office of Engineering & Technology
Applied Research and Technology Development and Deployment

Integrated Multi-Year Program Plan (FY 2008 – FY 2010)

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1 INTRODUCTION

The overarching goal of the Department of Energy (DOE) Office of Environmental Management's (EM) Engineering and Technology Applied Research and Technology Development and Deployment Program is to reduce the life-cycle resources required for cleanup by reducing technical barriers and uncertainty, improving safety performance, addressing emerging issues, and leveraging investments in scientific research conducted by other Departmental programs. The Multi-Year Program Plan (MYPP) focuses on a limited number of critical and high-payback projects, workshops, external and independent reviews, and technical exchanges, for example, where significant step improvements can be gained.

The MYPP outlines the vision, goals, and strategies for the fiscal years 2008 - 2010 to achieve safe and compliant cleanup of legacy waste. The result will be that safe and successful cleanup of the Nation's legacy waste will establish the United States as a world leader in processing waste, remediating groundwater and soil, and deactivating and decommissioning facilities.

The Engineering & Technology Applied Research and Technology Development and Deployment Program (Program) elements are tied to the overarching EM management performance objectives: 1) Improve Safety Performance; 2) Improve the EM Performance-Oriented Organization; 3) Reduce Risk; 4) Make EM a Better Customer; and 5) Reinvigorate EM's Human Capital to Accomplish the Program's Mission. The MYPP provides the detailed strategy for implementing the *EM Engineering and Technology Roadmap* (*Roadmap*)[1]. The *Roadmap* was issued as a draft April 2007, and currently is being finalized. Each program area has developed a program plan that provides additional detail for implementing the program area's initiatives. These plans are inputs to the budget process in addition to tools for managing the Program.

The tasks for each program area build upon successes in EM, continuation of tasks, and needs to support the current baseline. The tasks lists in the program areas have been developed based inputs from the Field Offices and the EM engineering and technology communities of practices. Planning from this broad input provides a comprehensive task list, priorities, and strategies for responding to different funding levels.

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[1] In the FY 2007 House Energy and Water Development Appropriations Report, the Department was directed to "prepare an EM technology roadmap that identifies technology gaps that exist in the current program, and a strategy with funding proposals to address them." The EM Engineering and Technology Roadmap, prepared in response to this Congressional direction, describes the current technology risks and the strategies to address those risks, and will be used to guide the ***Program***.

2. ENVIRONMENTAL MANAGEMENT STRATEGIC PLAN

2.1 LINKAGE TO DEPARTMENT OF ENERGY STRATEGIC PLAN

National Context

To meet the Department's commitments to the American public, its investments in the Environment area are focused on advancing scientific understanding and providing new technology to clean up the environmental legacy of the nuclear weapons programs, minimizing future waste generation, safely managing nuclear materials, and permanently disposing of the nation's radioactive waste. Accordingly, the Department charged EM and the Office of Civilian Radioactive Waste Management to align technology investments with the needs of the mission. These investments must provide the scientific knowledge and new technology necessary to meet the Department's regulatory commitments and to reduce the cost of complex-wide cleanup efforts, as stated in the Department's FY 2006 Strategic Plan, Strategic Theme #4, Goal #4.1, shown below.

DOE Vision

The DOE vision calls for "Results in Our Lifetime to Achieve: 1) Energy Security; 2) Nuclear Security; 3) Science-Driven Technology Revolutions; and 4) One Department of Energy – keeping our commitments."

DOE Strategic Themes

DOE has established five strategic themes, as follow.

1. Strategic Theme #1 Energy Security: Promoting America's energy security through reliable, clean, and affordable energy.
2. Strategic Theme #2 Nuclear Security: Ensuring America's nuclear security.
3. Strategic Theme #3 Scientific Discovery & Innovation: Strengthening U.S. scientific discovery, economic competitiveness, and improving quality of life through innovations in science and technology.
4. Strategic Theme # 4 Environmental Responsibility: Protecting the environment by providing a responsible resolution to the environmental legacy of nuclear weapons production.

   General Goal #4.1: Environmental Cleanup: Complete cleanup of the contaminated nuclear weapons manufacturing and testing sites across the US.

5. Strategic Theme #5 Management Excellence: Enabling the mission through sound management.

2.2 EM ENGINEERING AND TECHNOLOGY (E&T) MISSION AND VISION

The programs funded within the EM appropriations have one Program Goal that contributes to the General Goals in the "goal cascade." This General Goal 4.1, Environmental Management states: Accelerate cleanup of nuclear weapons manufacturing and testing sites, completing cleanup of 108 contaminated sites. Key elements of this goal are: improve EM project performance to 90 percent; better account for cleanup project unknowns/uncertainties; improve use of risk management plans and information; and train and certify Federal Project Directors.

The mission of EM is to complete the safe cleanup of the environmental legacy brought about from five decades of nuclear weapons development and government sponsored nuclear energy research. The EM program has embraced a mission completion philosophy based on reducing risk and reducing environmental liability. The momentum gained in this philosophy shift is underpinned by a three-prong foundation built on the complementary ideals: 1) safe for the workers and U.S. citizens; 2) protective of the environment; and 3) respectful of the taxpayer. These ideals are integrated into the everyday cleanup decisions and activities of the EM program.

The EM Engineering and Technology (E&T) Program's mission, and vision support the Department and EM goals.

Mission

To Identify Vulnerabilities and to Reduce the Technical Risk and Uncertainty of EM Programs and Projects

The E&T Applied Research and Technology Development and Deployment mission is to improve the performance of environmental cleanup projects over their entire life-cycle from planning to disposal, through targeted investments that identify, advance, develop, and implement the best engineering concepts, technologies, and practices. The ***Program*** strives to reduce total cleanup costs by promoting cross-site integration, standardizing best technical practices, beneficial research and technology development and deployment, and leveraging lesson learned through engagement of a, cadre of subject matter experts.

Vision

E&T initiatives will provide the engineering foundation, technical assistance, new approaches, and new technologies that contribute to significant reductions in risk (technology, environmental, safety, and health), cost, and schedule for completion of the EM mission. The ***Program*** provides the highest level of interdisciplinary engineering consultation, guidance, expertise, and continuity in the organization.

3 EM ENGINEERING AND TECHNOLOGY PROGRAM

3.1 GOAL AND OBJECTIVE

The EM Office of Engineering and Technology manages the EM Applied Research and Technology Development and Deployment Program (***Program***) that conducts applied research and technology development, demonstration and deployment.

The objective of the ***Program*** is to reduce the technical risk and uncertainty in the Department's clean-up programs and projects. To reduce those risks and uncertainties, the ***Program*** will provide technical solutions where none exist, improved solutions that enhance safety and operating efficiency, or technical alternatives that reduce programmatic risks (cost, schedule, or effectiveness). A successful applied technology and engineering program for EM will be comprised of programs designated as "technology-pull" (i.e., driven by project needs) and "technology push" (i.e., driven by insertion of technologies that are better, faster, or cheaper than the baseline technology). The ***Program*** will look at which alternative technology or technical approach can be a "forcing function" or a "transformational advancement" - impacting a baseline schedule or have the greatest potential for changing the dynamics of site cleanup.

To directly support opportunities identified in the EM cleanup initiatives, the *MYPP* is aligned and driven by site cleanup priorities, and corresponding technical needs. The EM cleanup sites have identified technical gaps in their baselines, which, if resolved, can offer significant cost and schedule reductions to current baselines and improve safety performance for both the workers and the public. The focus is on the largest DOE-Complex cleanup sites – Savannah River; Idaho; River Protection; Richland, Portsmouth and Paducah Project, and Oak Ridge -- without losing sight of the either the closure sites or the smaller sites.

Work activities will continue to support prior Congressional direction to evaluate commercially available remediation technologies to accelerate cleanup, reduce risks, and to provide increased safety to workers and the public. This effort was initiated in FY 2005 through issuance of a solicitation to private industry. In FY 2007, contracts were awarded for five Advanced Remediation Technology (ART) Phase II demonstrations. Four of these ART awards were in the Waste Processing program area, while one was in the Groundwater & Soil program area.

3.2 STRATEGIC APPROACHES TO ADDRESS THE MAJOR CHALLENGES

The ***Program*** will target three major challenges: 1) eliminating technical uncertainties/gaps in individual site baselines; 2) offering significant cost/schedule reductions to a site's current baseline; and 3) improving worker and public safety. The focus will be on providing innovative technical solutions in response to the highest priority needs of the sites. Support for applied engineering and research demonstrating the technical feasibility of higher-risk, high payoff technologies is included in this ***Program***.

In addition to the above challenges, the ***Program*** will continue to move towards establishing itself as credible E&T program that delivers transformational technology and technical assistance in support of the EM Cleanup Program.

To address these challenges, the ***Program*** is divided into six program areas:

- Waste Processing,
- Groundwater and Soil Remediation,
- D&D and Facility Engineering,
- DOE Spent Nuclear Fuel (SNF),
- Challenging Materials, and
- Integration and Cross-Cutting Initiatives.

Four strategic approaches were developed to successfully implement the ***Program***: technology development and deployment, technical assistance, leveraging, and engineering and technology integration.

3.2.1 Technology Development and Deployment

Alternative technologies must be delivered in time for implementation during the life-cycle of a site cleanup schedule. For those technology needs and priorities identified by the sites, but not addressed by the prime contractors, EM-complex priorities and funding profiles are established for the out years. Cleanup technologies are often developed at national laboratories, universities, other academic institutions, and commercial providers through a competitive bidding process. Such technologies must stand on their own merits, be safe, cost effective, and offer significant advantages over other approaches – without introducing unacceptable levels of technical risk or schedule impact. Technical needs will exist until cleanup is completed. Long-term technology planning becomes more difficult due to uncertainties associated with cleanup progress, delays with design and construction of already approved facilities/plants, and uncertain regulatory outcomes for specific disposal pathways.

3.2.2 Technical Assistance

Technical assistance is provided to sites to reduce the technical uncertainty and risk of site cleanup. Rapid response will be provided to address current technical issues impeding site cleanup, resulting in significant cost savings or producing a major improvement to the waste disposition pathway. Key services include engineering and scientific expertise, either for External Technical Reviews (ETRs), which address difficult technical problems or assist in the resolution of project management issues, or for Technology Readiness Assessments (TRAs), which evaluate whether technologies are sufficiently mature to be implemented. Technical assistance includes activities such as: baseline and project reviews; technical workshops with experts on specific crosscutting issues; engineering consultation; cost estimation support; scientific or engineering problem solving; technical analysis and studies; assistance with technology demonstrations; testing of alternative approaches; and contract and acquisition support.

3.2.3 Leveraging – Moving Towards a Community of Practice

Leveraging of technology development has been a consistent priority since the inception of EM in 1989. It continues to be a critical element in the effort to obtain maximum benefit from invested resources in technology development for the Office of Engineering and Technology Applied Research and Technology Development and Deployment component.

In support of technology development, leveraging occurs through many avenues including private industry investment, as well as research conducted by other DOE offices and federal programs. Examples of such leveraging include direct application of commercially available technology (often following field testing or a demonstration under EM conditions), the modification or adaptation of a commercial technology to meet waste processing needs, or the commercialization of a technology that was originally developed by a university or national laboratory. It is important to increase such technology leveraging as a means to maximizing EM's return on technology development investment.

EM also actively explores the use of international technologies for problems and issues in the Complex. This includes regular discussion of the EM program and some of its needs at international symposia, along with directed technical exchanges with several foreign entities (e.g., Russia, United Kingdom, France, South Korea, Germany, and Japan). These interactions have resulted in promising technologies, which are presently being demonstrated, and have provided valuable data to support current operations.

To improve the leveraging of information amongst the various organizations, the Office of Engineering and Technology has developed a management concept of "community of practice." This concept has been defined as follows:

> "A group of people who share a common interest in a subject or problem and who collaborate over an extended period to share ideas, fund solutions, and build innovations." (Wikipedia)

EM will be assisted in carrying out the Program by the Savannah River National Laboratory (SRNL). SRNL will pull together teams from the other national laboratories (Idaho National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory), the private sector, academia and others to provide support to EM. These "communities of practice" will function as centers for the purpose of resolving the risks, sharing information and increasing the level of collaboration.

3.2.4 Engineering and Technology Integration

The initial set of needs was generated at an EM Technical Integration Workshop held in October 2006 as input to the *Roadmap*. The objective of the workshop was to identify and prioritize EM's technical needs for the next ten years. Participants included EM Headquarters and field sites (both federal and contractor staff), other DOE programs, National Laboratories, the National Academy of Sciences (NAS), and the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), among others. Three breakout sessions were conducted: Waste Processing (WP); Groundwater and Soil Remediation (GW/S); and D&D/Facility Engineering. A key feature of the workshop was the sites demonstrating how technical needs are linked to project baselines, critical decisions, or other major milestones.

In February 2007, EM requested the NAS to conduct a project that will solicit input from key external groups such as the Nuclear Regulatory Commission (NRC), Defense Nuclear Facilities Safety Board (DNFSB), Environmental Protection Agency (EPA), and state regulators to provide advice to EM in support of the *Roadmap's* development and implementation.

In the development of the *MYPP*, the ***Program*** teams, i.e., Communities of Practice, used the needs generated at the EM Technical Integration Workshop and the *Roadmap* as input, and then met with the field sites for additional input. An initial prioritized listing of tasks was developed, then reviewed with the laboratories and field sites. The results of these interactions resulted in the current plan.

3.3 EM BUDGET PRIORITIES

The ***Program*** priorities align with the EM priorities, shown below:

1. Fully establishing the disposition capability for radioactive liquid tank waste and low level waste (i.e., River Protection (Office of River Protection) Waste Treatment Plant, Idaho Sodium-Bearing Waste Facility, and Savannah River Salt Waste Processing Facility).
2. Disposing of contact-handled and remote-handled TRU waste and LLW (i.e., Waste Isolation Pilot Plant (WIPP), Idaho and Oak Ridge waste processing facilities).
3. Deactivation and decommissioning of facilities that are no longer needed (i.e., Oak Ridge East Tennessee Technology Park and the Hanford River Corridor).
4. Remediation of contaminated soil and groundwater (i.e., complete cleanup of twelve sites or major areas between 2008 and 2010.

4 EM ENGINEERING AND TECHNOLOGY PROGRAM PLAN (2008-2010)

This section contains detailed description of the needs and scope of work for each of the program areas.

4.1 WASTE PROCESSING

Waste Processing Program activities within the *Roadmap* and the *MYPP* are described in five strategic initiatives:

- Improved Waste Storage Technology,
- Reliable & Efficient Waste Retrieval Technologies,
- Enhanced Tank Closure Processes,
- Next-Generation Pretreatment Solutions, and
- Enhanced Stabilization Technologies.

The strategic initiatives were developed with input from the appropriate EM sites, projects, and programs to ensure that the key waste processing needs throughout the EM Complex are fully represented. These initiatives and associated activities were developed by the Office of Waste Processing through a Community of Practice, formed with experts from the Office of Waste Processing, national laboratories, industry, and academia intimately familiar with the EM sites and programs that are involved with waste processing. Starting with the risks presented in the *Roadmap*, the Community of Practice conducted an in-depth analysis of the risks and impacts, if not mitigated. Additional information was gathered from reviews of external technical review documents, technology readiness assessments, and National Academy of Sciences (NAS) review reports. In addition, stakeholder comments made on the original draft of the *Roadmap* were also reviewed. The Community of Practice then performed a gap analysis against current projects funded by the EM sites, DOE programs, and other entities. Based on the results of this work, the team recommended activities within each strategic initiative area. The resulting list of activities represents an effort to develop a balanced research and development portfolio; one that addresses both near-term project needs, as well as the longer-term strategic needs in waste processing. In developing this portfolio, an effort was made to leverage prior EM-funded development work, commercial capabilities and international expertise and experience (further discussion of technology leveraging is found in Section 3.2.5 of this document).

4.1.1 Needs for Reducing Technical Risk and Uncertainty for EM

The waste processing portion of the EM mission encompasses the treatment and disposition of high level liquid waste (HLW) and the transportation and disposal of low-level waste (LLW) and transuranic waste (TRU). A large majority of these wastes and facilities are unique to DOE, with the result that many of the programs to treat these wastes are "first-of-a-kind" and unprecedented in scope and complexity. As a result, the technologies required to disposition these wastes must be developed from scratch or require significant re-engineering to adapt to EM's needs. The Waste Processing Program is focused on technology that enables the reduction of risk and uncertainty for handling and disposition of HLW, LLW, and TRU waste throughout the Complex. Priority is given to the technical areas and the sites with the highest risk, but the Office of Waste Processing technology development planning efforts encompass all sites and all waste issues.

Development of technologies that enhance the safety, effectiveness, and efficiency of handling, treating and disposing of the legacy wastes addresses a very large challenge. The DOE has approximately 95 million gallons of liquid waste stored in underground tanks and approximately 4,000 m^3 of solid waste derived from the liquid HLW stored in bins. The current DOE estimated cost for safe storage, retrieval, treatment and disposal of this waste exceeds $50 billion to be spent over several decades. The challenges associated with HLW include:

- **Safe storage** – millions of gallons of HLW reside in underground tanks located at Hanford and Savannah River, with some waste also remaining at Idaho. Storage space is at a premium and the tanks themselves must be maintained in good condition.
- **Waste retrieval** – safe and effective methods must be developed for the retrieval and transport of the HLW material from the storage tanks. This is particularly challenging due to large differences in waste composition between different tanks and sites.
- **Tank closure** – following removal of the HLW from storage tanks, the tanks must be cleaned to an appropriate level and closed. The tank closure process usually involves an assessment of the residual contamination followed by grouting to fix the contamination and place the tank into a safe and stable end-state.
- **Waste pretreatment** – processes must be developed to efficiently separate HLW into low-activity and high-activity components; this reduces the amount of high-activity waste that must be processed and disposed. The development of pretreatment processes is especially difficult because of the differences in waste composition between tanks and sites. Pretreatment processes must be tailored to the waste composition and to the waste treatment process that will follow.
- **Waste treatment/stabilization** – processes must be developed to treat both the low-and high-activity waste fractions in order to render them into forms suitable for long-term disposal. In some cases, new treatment or stabilization processes must be developed for a particular waste stream; in other cases, an existing process can be modified to accept a new stream.

Opportunities for cost and schedule improvement in treating and disposing of this waste, along with improving the safety of processing systems, depend on several factors including revised approaches, new acquisition strategies, and revised cleanup agreements. This *MYPP* focuses on achieving cost and schedule reductions in the development and implementation of new or improved technologies, at the appropriate time in site program schedules. Timely recognition of the need for an improved technology or technical approach and the initiation of a focused technology development program are the keys to successfully accelerating waste treatment and disposition. Processing of HLW at the sites involves integration of many complex shared retrieval, processing, and immobilization issues common to sites within the Complex. Through close interaction with EM site management, improved technical approaches for the highest cost HLW activities at each site can be developed. In addition, there will be opportunities to transfer technologies from one site to another and achieve additional improvements in safety, schedule, and cost.

The highly radioactive portion of the HLW at Hanford (ORP – Office of River Protection), Idaho (ID), and Savannah River (SR) must be treated and immobilized, and prepared for shipment to a geologic waste repository. The ORP is currently building a Waste Treatment and Immobilization Plant (WTP) to treat roughly 53 million gallons of HLW stored in 177 underground tanks. Idaho is committed to treating approximately 3 million gallons of liquid waste and transferring both the treated liquid and stored solid wastes to approved repositories. Savannah River has been processing tank sludge since 1996, gaining significant experience for the EM Complex; however, a number of processing challenges remain. All of these sites have aggressive schedules for waste treatment and tank closures and will require the support of improved technologies and approaches to meet or accelerate those schedules.

As a result of the importance of reducing technical risk and uncertainty in the EM Waste Processing programs, EM Engineering & Technology has focused considerable effort on identifying the key areas of risk in the Waste Processing programs. A summary of technical risks and needs was captured in the *Roadmap*. The *Roadmap* identifies the key Waste Processing initiative areas where technology development work should be focused. These areas are listed below.

- Improved Waste Storage Technology
  - Develop cost effective, real-time monitoring of tank integrity and waste volumes to ensure safe storage and maximum storage capacity.
  - Improve understanding of corrosion mechanisms and changing waste chemistry, including flammable gas generation, retention, release and behavior to establish appropriate assumptions in safety analyses.
- Reliable and Efficient Waste Retrieval Technologies
  - Develop optimization strategies and technologies for waste retrieval that lead to successful processing and tank closure.
  - Develop a suite of demonstrated cleaning technologies that can be readily deployed throughout the complex to achieve required levels of removal.
- Enhanced Tank Closure Processes
  - Improve methods for characterization and stabilization of residual materials
  - Develop cost-effective and improved materials (e.g., grouts) and technologies to efficiently close complicated ancillary systems.
  - Perform integrated cleaning, closure, and capping demonstrations.
- Next-Generation Pretreatment Approaches
  - Develop in- or at-tank separations solutions for varying tank compositions and configurations
  - Improve methods for separation to minimize the amount of waste processed as HLW.
- Enhanced Stabilization Technologies
  - Develop next-generation stabilization technologies to facilitate improved operations and cost.
  - Develop advanced glass formulations that simultaneously maximize loading and throughput.
  - Develop supplemental treatment technologies.

A summary discussion of each strategic initiative is provided below. The Waste Processing *MYPP* includes additional detail for each initiative and the planned approach to technology development.

4.1.2 SCOPE OF WASTE PROCESSING WORK

The strategic initiative areas listed in this section are identified in the *Roadmap* (and described above); they indicate technical challenges where development work is critical to reduce the key technical risks and uncertainties in the EM Waste Processing programs. Work in these initiative areas is expected to produce solutions and/or enable key decisions at one or more DOE sites facing a given risk. The Waste Processing Community of Practice developed a prioritized list of proposed tasks within each strategic initiative - the technology development portfolio - that aims at reducing the identified risks at EM sites. These prioritized lists were reviewed with senior DOE Site personnel prior to being finalized. This portfolio can be adjusted to suit any funding level. The prioritized portfolio was reviewed to ensure a balance between

- Near term (quick win) accomplishments and strategic activities addressing long term objectives,
- Activities addressing technologies requiring a long development cycle and those near deployment, and
- A reasonable distribution of activities across all of the strategic initiative areas and Sites.

For each strategic initiative discussed below, a general overview of the technical issues is provided, followed by a broad description of the technology development activities and approach.

4.1.2.1 *Improved Waste Storage Technology*

Both Hanford and Savannah River Sites are limited in available high-level tank space to support waste operations and tank retrieval. This limitation is further constrained by assumptions in the safety bases for tanks aimed at mitigating the chances for exceeding the lower flammability limits for hydrogen and by an incomplete understanding of the tank structural integrity risks. Improvements in waste storage efficiency are a necessity at all EM sites and will require a systematic effort to address all aspects of the current limitations. Three initiative activities were identified to address this need:

- Approaches for increasing high level waste tank capacity
- Improved waste tank integrity assessments
- Improved understanding of tank waste chemistry and behavior.

Approaches for Increasing High-Level Waste Tank Capacity

The current assumptions in the safety bases for HLW tanks at both the Savannah River and Hanford sites constrain the use of the available tank space in order to mitigate the chances of exceeding the lower flammability limits for hydrogen. This is an outcome of the present state of information on actual waste behavior that has resulted in models that can prevent optimized use of the available tank space. Similarly, the precision of present measurement technologies impacts fully-effective use of tank space.

Activities to address these issues will focus on the development of transformational numerical models for estimating gas retention and on the development of measurement technologies for quantifying critical waste properties. The modeling efforts will be supplemented and supported by laboratory testing for key properties. Characterization technologies, whether developed or obtained commercially, will be tested in laboratory settings and with actual tank waste material. It is envisioned that the tasks will involve commercial industry, national laboratories, and universities.

Improved Waste Tank Integrity Assessments

The HLW storage tanks at Hanford and Savannah River are critical national assets that must be maintained beyond their initial estimated design lives. However, it is difficult to determine the optimum measures to maximize the utility of the tanks and maintain their integrity due to incomplete understanding of the tank structural vulnerabilities and chemical corrosion mechanisms. Conservative assumptions have been put in place that preserves tank integrity; however, these assumptions can lead to less than optimal tank utilization.

Activities to address this issue will focus on developing an improved understanding of the chemical mechanisms that result in corrosion of HLW storage tanks and their ancillary systems, such that appropriate corrosion standards can be applied. The planned work includes further development of in-tank corrosion probes and chemical sensors needed to support real-time decisions, as well as detailed finite element analyses to establish appropriate assumptions for waste limits and development of advanced fracture mechanics methodology to reduce the uncertainties and conservatism in the understanding of tank integrity.

Improved Understanding of Tank Waste Chemistry and Behavior

Safe storage, management and treatment of the EM high-level waste inventory require a detailed understanding of waste composition and chemical reactivity. This information is difficult to obtain, given the complex composition of the wastes, and is further complicated by multiple transfers, evaporation campaigns, and aging that have created unique solids and liquids in each tank. As a result, site contractors are often forced to develop one-of-a-kind solutions for many waste operations.

Activities to address this issue will focus on developing and assessing models, tools, and analytical methods that can address critical compositional and operational challenges. The goal is to develop recommendations on models, techniques and tools that will allow sites to apply consistent solutions to common challenges. The work will be accomplished through a mix of modeling activities, laboratory work, and applications of commercial technology. It is envisioned that the activities will involve commercial industry, national laboratories, and universities.

4.1.2.2 *Waste Retrieval Technologies*

Technology development within this strategic initiative area will focus on the development of methods that allow the retrieval of waste to the maximum extent practical for subsequent processing and treatment, followed by chemical cleaning of the waste tank prior to closure. Current waste removal and retrieval operations can be costly and are often limited in effectiveness by tank conditions. Complications include difficult-to-remove waste deposits, limited accessibility, in-tank debris, etc. Also, inhomogeneous (i.e., different size, shape, consistency) bulk waste retrieval could leave waste that is not acceptable for downstream processing due to size or composition. Additionally, a number of tanks are known or suspected to have leaked in the past; this may limit the use of current technologies that require addition of significant volumes of water. Finally, improved mechanical and chemical retrieval technologies are also needed. Within this strategic initiative, the Waste Processing Community of Practice identified two major initiative activity areas for technology development activities that support the needs of the EM Complex:

- Develop a suite of residual waste removal technologies
- Develop options for chemical cleaning.

<u>Develop a Suite of Residual Waste Removal Technologies</u>

A key aim in this initiative activity area is the development of a "toolbox" of technology solutions to improve bulk waste removal operations and assist in the removal of liquid and solids remaining in tanks and ancillary equipment after bulk waste removal operations are completed. This effort will include identifying and developing the requirements and deployment strategies for adaptable concepts and technologies and identifying the gaps in existing DOE-sponsored and industrial technologies. A central part of the work in this area is the creation of a resource center with information on deployment experiences and lessons-learned. Other activities include the development of sampling and characterization tools for use prior to and during residual waste retrieval to assist with the efficiency of retrieval operation. Technologies and engineered solutions will be developed to remove radioactive material on the internal surfaces (walls, cooling coils, and other internal obstructions) and agglomerated materials that resist physical removal.

The general approach to the work in this initiative activity area involves a mix of the application of commercially available technologies along with the development of dedicated, specialized equipment. It is envisioned that the tasks in this initiative will involve private industry, national laboratories, and universities. Industry experience will be utilized as much as practical. Industry tools will be integrated into overall deployable systems as appropriate. International experience and capabilities will be considered as well. The Community of Practice will work with the major sites (particularly Savannah River and Hanford) to determine the priorities and appropriate timing for insertion of the appropriate technology. A method of communicating the status of the toolbox of technologies will be developed and communicated.

<u>Develop Options for Chemical Cleaning</u>

Chemical cleaning of HLW tanks involves the addition of chemicals to the HLW tank following bulk and/or residual waste removal in order to dissolve and remove the residual tank waste. This is an important step on the path to tank closure as it reduces the source term of radioactive material in the waste tanks. Application of chemical cleaning to HLW tanks must give consideration to the tank integrity, the presence of significant tank obstructions, the impact of the residual chemicals on downstream processes and limitations on liquid chemical additions due to leak sites or tank space restrictions. The work in this initiative activity area will focus on the development of a technology base to perform chemical cleaning for a variety of potential applications. The focus of these efforts will be to develop versatile, low-impact technologies that are suitable for deployment in tanks with significant obstructions and limitations on liquid addition.

The approach in this initiative activity area will involve defining the requirements for chemical cleaning by considering tank integrity, downstream impacts, and limitations on liquid additions. This will be accomplished by gathering the information gained from chemical cleaning experience at Savannah River and Hanford, and utilizing a team of experts to evaluate potential cleaning strategies. Further work will include development of an improved understanding of the impact of chemical cleaning on the waste itself, including gas generation, chemical speciation, and process impacts on downstream facilities. Testing with real waste will also be performed.

4.1.2.3 *Enhanced Tank Closure Processes*

Technology development and engineering activities within this strategic initiative area center on the effective characterization and stabilization of remaining material in waste tanks and ancillary systems, after bulk waste removal has been completed. Because these residual materials and the associated limits play such an important role in the tank closure process, accurate and reliable methods for measuring the quantity and composition/radionuclide content of residual materials are important. The size and geometry of tanks, limited points of access and obstructions (cooling coils and other tank components) make accurate residual waste measurements difficult. New techniques and/or technologies will enhance the ability to make accurate and reliable measurements. Waste classification (either under DOE Order 435.1 or Section 3116 of the National Defense Authorization Act of 2006) is an integral part of the closure process at all sites and requires immobilization of the radioactive waste residues in the tanks. Cementitious materials (grout) are used worldwide to immobilize LLW and have been chosen by DOE for tank closure applications. These materials are also planned for closure of ancillary equipment (such as pumps, valve boxes, and underground transfer lines). Formulations for these grout materials that provide the necessary chemical and physical properties (including aging properties), and that can be deployed in difficult to access locations, are necessary. Within this strategic initiative, the Waste Processing Community of Practice identified three major initiative activity areas for technology development activities that support the needs of the EM Complex:

- Improved residual waste characterization and stabilization
- Develop materials and technologies to close ancillary systems
- Perform integrated cleaning, closure and capping demonstrations

Improved Residual Waste Characterization and Stabilization

This initiative activity area will focus on the development of sampling and analysis methods to assess the quantity, composition, and radioactivity of residual tank waste and on the development of improved materials for stabilization of the residual waste. Assessment of residual materials in waste tanks is often hindered by difficult-to-access tanks, tank obstructions, poor lighting, etc.

Initial activities in this initiative activity area will focus on an assessment of commercial capabilities related to sampling/analysis tools and techniques, using a complex-wide team of technical experts. This team will also define requirements for the accuracy needs of these sampling and analysis methods as well as testing requirements prior to deployment. The results of these efforts will be evaluated along with a collection of lessons-learned and results of workshops. Industry experience and tools will be integrated into the overall effort, as appropriate. International experience and capabilities will be considered as well. The team will work with the major sites (particularly Savannah River Site (SRS) and Hanford) to determine the priorities and appropriate timing for insertion of the appropriate technology.

The other major activities of this initiative activity area will focus on the development of improved materials for stabilization of residual tank waste. Some work has been performed in this area and two tanks have been closed at SRS. However, additional grout property data is needed to support performance assessments; in particular, a better understanding of leaching and permeability of grouts is needed. Improved methods to collect these data will be developed and a database of information generated to support formulation efforts.

Develop Materials and Technologies to Close Ancillary Systems
This initiative activity area will focus on developing requirements and strategies for closing ancillary systems such as cooling coils, transfer lines, pump pits, etc. These areas are often very difficult to access and little is known about their current condition. In addition, standards and requirements for the closure of ancillary systems are not well defined.

The general approach to this initiative activity area will be the early formation of an expert panel to discuss the needs and requirements for closing these systems. Work on methods for characterizing residual material inside pumps, coils, transfer lines, etc. will be initiated. It is envisioned that the tasks in this initiative will involve private industry, national laboratories, and universities. Because of the potential applicability of commercial technologies and experience in this area, broad industry and international input and participation will be sought on potential technologies in this area. The technology development and engineering work in this area will require both laboratory testing with actual waste materials as well as selected pilot scale demonstrations.

Work will also be initiated to develop grout formulations that can be deployed over long distances (cooling coils, transfer lines, etc.) while still maintaining acceptable properties. This effort will be leveraged with work planned for residual waste characterization and stabilization.

Perform Integrated Cleaning, Closure and Capping Demonstrations
This initiative activity area will develop demonstration capabilities and facilities to support the development, engineering and field testing of residual waste cleaning, characterization, and closure systems for waste tanks and their ancillary systems. Initial efforts in this area will focus on developing the requirements for integrated demonstrations.

4.1.2.4 *Next-Generation Pretreatment Solutions*
This strategic initiative encompasses the identification and development of technologies that allow pretreatment of liquid waste in order to reduce the amount of waste processed and disposed as HLW. A significant impact can be made in cost and risk reduction in the treatment and disposition of HLW through development of innovative technical approaches that improve baseline treatment technologies, yield alternative treatment approaches, or add supplemental treatment options to allow parallel processing (and, therewith, lifecycle cost reductions). The goal of this strategic initiative is to develop such pretreatment technologies for applications that maximize the reduction of technical risk. Particular attention is given to technologies that offer multi-site benefit. Within this strategic initiative, the Waste Processing Community of Practice identified two major initiative activity areas for technology development activities that support the needs of the EM Complex:

- Develop in- or at-tank separations solutions
- Develop improved methods for waste separation

Develop In- or At-Tank Separations Solutions
This initiative activity area will develop engineering and technology for separating low-level waste from high-level waste fractions and removing solids from these solutions as required. A key transformational aspect of this initiative is to locate the treatment technology in- or at-tank. This requires re-examination of process flowsheet options and engineering solutions to closely couple the waste retrieval with pretreatment. Additionally, a goal is to develop tailored process flowsheets, for varying tank conditions and compositions, which provide flexibility and functionality for the pretreatment technology.

A key activity in this initiative activity area is to leverage existing Office of Waste Processing-funded projects for in-tank treatment for TRU, strontium, and cesium, while evaluating developing needs from the EM sites. Tasks funded under this initiative will use a mix of national laboratory, university and industrial assets and expertise, as appropriate, to develop treatment options and improve and optimize the processing flowsheets.

Develop Improved Methods for Waste Separation
The technology development and engineering efforts in this initiative activity area will seek to develop engineered solutions that more effectively separate inert materials and low activity waste from HLW, such that only the HLW fraction is stabilized for geological disposal. Among the key challenges being addressed at this time is the development of technology solutions that would allow for the removal of large amounts of aluminum from HLW sludge at Savannah River and Hanford in order to reduce the burden on the HLW vitrification facilities. Additionally, a significant fraction of predicted sludge batches at Hanford are limited by the chromium content. Technologies are needed to advance the understanding of chromium-oxidants and their impact on downstream processing.

Activities in this initiative activity area will leverage on-going efforts for the development of treatment technologies for the removal of aluminum and chromium from HLW sludge. The approach will center on developing the science and engineering required to support the processing flowsheets. Resources at the national laboratories will be utilized, along with assistance from other sources such as universities and commercial industry.

4.1.2.5 *Enhanced Stabilization Technologies*
Technology development efforts in this strategic initiative include all aspects of the waste immobilization processes. Improvements in immobilization processes (e.g., vitrification) will have a multi-site benefit and yield significant cost savings and reduction of risk. Alternative or improved melter designs may enable operations at elevated temperatures and higher throughput in the same plant footprint. Improved glass formulations that allow a higher waste loading will reduce the number of waste packages and improve process throughput, both of which have significant benefits. Incremental gains could benefit current processing activities, while exploratory work on future wastes will also be used in planning activities and step function improvement in efficiency and reduction of programmatic risk.

There are some wastes that are not appropriate for vitrification. For these wastes, supplemental treatment operations will be developed and tested.

Within this strategic initiative, the Waste Processing Community of Practice identified three major initiative activity areas for technology development activities that support the needs of the EM Complex:

- Develop next-generation melter technology
- Develop advanced glass formulations
- Develop supplemental treatment processes

Develop Next-Generation Melter Technology
This initiative activity area will develop alternative technologies for glass melting and melter operation that will permit higher melter throughput and/or increased waste loading. Waste glass melter throughput is determined by a number of interdependent parameters. To increase melter throughput these parameters must be considered and optimized specifically for the waste and facility to enable higher glass production rates. The loading of waste in glass is controlled in part by the melter processing related parameters. Certain melter design changes could yield improved loading of Savannah River HLW in glass, Hanford HLW in glass, and Hanford LAW in glass.

A research and engineering program has been planned to systematically evaluate key melter design parameters for improved melting rate, enhanced waste loading, and acceptable or improved service life. In addition to melter enhancement, facility enhancements are often required to recognize the benefits of improved waste throughput. Tasks aimed at improvements to melter feed systems, canister handling systems, and decontamination systems will also considered. These design features will be developed and tested for optimal waste throughput at the three facilities. This work will incorporate work at national laboratories, universities, commercial industry, and international experience (leveraging the EM International Program). A complex-wide team of technical experts will work with the major sites (particularly SRS and Hanford) to determine the constraints, priorities and appropriate timing for insertion of the improved melter technologies.

Develop Advanced Glass Formulations
Activities in this initiative activity area will seek to improve existing glass formulations by increasing waste loading and waste throughput. This, in turn, will reduce the life-cycle cost of waste processing operations and/or the number of glass canisters that must be disposed. In addition, this work will refine the predictive models used for operation of the waste processing facilities to allow for enhanced operational control and improved life-cycle management by integrated storage, retrieval, pretreatment, and stabilization system optimization.

A research program has been planned to accomplish increases in waste throughput at Hanford and Savannah River. The program will systematically evaluate key waste glass parameters, develop glass data for expansion of composition regions, and integrate with advanced melter technology development. Testing of glasses must be performed over a range of scales from small crucible testing to pilot scale melters. Both domestic and international experience and capabilities will be used for the best benefit of DOE. As the tasks to perform in this initiative are highly integrated with the melter development initiative and between tasks within the advanced glass formulation initiative, a team of experts from the national laboratories and academia will be assembled to perform the research. The team will work with the major sites (particularly SRS and Hanford) to determine the priorities and appropriate timing and formulation direction throughout the research.

Develop Supplemental Treatment Processes
Activities in this initiative activity area will develop and demonstrate technology for the immobilization of secondary waste streams from the major EM sites. Several streams are to be considered, including: 1) excess pretreated LAW from Hanford, 2) pretreated salt wastes from SRS, 3) Melton Valley tank wastes from ORNL, 4) secondary wastes from tank farm and vitrification plant operations at SRS, Hanford, INL, and ORNL, and 5) calcine and sodium bearing wastes at INL. It is critical to address these secondary waste streams as an inability to safely dispose of these streams can limit the deployment and/or utility of the primary waste treatment processes that they support.

Studies in support of supplemental treatment of Hanford LAW will include advancements to the effectiveness and risk reduction for the bulk vitrification process. In addition, limited studies on alternate bulk vitrification concepts and alternate processes for treating excess Hanford LAW will be considered. Studies in support of the SRS salt waste treatment include advanced grout formulations, process control approaches, and qualification approaches. A treatability study of Melton Valley tank waste will be performed to demonstrate that a broader range of disposal paths are possible. Low temperature immobilization forms will be developed and demonstrated for secondary wastes from the four sites to include tank farm and treatment plant operation wastes. Backup treatment technologies will be investigated for INL calcine and sodium bearing wastes.

A research and demonstration program has been planned to lower the risk and improve the efficiency of waste treatment activities for these streams. The program will systematically evaluate improved treatment approaches and advanced flowsheets for the current treatment approaches. Commercial industry capabilities and international experience will be incorporated, as appropriate.

4.2 GROUNDWATER AND SOIL REMEDIATION

Groundwater and Soil Remediation Program activities are directed by the Office of Groundwater & Soil Remediation (EM-22) and, within the *Roadmap* and the *MYPP,* are described in four strategic initiatives: Improved Sampling & Characterization Strategies; Advanced Predictive Capabilities; Enhanced Remediation Methods; and Enhanced Long-Term Monitoring Strategies. An additional two elements for this program have been developed to support the strategic initiatives and EM's needs: Center for Sustainable Groundwater and Soil Solutions, and Columbia River Projects.

The Groundwater and Soils Remediation Program maintains a strong interface with the DOE Office of Science to leverage the basic science work to the ***Program's*** applied research needs.

4.2.1 Needs for Reducing Technical Uncertainty and Risk for EM

The EM sites identified groundwater and soil needs in six areas: sampling/characterization technology, basic and applied research, modeling, *in situ* technology, *ex situ* technology, and long-term monitoring. Common needs were identified for each of these areas and became the focus for defining the Strategic Initiatives that comprise the Groundwater and Soil Remediation Program as shown in below:

- Improve Sampling & Characterization Strategies
- Advanced Predictive Capabilities
- Enhanced Remediation Methods
- Enhanced Long-Term Monitoring Strategies

The Enhanced Long-Term Monitoring Strategies is part of the Integration And Cross-Cutting Initiatives program area defined in the *Roadmap*. The initiative is addressed here since the Groundwater and Soil Remediation Program is currently managing the active tasks in this area.

4.2.2 Scope of Groundwater and Soil Remediation Work

For each of the four strategic initiatives, national technology development and deployment (TDD) alternative projects were established to initiate implementation of this *MYPP*. The *work scope* is organized by WBS element. Initial funding was provided in FY 2007 for specific elements within the first three strategic initiative areas, with the intent of continuing these projects and including additional TDD projects within all four strategic initiatives in FY 2008 to fully implement the *MYPP*. Other WBS elements were also identified to capture Office of Groundwater and Soil Program Management needs, high-priority site-specific projects, and other program areas. Current WBS elements are listed below:

- Improve Sampling & Characterization Strategies
- Advanced Predictive Capabilities
- Enhanced Remediation Methods
- Enhanced Long-Term Monitoring Strategies
- Advanced Remediation Technologies
- Columbia River Projects
- EM Center for Sustainable Groundwater and Soil Solutions

Each of the elements is described in more detail in the following sections.

4.2.2.1 *Improved Sampling and Characterization Strategies*

Develop Next Generation Characterization Technologies & Strategies

The primary goal/objective of this initiative is to identify high-risk, complex-wide characterization needs within DOE and then to use the core technical team concept to develop technical toolboxes and approaches that can be used to address the problems at a specific waste site. These toolboxes and technical approaches will then be applied to similar problems at other DOE waste sites throughout the complex. The preliminary product of this exercise will be a series of contaminant-specific matrixes of characterization sensors and tools with recommendations that address specific high-risk needs applicable to multiple sites within the complex. Three specific initial target problem areas have been identified from the needs with each technical solution/approach to be implemented at a minimum of two DOE sites.

4.2.2.2 *Advanced Predictive Capabilities*

Develop Advanced Fate & Transport Models

The major objective of the Advanced Fate and Transport Models Initiative is to develop strategies and methodologies to address modeling issues for complex DOE EM waste sites.

The major goals are to:

- Provide a technical framework for translating the best science into useful information for developing conceptual and numerical models for complex sites and develop "handbooks" for key contaminants (uranium, technetium-99, and strontium-90 among others to be defined)
- Develop methodologies for defining and assessing alternative conceptual models that address uncertainty for complex sites
- Provide protocols for selecting, applying, modifying, or when necessary developing, numerical codes that can adequately address complexity
- Provide guidance for characterizing complex sites to obtain data for developing alternative conceptual and numerical models that support decision making.

4.2.2.3 *Enhanced Remediation Methods*

Enhanced Attenuation (EA) for Chlorinated Solvents Technology Alternative Project

To aid practitioners in implementing enhanced attenuation, the primary objective of this initiative will be to develop technical guidance for a variety of technologies deployed under the enhanced attenuation (EA) concept that will provide end users with the tools for assessing, designing, implementing, and monitoring sites with chlorinated solvent contaminated groundwater, as well as provide regulators a technical basis on which to evaluate proposed implementation of selected technologies under the EA paradigm. The major elements of this work are:

- Evaluate past datasets to assess effectiveness and sustainability of attenuation remedies under varying conditions.
- Perform focused field studies of enhancements with detailed monitoring and a sufficient period of record to document sustainability.

Demonstrate Methods to Reduce Transport Rate of Chlorinated Organics through the Deep Vadose Zone

This project will examine vadose zone transport processes for chlorinated organics, identify improved remediation approaches, and provide guidance and methods to support remediation objectives. Feasible remediation approaches for chlorinated organics in the deep vadose zone and groundwater will be identified that bridge from active remediation used in current baseline through alternative approaches and finally to MNA. The project objectives are:

- Identify and provide technical information necessary to implement methods for remediation of chlorinated organics in the vadose zone that are more effective than baseline soil vapor extraction at reducing transport through the vadose zone over the short and long term.
- Identify and provide technical information necessary to support approaches for setting and monitoring remediation objectives for chlorinated organics in the vadose zone.

Scientific & Technical Basis for In Situ Treatment Systems for Metals & Radionuclides

This initiative will provide improved methods to control, reduce, and/or remove troublesome metals and radionuclides in the vadose zone. It will generate both scientific information and cost effective *in situ* remediation technologies needed to treat metals and radionuclide contamination at a number of waste sites in which the capacity of the natural system to attenuate the contaminants is exceeded. Activities and products will support the following key objectives.

- Increase the scientific and technical knowledge base to better understanding the behavior of specific metals and radionuclides in the subsurface environment.
- Introduce innovative remedial approaches for in situ treatment of specific metals and radionuclides in the subsurface environment, including monitoring based on this knowledge.
- Reduce the overall technical risk related to the Department of Energy's cleanup mission and gain regulatory concurrence for remediation decisions.

Scientific Basis for Attenuation Based Remedies for Metal and Radionuclide Contaminated Groundwater

This initiative will provide the scientific and policy support to facilitate implementation of appropriate cleanup strategies relying on natural attenuation processes at DOE metal and/or radionuclide contaminated sites. Guidance on natural attenuation of metals and radionuclides will be developed to allow waste site managers to leverage the broad base of scientific information on specific contaminant attenuation mechanisms and predict the long-term efficacy of attenuation based strategies.

The implementation activities and overall structure of this initiative, along with the specific science selected for systematic deployment and documentation will support the following key objectives.

- Advance the science and broaden the understanding of attenuation based remedies for metals and radionuclides and how they should be used in long-term stewardship planning.
- Expand the concept of enhanced attenuation to the area of metal and radionuclide contaminants and how it should be used in long-term stewardship planning.
- Gain regulatory concurrence in the states and regions overseeing Department of Energy sites by working with interstate and national regulatory partners to contribute to a national effort that will provide guidance on implementing attenuation based remedies for metals and radionuclides.
- Establish and document new monitoring paradigms that provide high levels of performance for reduced costs.

Idaho Sr-90 Immobilization/Uncertainty Reduction Project

The field-scale mobility of Sr-90 in the subsurface and methods to alter this mobility, are the focal points of this initiative. The primary objective is to develop effective and sustainable technological solutions for treatment of Sr-90 in the vadose zone. Key goals include:

- Develop effective and sustainable *in situ* remediation solutions for Sr-90 plumes in the deep vadose zones, focusing on gas-phase fluid delivery systems

- Provide data and methods to incorporate Sr-90 retardation processes in advanced simulation codes for predicting migration of plumes with geochemical transients, and
- Evaluate methods to verify performance in in situ gas-phase remediation during and after emplacement of amendments.

4.2.2.4 *Enhanced Long-Term Performance Evaluation and Monitoring (Cross-cutting initiative)*

Develop Technical Basis for Paradigm Shift for Life-Cycle Monitoring

This initiative will develop improved and optimized long term monitoring systems to document the transition to, and sustainability of, DOE EM contaminant stabilization and remediation actions. One element of this activity will be to encourage integrating the waste sites within an area (the area closure concept), both for remediation decisions and monitoring, to maximize the overall risk reduction and promote synergistic decision-making. In particular, the initiative proposes using alternative and improved performance objectives, such as basing performance metrics primarily on plume stability/shrinkage rather than simply measuring a large number of "point" concentrations. It also proposes to link plume stability to broad scale controlling factors, such as weather, ecological or geochemical conditions/changes, and the like. A research portfolio will be developed that will solicit the best concepts from industry and universities in the following broad themes:

- spatially integrated monitoring tools;
- onsite and field monitoring tools and sensors; and
- engineered diagnostic components.

Develop Approaches for Integrating Life-Cycle Monitoring Data into Site Models

Alternative options for monitoring are emerging. These options include: use of tools that can provide volumetric or flux data that better delineate the contaminant plume and measures its behavior; emerging biosentinel or biomarker approaches that provide earlier and more direct indicators of ecosystem health than contaminant concentration alone; and aerial/remote monitoring techniques that can precede changes over wide geographic area. Although these tools are beginning to be demonstrated for sampling and characterization, there is a computational component that is needed to interpret the signal and correlate it to concentrations of species of concern.

The major objectives of this initiative are to:

- Provide the technical basis to shift the existing paradigm of point source monitoring to spatially integrated monitoring tools incorporating onsite field monitoring and sensors.
- Development of integrated risk management and decision support tools for a more system-based monitoring paradigm.

4.2.2.5 *Advanced Remediation Technologies (ART) Project*

Cost-effective *In Situ* Groundwater Remediation of DOE High Level Waste Sites with Enhanced Anaerobic Reductive Precipitation/Enhanced Reductive Dechlorination

The objective of this work is to demonstrate that a commercially available, *in situ* remediation technology, Enhanced Anaerobic Reductive Precipitation (EARP)/Enhanced Reductive Dechlorination (ERD) can provide cost effective groundwater remediation for Department of Energy (DOE) High Level Waste Sites. This technology has already been used at 190 sites, including 21 Federal sites, for a wide variety of metals, energetic materials, chlorinated volatile organic compounds (CVOC), nitrate and uranium. However, this technology has yet to be applied at field scale for radionuclides at a DOE facility.

The initial phase of this project includes:

- In-situ bioreductive process to immobilize contaminant metals and radionuclides within the subsurface at Hanford.
- Injection of a biodegradable substrate into the subsurface to stimulate native microorganisms that will couple the oxidation of the degradable substrate.

4.2.2.6 ***Columbia River Projects***

300 Area Uranium Plume Treatability Demonstration

The objective of this project is to test the application of long-chair polyphosphate compounds to stabilize uranium in groundwater. Laboratory tests are currently being conduct and a field test has been designed to determine if it is possible to treat groundwater in the aquifer in the 300 Area of the Hanford site. Finally, this project will determine if this approach can be implemented on a large scale and if it would be cost-effective.

100-N Area Sr-90 Treatability Demonstration (Phytoremediation)

The objective of this project is to demonstrate phytoremediation technology to extract Sr 90 from shallow soils and incorporate it into above-ground biomass. The Coyote willow is plant selected for the demonstration. The project will identify the best way to grow and fertilize these plants so that they generate the greatest biomass possible, thus removing greater quantities of Sr-90 from the subsurface. Greenhouse studies and field tests will be utilized. This technology can be used with other methods of remediation and be a polishing step specific to the very near river shoreline.

Refine Location of Chromium Source

The objective of this project is to locate the vadose zone source(s) feeding the northern chromium groundwater plume at the Hanford 100-D Area. Two facilities near the proximal portion of this plume processed highly concentrated (6M) sodium dichromate, and yellow staining indicative of chromate at fairly high concentrations has been observed on the foundations of one of the facilities. This investigation, to begin in the winter of 2008, will utilize an innovative push-technology to collect samples in the shallow and intermediate vadose zone in an attempt to directly find the source(s). Three groundwater wells will also be installed to assist in source location.

4.2.2.7 ***EM Center for Sustainable Groundwater and Soil Solutions***

The mission for the Groundwater and Soil Remediation Program is to identify problems and subsequent needs of the Federal cleanup projects and to provide applied research and development (R&D) solutions that reduce life-cycle technical risk and uncertainty for EM soils and groundwater programs and projects. The Savannah River National Laboratory (SRNL), as the EM Corporate Laboratory and the premier applied science laboratory for DOE, is uniquely positioned to serve as a focal point for this mission, in collaboration with other DOE national laboratories and sites, federal agencies, universities and industry, regulators, and public stakeholders.

The *EM Center for Sustainable Groundwater and Soil Solutions* at SRNL provides comprehensive and coordinated applied science and engineering resources and actively fosters collaboration among DOE laboratories and sites, federal agencies, universities and industry, regulators, and public stakeholders. As an applied science center of DOE, the products and support will:

- serve as a bridge to bring advances in basic research into practical use;
- develop, test and support technologies that employ natural and enhanced attenuation where appropriate;
- support the matching of technologies to site specific problems and the follow-on implementation;
- develop, test and support environmental remediation technologies that reduce energy use and minimize collateral damages -- develop new strategies for soil and groundwater cleanup that incorporate metrics related to the environmental impacts associated with the action; and
- serve as a clearinghouse for information and a central forum for technology innovators and environmental service providers.

4.3 D&D AND FACILITY ENGINEERING

The D&D engineering and technology investment strategy is linked to EM's mission priorities as reflected in the Site Performance Baselines, corporate performance measures, Performance Management Plans (PMPs), Risk Management Plans and defined end-states. The EM sites have identified technical gaps in their cost and schedule baselines, which if resolved can offer significant improvements to current baselines and safety performance for both workers and the public. EM's challenge is to identify alternate technologies or technical approaches that will serve as "forcing functions" or "transformational advancements", impacting the baseline schedules or having significant potential for changing the dynamics of site D&D work scope.

The current D&D strategy recognizes that many facilities will be maintained in a surveillance and maintenance (S&M) mode until appropriate levels of funding are made available to pursue D&D work scope. The Office of D&D and Facility Engineering works with the site Federal Project Directors, project managers, and others to identify opportunities to insert new and enhanced D&D technologies that reduce long-term S&M and deactivation costs.

4.3.1 Needs for Reducing Technical Uncertainty and Risk for EM

Major Technical Risks And Uncertainties

- The extent of facility deterioration and contamination throughout the complex is not fully understood, leading to uncertainties in programmatic requirements. Improved information acquisition and management, and advanced characterization strategies are required to better define and manage requirements for facility maintenance and decommissioning.

- Facility deterioration; chemical, industrial, bio-hazards and radiation contamination; and/or high radiation levels preclude safe entry by personnel. Safe entry restrictions necessitate the development and deployment of adaptable robotic and remote data acquisition platforms. Demolition of such facilities requires similar technologies for disassembly and size reduction.

- Identifying the quantity and location of radioactive and hazardous chemical contamination, and control and containment of airborne contamination generated by demolition operations during the D&D of facilities requires improved technologies and processes.

- Technologies to select and achieve the most appropriate and protective end states for facilities are needed to advance defensible strategies for facility decommissioning.

A National Research Council report[2] identified four broad areas of research where technologies could make significant contributions to solving D&D problems, decreasing lifecycle costs, and improving safety performance, including: 1) Characterization of contaminated materials; 2) Decontamination of equipment and facilities; 3) Remote intelligent systems; and 4) End state definition for facility D&D. The DOE Research and Development (R&D) Portfolio – Environmental Quality[3] report indicates that "site problem holders for facility D&D activities have identified 180 active needs that must be met to accomplish the current baseline." The broad categories of

[2] National Research Council report: *Research Opportunities for Deactivating and Decommissioning Department of Energy Facilities, 2001*

[3] *DOE Research and Development Portfolio, Volume II, Environmental Quality,* February 2000

problem areas/needs identified generally match those recommended by the National Research Council, with added specificity (e.g., underwater characterization related to spent nuclear fuel pools and remote/robotic capabilities for hot cells/glove-boxes), and the inclusion of technology needs related to D&D of reactors and entombment end states.

4.3.2 Scope of Decontamination and Decommissioning Work

The overarching strategic initiative for the D&D work is *Adapted Technologies for Site-Specific and Complex-Wide D&D Applications.* This initiative and associated strategic elements described in this section were developed from the Roadmap by the Office of D&D and Facility Engineering through a Community of Practice formed with experts from national laboratories, industry and academia intimately familiar with the EM sites, the EM D&D program, or otherwise engaged in D&D activities in the private sector.

The second element of this plan includes needs for *Facility Engineering and Real Property Asset Management*. The EM-D&D Clean-up program currently involves 114 sites, 5000 buildings and other structures and currently accounts for 47 percent of the Department's assets. Additionally, it is anticipated that EM will be receiving additional facilities from other DOE Programs (i.e. SC, NE, NNSA). Planning for and managing these assets is a key programmatic responsibility with significant budgetary consequences for the Department.

4.3.2.1 *Adapted Technologies for Site-Specific and Complex-Wide D&D Applications*

Planning Strategies: understand the magnitude, technical complexity, and cost of D&D in the DOE-complex to simplify optimization of prioritization, scheduling, and communications; understand the intra- and inter-site linkages to facilitate focused application of lessons learned and best practices; address issues of historical facility operations, information management and optimization of maintenance/demolition decisions.

Characterization Strategies: improve characterization and monitoring technologies in radiological, chemical, industrial, physical areas; identify needs and technologies for remote characterization of hazardous facilities and components; field screening technologies for unique contaminants and mixtures.

Deactivation Strategies: enhance D&D technologies and equipment for surveillance and maintenance; radiological controls/engineering; stabilization; disposal of hazardous chemicals; isolation of systems and equipment; and removal of valuable excess equipment; access to, and operation in, hazardous and inaccessible areas and components.

Decontamination Strategies: develop approaches for decontamination of unique materials for stabilization and disposal (e.g. Na coolants, Be reflectors, Pu-238 particles) that have no disposal path, or path is prohibitively complex or expensive.

Demolition Strategies: improve disassembling, size reduction, and other demolition technologies used for cutting, reducing, and removal of equipment and infrastructure; prediction and analysis of airborne contaminants released from demolition technologies; improve containment and waste management of effluents, including dispersion modeling, loading and packaging, and water accumulation handling.

Closure Strategies: develop technology and approaches for informed end-state strategies in characterization; containment/entombment; and continuous surveillance and monitoring; develop an EM Strategy for permanent in-situ decommissioning of radioactively contaminated facilities and policy defining DOE's position on permanent entombment, and the flow down requirements to allow implementation; develop in-situ entombment technology enhancement, development, and demonstration initiatives.

Cross Cutting Strategies: use an integrated systems approach to develop and deploy a suite of D&D technologies (i.e. a D&D "Toolbox") that can be readily used across the DOE complex to reduce technical risks, improve safety, and to limit uncertainty within D&D operations; achieve by funding efforts, including technology development and demonstrations, at appropriate EM facilities with representative challenges; ensure knowledge management and dissemination through information exchange workshops, technical reviews, and other approaches to knowledge sharing and communications.

Under this overarching strategic initiative the focus and priority will be placed on identifying and addressing needs across the complex and better defining the overall and specific challenges faced by the D&D and Facility Engineering Program. Preference will be given to identifying and adopting best practices and technologies from the commercial sector and international community. Where approaches and technologies are not directly applicable, investment will be focused on adaptation to the specific and complex-wide needs of the DOE program.

4.3.2.2 ***Facility Engineering and Real Property Asset Management***

As steward of its facilities and infrastructure (F&I), the EM Program has made important progress in improving real property management. Unlike the other DOE programs, such as the National Nuclear Security Agency and Office of Science, the primary mission of EM is to cleanup and demolish or transfer assets; therefore EM assets are generally not maintained for indefinite operations. Much of DOE's direction and guidance is intended to maintain sustained operations, therefore extensive tailoring is needed to provide adequate guidance for cleanup projects.

- Facilities that are shutdown, or planned for near term shutdown in the FY2015 timeframe, are not required to be maintained for sustainability. Such facilities are the focus of deactivation and demolition as a final step in the cleanup process. The facilities are maintained sufficiently to support worker safety and health. The sustainment footprint may shrink as cleanup milestones reduce risks. However, many preventive maintenance tasks are no longer necessary with the understanding that future access will be required for D&D activities.

- Facilities that are shutdown, deactivated, demolished, excessed, transferred or sold in the near term do not need to comply with Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management".

New technologies and approaches for real property management need to be encouraged, as well as identifying and implementing best practices and lessons learned from existing efforts. New tools need to be developed to mitigate risk and maximize performance of real asset portfolios. Key to effective management of EM facilities is developing a comprehensive EM asset management plan that coordinates real property acquisition; utilization; maintenance and repair; recapitalization, disposition, and long-term stewardship functions with the EM mission.

The cornerstones of facility planning in the Department are the Ten Year Site Plans (TYSPs) and/or Closure Plans developed by each site, and the facilities data in the Facilities Information Management System (FIMS). The TYSPs and Closure Plans identify the site requirements and priorities that form the basis for fiscal decisions. The TYSPs rely heavily on the data in FIMS which is the Department's repository of real property information. FIMS data are also used to support Department funding decisions, and are the primary data source for the data elements and metrics supporting Federal Real Property Council requirements. While the sites are continuing to improve the TYSPs and accuracy of their FIMS data, EM Headquarters plans to provide additional guidance for updating TYSPs in FY 2009 to establish consistent facility management strategy across the EM Program.

The Lead Program Secretarial Officers are delegated direct responsibility by the Secretary for implementing F&I stewardship. Guidance and procedures need to be developed to ensure senior management has the necessary information and level of control necessary to set priorities across the all sites and maximize performance of the entire complex.

4.4 DOE SPENT NUCLEAR FUEL

4.4.1 Needs for Reducing Technical Risk and Uncertainty for EM

The processes for storing, stabilizing and packaging for disposal of DOE SNF have known limitations. The SNF in wet storage systems are exhibiting degradation; and the basins provide limited capacity and are at the end of their design life. Some of the drying and dry storage systems are inefficient and lead to uncertainty in final repository receipt. Stabilization processes for all SNF in the inventory have not been developed. Plans for disposing SNF include use of either a canister or overpack that requires a final closure weld to be performed, inspected and repaired remotely in a high radiation environment. A commercial system for this application does not currently exist. The final package must prevent nuclear criticality in the postulated event in which a spent fuel storage/disposal canister is breached and water enters the canister. A material with appropriate mechanical and physical properties, thermal neutron absorption capability, and corrosion resistance to meet the SNF disposal requirements must be developed.

Spent Fuel Storage
Storage of vulnerable SNF types (e.g., aluminum-clad) and conditions (SNF and basins) are subject to continued deterioration, and may impact repository acceptance.

Spent Fuel Stabilization
Present facilities and methods are not designed for processing all SNF types.

Disposal Packaging Preparation
Geologic disposal of SNF requires assurance of criticality control over long timeframes.
Current plans identify the need for a canister closure weld in a high radiation environment for which commercial systems do not exist.

4.4.2 Scope of DOE Spent Nuclear Fuel Work

4.4.2.1 *Improved SNF Storage, Stabilization and Disposal Preparation*

- Implementation of monitoring and process analysis systems will provide real-time data in SNF and storage system integrity. Results of this development will be wet and dry storage systems that are more effective in meeting standards.
- Development of decladding mechanisms and new processes that will allow for improved management and stabilization of SNF, resulting in decreased hazards to the worker, public and environment.
- Develop criticality controls and welding processes to meet safe storage over long timeframes and allow the safe preparation for disposal, resulting in the reduction in personnel exposure.

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4.5 CHALLENGING MATERIALS

4.5.1 Needs for Reducing Technical Risk and Uncertainty for EM

An inventory of miscellaneous nuclear materials that cannot be dispositioned in their current configuration exists throughout the DOE complex. Many of these challenging materials could be disposed through appropriate conditioning, processing, and/or repackaging. The inventory ranges from special nuclear material (SNM), to activated reactor components and test assemblies, to classified nuclear components, and unique TRU waste. Detailed inventory data for these materials are needed to support selection of stabilization and disposition paths. Some of these materials are stored in packages meant for transportation or interim storage, resulting in the need for surveillance and repackaging systems.

Storage
Improved inventory analyses, monitoring and storage systems are needed for unique TRU wastes and special nuclear materials.

Stabilization and Disposition
Some materials have no defined path for disposal in their current condition.

4.5.2 Scope of Challenging Materials Work

4.5.2.1 *Enhanced Storage, Monitoring and Stabilization Systems*

- Improved understanding of material inventory and the behavior of the material. Longer term storage systems requiring less handling and processing.
- Complete tests, analyses and models to demonstrate stabilization processes that meet regulatory requirements.

4.6 INTEGRATION AND CROSS-CUTTING INITIATIVES

4.6.1 Needs for Reducing Technical Risk and Uncertainty for EM

Technical challenges exist in the assessment of uncertainties associated with waste processing, soil and groundwater remediation, and D&D approaches. Evaluating the performance of the integrated waste closure unit requires extrapolation of short-term performance data to extended periods of time. Current materials (i.e., glass, grout, etc.) are commonly used to immobilize high-level and low-level radioactive wastes. Storage for extended periods of time (100's or 1,000's of years) is difficult to predict and leads to uncertainties in the long-term performance of the closure unit. Additional data and integrated approaches are needed to provide the necessary understanding of the behavior of the closure unit over the long-term, so that appropriate strategies can be selected, and so that performance assessments will be based on improved predictive capabilities. Cost-effective approaches are needed to monitor residual contamination in soil and groundwater and to verify remedial performance over many years, in some instances for decades or centuries.

Assessing Long-Term Performance

- Inadequate fundamental understanding of wasteform performance and contaminant release, transport, and transformation processes result in inadequate conceptual models potentially leading to selection and design of non-optimal remedial actions.
- Inadequate long-term monitoring and maintenance strategies and technologies to verify cleanup performance could potentially invalidate the selected remedy and escalate cleanup costs.

Requirements for transportation and disposal of DOE SNF, challenging nuclear materials, and unique TRU waste are limited by flammable gases generation and other conditions within the canister. Corrosion products have accumulated on aluminum-based spent fuels during reactor operation and/or subsequent underwater storage. Other material forms also have corrosion/aging processes that result in the generation of gases and packaging limitations. These corrosion/aging products may retain significant quantities of metal hydroxides which could be released as a result of decomposition of the corrosion product or dehydration following a drying process, which has the potential to result in pressurization and/or unacceptable hydrogen concentrations within a package. Some TRU waste containers have high flammable volatile organic compounds; these containers have no shipping path, and it is unclear if repackaging will address this issue.

Transportation and Disposal Packaging

- Disposal and transportation restrictions include flammable gas limitations, material characteristics and configuration. Existing data are insufficient to quantify the effects of potential sources of hydrogen, deflagration events, degraded fuel, impurities, and other conditions for challenging materials.

4.6.2 Scope of Integration and Cross-Cutting Work

4.6.2.1 *Enhanced Long-Term Performance Evaluation and Monitoring*

(See 4.2.2.4 Enhanced Long-Term Performance Evaluation and Monitoring)

4.6.2.2 *Improved Packaging of SNF, TRU Waste and Nuclear Materials*

- Complete tests, analyses and models to demonstrate regulatory compliance.
- Improve the management and disposal of these materials through improved inventories and material data.

ACRONYM LIST

A	
ACI	Asset Condition Index
ACL	Alternative Concentration Levels
Al/Cr	Aluminum / Chromium
ANS	American Nuclear Society
ART	Advanced Remediation Technology
B	
BGRR	Brookhaven Graphite Research Reactor
BNL	Brookhaven National Laboratory
C	
CA	Composite Analysis
CAIS	Condition Assessment Information System
CAS	Condition Analysis System
CD	Critical Decision
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRESP	Consortium for Risk Evaluation with Stakeholder Participation
CRL	Capability Replacement Laboratory (PNNL CRL Project)
D	
DBVS	Demonstration Bulk Vitrification System
D&D	Deactivation and Decommissioning
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DU	Depleted Uranium
E	
ECOS	Environmental Council of States
EFCOG	Energy Facility Contractors Group
EM	Environmental Management
EMAB	Environmental Management Advisory Board
EMS	Environmental Management System
EMSSAB	EM Site Specific Advisory Boards
EPA	U.S. Environmental Protection Agency
EPP	Environmentally Preferable Purchasing
EPRI	Electric Power Research Institute
ES&H	Environment, Safety and Health
ESAAB	Energy Systems Acquisition Advisory Board
ESTCP	Environmental Security Technology Certification Program
ET	Office of Engineering and Technology
ETR	External Technical Review
ETTP	East Tennessee Technology Park
EU	Enriched Uranium
F	
F&I	Facilities and Infrastructure
FCFF	Fuel Cycle Facilities Forum
FE	Facility Engineering
FERC	Federal Energy Regulatory Commission
FIMS	Facilities Information Management System
FIU	Florida International University

G	
GAO	General Accountability Office
GDP	Gaseous Diffusion Plant
GW/S	Groundwater and Soil
H	
HFBR	High Flux Beam Reactor
HLW	High Level Waste
HHS	DOE Office of Human Health and Safety
I	
IAEA	International Atomic Energy Agency
ICET	Institute for Clean Energy Technology (Mississippi State University)
ID	Idaho Site
IFI	Integrated Facility Infrastructure
INL	Idaho National Laboratory
IPT	Integrated Project Team
ITRC	Interstate Technology and Regulatory Council
K	
kg	kilogram
L	
LANL	Los Alamos National Laboratory
LLW	Low Level Waste
LLMW	Low level Mixed Waste
LM	Office of Legacy Management
LPSO	Lead Program Secretarial Officer
M	
m^3	Cubic Meters
M&R	Maintenance and Repair
MLLW	Mixed Low Level Waste
MSE/WETO	Western Environmental Technology Office
MTHM	Metric Tons Heavy Metal
N	
NAS/NRC	National Academy of Sciences/National Research Council
NEBA	Net Environmental Benefit Analysis
NEPA	National Environmental Policy Act of 1969
NDA	National Defense Authority (United Kingdom)
NE	DOE Office of Nuclear Energy, Science and Technology
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Council
O	
OECM	DOE Office of Engineering and Construction Management
OIG	DOE Office of Inspector General
OMB	Office of Management and Budget
OR	Oak Ridge Operations Office
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORP	Office of River Protection

P	
PA	Performance Assessment
PBS	Project Baseline Summary
PCB	Polychlorinated Biphenyl
PEP	Project Execution Plan
PMA	President's Management Agenda
PMP	Performance Management Plan
PNNL	Pacific Northwest National Laboratory
PPPO	Portsmouth and Paducah Project Office
PSF	Physical Sciences Facility
PSO	Program Secretarial Officer
PU	Plutonium
Q	
QA	Quality Assurance
R	
R&D	Research & Development
RACER	Remedial Action Cost Estimating and Requirement
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radiation
RFP	Request for Proposal
RL	DOE Richland Operations Office
ROD	Record of Decision
ROI	Return on Investment
RPAM	Real Property Asset Management
RW	DOE Office of Civilian Radioactive Waste Management
S	
SBIR	Small Business Innovation Research (Program)
SC	DOE Office of Science
SERDP	Strategic Environmental Research and Development Program
SNF	Spent Nuclear Fuel
SR	Savannah River
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
S&M	Surveillance and Monitoring
SWPF	Salt Waste Processing Facility
T	
TDD	Technology Development and Deployment
TPA	Tri-Party Agreement (DOE/EPA/State)
TRU	Transuranic Waste
TYSP	Ten Year Site Plan
U	
U	Uranium
W	
WIPP	Waste Isolation Pilot Plant
WP	Waste Processing
WTP	Waste Treatment Plant
WV	West Valley Site