US DOE Office of Technology Innovation and Development – Integration of the EM R&D Program in 2012 and Beyond

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ABSTRACT

Applied research and technology development has the potential to accelerate environmental cleanup and reduce the cost for cleanup and closure of U.S. Department of Energy (DOE) legacy waste sites throughout the United States. Providing the scientific understanding, knowledge, and technologies to enable successful completion of the DOE Office of Environmental Management (EM) mission, the Technology Innovation and Development program is transforming science and innovation into practical solutions for environmental cleanup. Through integration, collaboration, and communication with DOE partner organization, DOE site managers and contractors, these technologies will reduce human health and environmental risk, cost, and time associated with cleanup and closure.

The Office of Technology Innovation and Development (OTID) focused efforts in fiscal year 2011 (FY 2011) to a proactive, visionary program balance with integrated, cross-disciplinary applied research and technology development activities. This transition provides the necessary scientific and technical advancements to address near-term needs. In addition, it fills the critical role in providing scientific approaches and advanced technologies that look beyond today's known needs and requirements to provide innovative technologies to make the necessary long-term changes required to facilitate cleanup and bring sites to closure. The outcomes and impacts of this strategy are summarized in the Impact Plan, which describes potential reduction in life-cycle costs through the development and deployment of advanced technologies supporting EM needs associated with waste processing, groundwater and soil remediation, deactivation and decommissioning, and spent nuclear fuel and materials disposition. Additionally, the *OTID International Program Strategic Plan 2010-2015* (DOE 2010a) outlines cooperation and collaboration with the international community that has similar nuclear legacy management experience and expertise to foster transfer of best science practices being used in the field.

INTRODUCTION

Cleaning up the nation's nuclear weapons complex remains one of the most technologically challenging and financially costly problems facing DOE EM. This challenge encompasses the largest cleanup program in the world, previously involving 110 sites in 35 states (including the commonwealth of Puerto Rico). Since the inception of EM in 1989, the Department's commitment to the legacy waste cleanup mission has not changed and is reflected in the sub-objectives listed under the Complete Environmental Remediation of Our Legacy and Active Sites objective outlined in the recently released *U.S. Department of Energy Strategic Plan* (DOE 2011):

- Protecting Human Health and Environment

- Maximizing Success of Construction and Operation Outcomes
- Implementing a Technical Roadmap to Address Radioactive Liquid Tank Waste
- Ensuring a Long-term Solution to the Cold War Environmental Legacy.

Over the past 22 years, EM has cleaned up 2225 square miles of contaminated land. Today, only 18 sites in ten states remain, representing 900 square miles. Although EM has made significant progress in addressing the nation's legacy waste issues, the financial obligation required to address the most complex challenges EM has ever faced, ranges between $272 and $327 billion. This is a cost the nation cannot bear (DOE 2010a). Therefore, sustained investments in AR&TD play a critical role in helping to address the remaining challenges and decrease the life-cycle cost.

Figure 1 (NRC 2010) presents the DOE-EM cleanup program budget and the DOE-EM AR&TD program budget. Historically, investments in AR&TD represent less than 9% of EM's Congressional budget and have continued to decline since 1995.

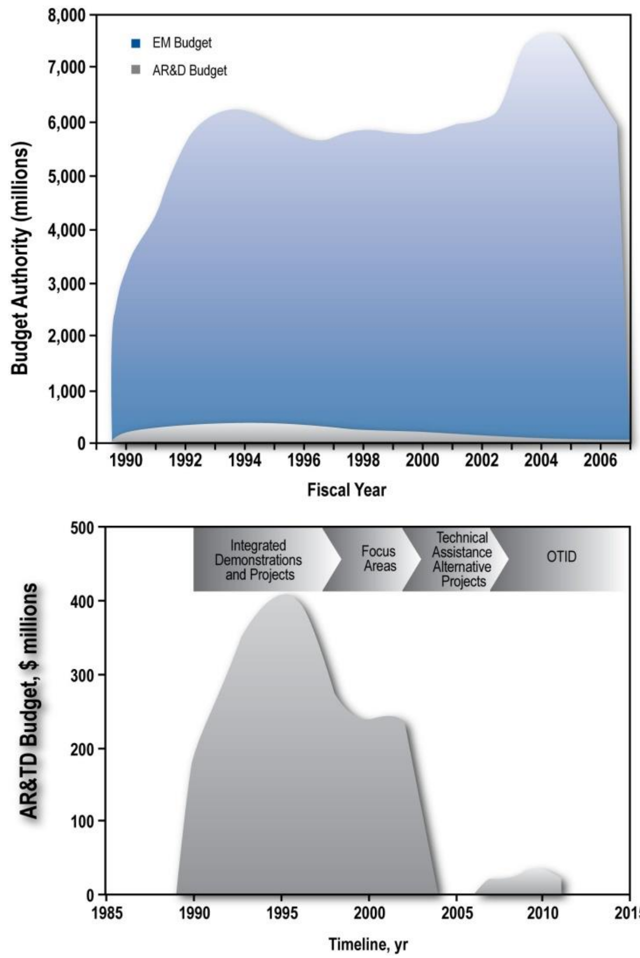

Figure 1. Federal budget authority for the DOE–EM cleanup program and the DOE-EM headquarters AR&TD program (adapted from NRC 2010). The graph below is an expansion of the DOE-EM headquarters AR&TD program budget. Although some technology development investments occurred at the sites between 2003–2010, these activities focus on technology maturation activities (late-stage TRL).

The most substantial AR&TD investments occurred from 1991 through 2000. These investments represented approximately 6 to 9% of EM's Congressional budget, which contained a significant element aimed at longer-range applied research and technology development. The return on these investments contributed to the maturation and implementation of technical solutions that assisted in reducing EM's life-cycle cost at many of the currently closed legacy waste sites.

For example, investments in AR&TD enabled accelerated cleanup of the Fernald Site near Cincinnati, Ohio, and the Rocky Flats Site near Denver, Colorado, during the "Accelerating Cleanup: Path to Closure" initiative, by improving the technical basis and providing new and innovative technologies for closure (DOE, 1998). Some of these technologies, such as retrieval and transfer approaches, are still in use today at several EM sites.

However, continued reductions in AR&TD investments, from 2000 to present (Figure 1), have created a gap in the EM technology maturation process. Next generation approaches and advanced technologies needed to address the remaining complex challenges facing EM today are not readily available. This lack of continuity in applied research and technology development, maturation, and deployment is revealed in existing EM projects as technical challenges that cannot be easily resolved.

As noted in numerous reviews by the National Research Council of the National Academy of Sciences (e.g. NRC 2010, 2011), consistent and sustained investments in AR&TD are critical to providing the technological innovation necessary to improve and maintain EM's ability to proactively address emerging issues and reduce overall project and, in turn, EM program life-cycle costs (Figure 2).

In an attempt to close the AR&TD gap, the *U.S. Department of Energy Strategic Plan* (DOE 2011a), published in May 2011, addressed the need for EM AR&TD investments. Specific areas identified in the Strategic Plan for scientific research and technology development are summarized here and include the following:

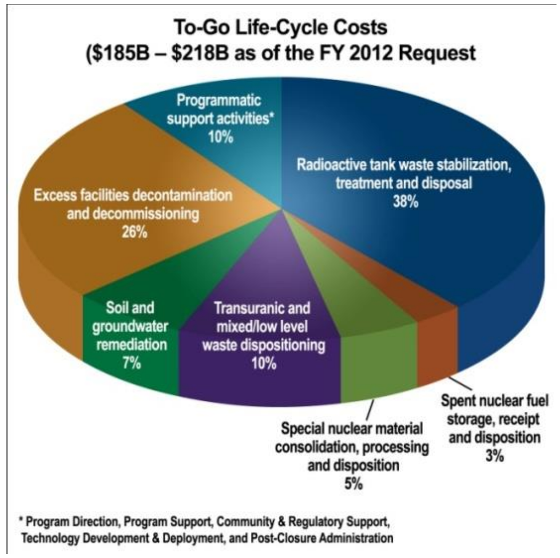

Figure 2. Breakdown of EM Life-cycle Cost Projections for Existing Work Scope (Mustin, 2011).

- Developing and applying enhanced technologies for a subset of our integrated soil and groundwater remediation activities
- Developing and applying advanced modeling and simulation tools to aid in streamlining treatment and deploying defensible monitoring and surveillance strategies
- Developing advanced concepts and technologies in characterizing, treating, immobilizing, and disposing of tank waste
- Developing advanced concepts in long-term surveillance and monitoring that are expected to be required at some sites for hundreds or even thousands of years.

MEETING THE CHALLENGE – DOE EM'S APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT PROGRAM

The mission of the DOE EM's Technology Innovation and Development Program is to transform science and innovation into practical solutions for environmental cleanup. The vision for the OTID Program is to accelerate environmental cleanup and reduce cost through integration, collaboration, and communication.

A number of EM AR&TD areas identified in the *U.S. Department of Energy Strategic Plan* (DOE 2011a), as well as mature technologies that are closer to being implemented across the Department complex, were included in a review of the EM Program FY2010 and FY2011 funding portfolio. This work scope represents activities that are being performed in four programmatic areas: waste processing, groundwater and soil remediation, nuclear materials disposition, and deactivation and decommissioning (D&D).

Waste Processing: Addressing the high-level tank waste challenge represents the largest fraction of the remaining EM life-cycle cost, ~38% (Figure 2). Currently ~90 million gallons of radioactive waste is being safely stored in 230 tanks at the Department's Hanford Site, Savannah River Site (SRS), and Idaho Site. High radioactivity, complex chemistry that can vary from tank to tank, and the various physical forms of the waste (e.g., salt cake, sludge, etc.) makes the steps of retrieval, processing, and immobilization of the tank waste one of the most technologically complicated efforts in the Department. The majority of the OTID projects performed in the FY2008 – FY2011 focused on near-term, mid-TRL technologies (TRL 4 – 6) that supported EM's current strategy for treating high-level tank waste, which centers on the operation of the Defense Waste Processing Facility at SRS as well as the construction of the Salt Waste Processing Facility and the Waste Treatment and Immobilization Plant (WTP) at SRS and the Hanford Site, respectively. These projects were categorized into five areas:

- Alternative waste pretreatment
- Improved vitrification capacity
- Increased waste loading
- Accelerated waste retrieval and closure
- Advance unit operations and scaling

The objectives, which were derived from the EM report *Technical Evaluation of Strategies for Transforming the Tank Waste System: Tank Waste System Integrated Project Team Final Report* (DOE 2010b), of the AR&TD Program performed in FY2008 – FY2011 was to optimize tank waste processing by increasing processing rates and/or efficiencies to reduce life-cycle cost and schedule; separate and treat lower hazard constituents to reduce life-cycle cost and schedule; accelerating tank waste retrieval and closure; and developing and reducing identified project and safety risks. A portion of the AR&TD Program activities that were performed in FY2008 – FY2010 were incorporated into the *Enhanced Tank Waste Treatment Strategy* (e.g., fluidized bed steam reformation, rotary microfiltration, small column ion exchange, and next-generation solvents) and are currently being pursued by the operating contractors at both the Hanford Site and SRS. Finally, because of the complexity of the tank waste challenge, the AR&TD Program presently is forecast to have a remaining duration of more than 30 years. Given this time duration and projected cost, AR&TD investments—as in previous years—are expected to make a significant contribution and impact on the overall life-cycle cost.

Groundwater & Soil Remediation: One important component of DOE's environmental management mission is the cleanup of groundwater, soils, and sediments in highly diverse environments contaminated with radionuclides, metals, and organics—sometimes present as complex mixtures. While groundwater and soil remediation has a relatively small fraction of the EM life-cycle cost, ~7% (Figure 2), the complexity of the cleanup mission of these resource represents many challenges for DOE. These resources were contaminated through a variety of pathways, including intentional disposal into the ground through injection wells, disposal pits, and settling ponds as well as from accidental spills and leaks from storage tanks and waste transfer lines. In some cases, minimal historical information exists of the magnitude, timing, and content of contaminant releases to the environment. Additionally, the broad range of climatic, ecologic, and hydrogeologic conditions that exist across the Department complex makes it difficult to predict the location, transport, and fate of these contaminants in the environment. A combination of limited documentation and the difficulty in predicting the fate and transport after contaminant releases makes estimates of the magnitude of the problem and cleanup costs vary considerably. The intractable subsurface problems that remain to be dealt with are some of the most complex ever encountered by the technical community and represent a challenge that will face the Department for the next decade, especially at the larger sites within the complex such as the Savannah River Site, Oak Ridge Site, and Hanford Site. Many of the challenges that affect the larger sites also plague closure efforts at smaller sites (e.g., Los Alamos National Laboratory, Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, West Valley Reprocessing Plant, etc.). The financial obligation required to remediate this volume of contaminated environment is estimated to cost more than 7% of the to-go life-cycle cost (Figure 2).

The current groundwater and soil program consists of four applied field research initiatives:

- Attenuation Based Remedies – Applied Field Research Initiative at the Savannah River Site

- Deep Vadose Zone-Applied Field Research Initiative at the Hanford Site
- Remediation of Mercury and Industrial Contaminants–Applied Field Research Initiative at the Y-12 National Security Complex in Oak Ridge
- Advanced Simulation Capability for Environmental Management.

The overarching objective of each of the applied field research initiatives is to provide defense-in-depth remedial strategies that provide the new baseline against which further progress can be realized for subsurface remediation and prevention of future degradation of water resources. Application of existing and emerging scientific knowledge regarding natural and enhanced attenuation processes and the evolution of geochemical conditions at subsurface waste sites will provide innovative tools, approaches, and guidance to support effective, sustainable, lower cost remedies. The ASCEM initiative will improve the understanding of contaminant fate and transport, proactively guide development and implementation of remedial strategies, and enable better predictions of future impacts to human health and the environment from the Department's cleanup actions.

Nuclear Materials: The Nuclear Materials Disposition Program will assist in providing the assurance needed to prevent against failure of containers throughout the storage period. The EM life-cycle cost for the Nuclear Materials Program is captured in three areas: special nuclear material consolidation, processing and disposition, 5%; spent nuclear fuel storage, receipt and disposition, 3%, and transuranic and mixed low level waste disposition, 10% (Figure 2).

- Spent Nuclear Fuel (SNF) Management
- Challenging Materials (CM) Disposition
- Plutonium Materials Management and Disposition.

DOE has over 2,400 metric tons of SNF and 250 different fuels types stored at three primary locations: Hanford Site, Idaho Site, and SRS. Additional fuel is expected to be received into inventory over the next decade, primarily from domestic research reactors (DRRs) and foreign research reactors. Managing the challenging materials inventory involves characterization, safe interim storage, and conditioning or stabilization treatments that lead to the disposition of miscellaneous materials that cannot be dispositioned in their current configuration. The challenging materials inventory is managed by various offices including EM, SC, NE, and the National Nuclear Security Administration (NNSA). This management strategy is important because many of the materials present similar stabilization, packaging, and disposition challenges, which requires coordination with other DOE offices. In addition to SNF and other challenging materials, DOE has approximately 13 metric tons of excess plutonium that is safely stored in the K-Area Materials Storage facility at SRS. The Nuclear Materials Disposition Program will assist in providing the assurance needed to prevent against failure of containers throughout the storage period.

Deactivation and Decommissioning (D&D): The D&D of facilities represents the second highest cost center in the EM Program, 26% of the total life-cycle cost (Figure 2). EM's current life-cycle scope comprises 3000 facilities, including over 1000 nuclear and radioactive buildings. It is worth noting that while this inventory (3,000 facilities) will decrease as more D&D is completed, the decrease will likely be offset by additional facilities as they become obsolete and excess and are accepted into the EM cleanup program. A significant number of these facilities are over 50 years old, have and continue to degrade over time, and contain a significant amount of radioactive holdup and contamination that represent a source term for potential air, soil and surface/groundwater contamination. The National Research Council's 2001 report states "…while current technologies probably can be made to work in the D&D of Department facilities, there are opportunities to do the job more safely and effectively by developing and using new technologies" (NRC 2001). Though footprint reduction has been achieved using the low technology/forceful approach, EM's current focus on accelerated footprint reduction of highly contaminated—and in some cases— structurally unsound facilities will present significant new technological challenges to maintain worker safety and effective project execution. As a result of these issues and the NRC advice (NRC 2001), the current D&D program is structured around five research areas:

- Characterization, equipment removal, and dismantlement
- Personal protective equipment and worker protection
- Decontamination
- Robotics and intelligent systems
- End states –in situ decommissioning.

The overarching objective of the D&D program is to support the identification, development, and timely deployment of adaptive and transformational technologies needed for the safe closure of nuclear, radiological, and industrial Department facilities.

CROSSCUTTING INITIATIVES

Since its inception, EM investments in AR&TD have resulted in the development of numerous new and innovative approaches for addressing a number of near-, mid-, and long-term issues associated with processing radioactive tank waste, remediating groundwater and soil, deactivating and decommissioning facilities and reactors, and disposing and storage of nuclear materials and spent nuclear fuel (SNF). Recent examples include the Caustic Side Solvent eXtraction (CSSX) process and Advanced Approaches for Subsurface Characterization and Monitoring. These technological advancements have transitioned from fundamental science through applied research and technology development, and into site implementation.

In order to allow for flexible, holistic approaches necessary to address the remaining complex problems limiting EM's ability to achieve site cleanup and closure, the EM AR&TD Program has been transitioned from a role of site support, focused on near-term needs, to a more balanced, forward-reaching program with integrated, cross-disciplinary applied research and technology development. This transition provides the necessary proactive, strategic approach to advancing science and technology to address near-term needs, as well as looking beyond today's known needs and requirements and provide the innovative technologies necessary to support EM needs associated with waste processing, groundwater and soil remediation, deactivation and decommissioning, and spent nuclear fuel and materials disposition.

The short-term AR&TD Program represents activities that are focused on addressing specific near-term EM challenges facing the larger EM site within each of the four programmatic areas (i.e., waste processing, groundwater and soil remediation, nuclear materials, and D&D) (Figure 3). Thus, the use of long-term initiatives enhances integration of activities across the program areas and addresses a common theme from the Environmental Management Advisory Board (EMAB) Tank Waste Strategy (DOE 2010c) review and the EM Technical Expert Group (EM-TEG) review of the tank waste technology development program regarding site contractors focusing on executing baseline scope and schedule, rather than new emerging technologies and implementing these alternatives prior to technologies reaching the maturity level required for success. These long-term initiatives allow for the synergistic interrelationships that exist between each of the four program areas to be exploited to the maximum extent practical and solve long-term problems.

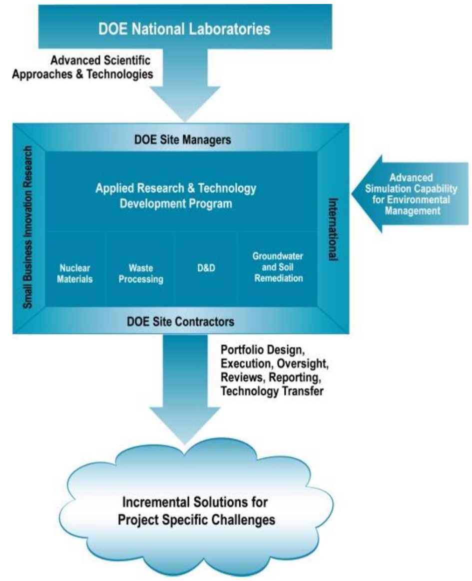

Figure 3. Graphical Representation of the OTID Short Term AR&TD Program

The long-term AR&TD program is organized around four strategic initiatives (i.e., materials performance, tank waste chemistry, end states, and mercury) that maximize synergistic relationships, resources, and impact (Figure 4).

- Material Science to Enable Immobilization, Containment, and Disposition of Radioactive Waste, Spent Fuels, and Nuclear Materials
- High Level Waste Management Systems Optimization – Waste Forms, Pretreatment/Separations, Immobilization, and Disposal
- Closure End States for Facilities, Waste Sites, and Subsurface Contamination
- Remediation, Treatment, and Closure of Mercury Contaminated Waste Sites, Water, and Facility Debris to Enable Future DOE Missions

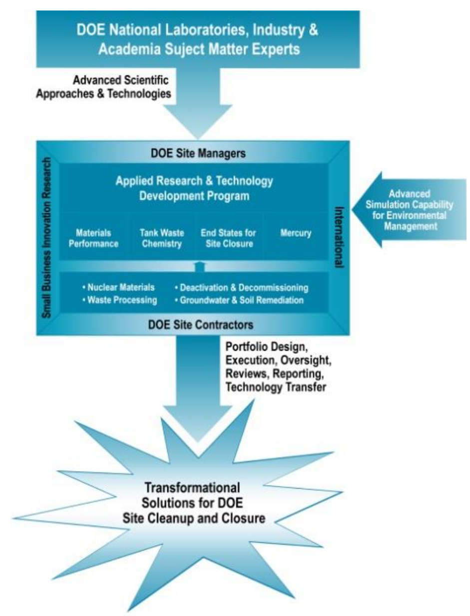

Figure 4. Graphical Representation of the OTID Long Term AR&TD Program

Each of these initiatives plays a role in integrating the areas—1) waste processing, 2) groundwater and soil remediation, 3) D&D, and 4) nuclear materials—by taking a comprehensive view of the critical problems and aligning the components required to address these problems under a single vision (i.e., defined problem statement).

This type of structure allows for AR&TD Program funding to be leveraged in a manner that advances large research activities forward in a timely manner and allows for transformational solutions for development of DOE site cleanup and closure. Having a consensus focus within each initiative provides:

- the framework required for a systems-level approach to cleanup,

- the flexibility to address emerging issues while simultaneously working on long-range solutions to EM's most complex challenges, yet also realizing near-term impacts, and
- improved alignment and ability to work with and leverage investments by other federal agencies

Material Science to Enable Immobilization, Containment, and Disposition of Radioactive Waste, Spent Fuels, and Nuclear Materials

Problem: Uncertainties in material performance of Department SNF, high-level waste (HLW), and nuclear material waste forms and package systems, which include entombed structures, result in ineffective, costly, and suboptimal storage and disposal practices.

Vision: A significant inventory of SNF—approximately 2,420 metric tons of heavy metal that includes fuels from foreign research reactors, DRRs, and DOE production reactors—is currently stored at various locations across the United States. In addition to SNF, other various forms of DOE nuclear waste, vitrified HLW and special nuclear materials (e.g., excess plutonium, highly enriched uranium, lowly enriched uranium, etc.), and recyclable contaminated metal is also being stored at various locations in the United States. Other waste forms for HLW are also being planned or considered, such as the immobilized Idaho calcine (i.e., ceramic waste form produced using hot isostatic pressing), and other advanced waste forms including iron phosphate (FeP) and alumino-silicate (AlSi) glass-ceramics. Although it is anticipated that DOE SNF and HLW forms will eventually be disposed of in a geologic repository, the current disposition pathway is undefined because of the uncertainty related to the location/environment (i.e., geochemistry) and schedule of availability of a nuclear waste repository. This uncertainty is expected to result in nuclear waste being stored at DOE facilities across the country for several decades, if not longer. The motivation of this initiative is to enable long-term interim storage (i.e., develop understanding of degradation of storage systems, structures, and components) and optimal final disposition of legacy materials (i.e., develop scientific basis for disposition of HLW forms and SNF), as well as newly developed advanced waste forms (i.e., multi-phase materials [specifically grouts and glass- or metal-ceramic waste forms]), that may be required for the disposition of certain forms of reprocessed nuclear material. Additionally, the initiative addresses developing an understanding of the degradation process and indicators for entombed structures to provide a scientifically based and defensible approach for monitoring of in situ decommissioned facilities and structures. Finally, the initiative will help develop a defensible approach for recycling materials that are suitable for reuse.

Outcome: Through the development of a more robust scientific understanding of degradation processes, this initiative will allow for a step change in how the nation manages and dispositions immobilized waste, spent nuclear fuel, and nuclear materials by:

- Improving the preparation, packaging, storage and monitoring processes for SNF and excess nuclear materials
- Increasing the fundamental understanding of degradation processes of these inventories, as well as that of packaging materials
- Increasing the fundamental understanding of the degradation processes and products of HLW forms within packages, as well as their interactions with specific repository environments will reduce life cycle cost and schedule, resulting in a much more efficient waste disposition system that maximizes use of repository capacities
- Providing reliable benchmark data and new technologies for entombed structures to ensure safe operations, to gain regulatory and stakeholder acceptance, and expedite closure.

High-Level Waste Management Systems Optimization – Waste Forms, Pretreatment/ Separations, Immobilization, and Disposal

Problem: Current treatment processes are costly and suboptimized. Waste loadings and throughput rates are not maximized for all waste streams in current baseline waste forms (i.e. borosilicate glass). This is due in part to variability in tank waste composition and limitations of available technologies (e.g., separations, immobilization).

Vision: This multi-tiered initiative will develop and deploy tank waste technologies and optimize the tank waste system to reduce the system life-cycle cost by one-third, provide technically defensible alternatives for waste processing in new and existing facilities, including advanced separations and immobilization technologies. This effort will provide the scientific development needed to achieve the following:

- Define an approach for tank residuals and hazards supporting risk informed closure
- Provide technically defensible alternatives for waste processing challenges in new and existing facilities, including advanced separations technologies and next generation melter and/or immobilization technologies
- Systematically and defensibly identify and accelerate the appropriate technology insertion into existing treatment processes
- Significantly reduce anticipated delays adjusting the treatment plant processes for variable feeds, avoiding the likely impacts of staging wastes without a treatment strategy.

Outcome: Develop the scientific and engineering knowledge base needed to develop optimal combinations of waste forms, separations technologies, and immobilization technologies for efficiently processing highly variable HLW feeds.

Closure End States for Facilities, Waste Sites, and Subsurface Contamination

Problem: Uncertainties in the delineation and releases for sources and contaminated environmental media, debris, and facilities often result in unachievable end states that are not systems-based, drive costly and ineffective treatment processes, and prevent risk-informed decisions.

Vision: Define technically defensible end states, systems-based deactivation and decommissioning and remediation approaches, and systems-based monitoring strategies that include potential source terms and pathways to receptors (i.e., legacy facilities, tanks, special nuclear materials, and groundwater and soil) to provide closure solutions that are cost effective, sustainable, and protective of human health and natural resources at DOE sites.

Outcome: Through a holistic, scientific and technical understanding of DOE site closure challenges, including, facility D&D, groundwater and soil remediation, and legacy source terms (i.e. waste sites and facilities), the technical framework to define risk-informed, defensible end states or conditions that constitute progress toward, and completion of cleanup, will be developed and implemented into DOE site baselines. Scientifically and technically defensible approaches for alternative facility D&D (e.g., entombment) and alternative retrieval strategies, particularly retrieval strategies that involve leaving more source term in the HLW tanks, that are protective of human health and the environment will be developed to enable achieving these end states. Critical deliverables include the following:

- Compilation of D&D, tank, and subsurface remediation technology, closure, and transition decisions guidance
- Frameworks for remediation, tank and site closure, and transition decisions supporting D&D, waste sites and facilities, and groundwater and soil environments
- Scientific, public, and regulatory acceptance of risk-informed end states, and systems-based remediation and monitoring strategies for site closure

- A robust and sustained research and development effort to provide the technologies and technical approaches necessary for implementation of defensible cleanup and closure strategies.

Remediation, Treatment, and Closure of Mercury Contaminated Waste Sites, Water, and Facility Debris to Enable Future Department Missions

Problem: Uncertainty in the concise delineation of source zones, remediation treatment, and disposition of mercury-contaminated environmental media, debris, and facilities inhibits the achievement of regulatory-approved end states required to support future Department missions.

Vision: At this stage of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) cleanup process for the Oak Ridge Reservation, EM has a unique opportunity to develop science-based solutions for the remediation of mercury as well as other contaminants at the Y-12 National Security Complex prior to finalizing an acquisition strategy and developing a project baseline. For the Y-12 National Security Complex and EM, mercury represents the single most challenging contaminant present within the footprint of the Oak Ridge Reservation. Therefore, mercury is the focus of this long-term initiative. The development and implementation of science-based solutions alone will not be sufficient to successfully address legacy mercury. Thus, an approach that links science and engineering application with changes to the existing Land Disposal Restrictions will be required to address both the D&D and subsurface mercury challenge facing EM.

Outcome: Improvements will be realized in the characterization of mercury contamination, concise delineation of source zones requiring remediation, and segregation and treatment of mercury-bearing wastes and debris. Incentives for use of new technologies and approaches will be incorporated into the acquisition process for Y-12 National Security Complex remediation and D&D, leading to a realistic project cost and schedule for cleanup that accurately reflects key project risks.

Working cooperatively across OTID, EM and operations offices, and other federal agencies is paramount to continue the quest to reduce the life-cycle cost of cleanup and meet the goals of the DOE Strategic Plan (DOE 2011a). The more detailed AR&TD initiative scope, developed in consultation with a broad collection of stakeholders, experts and advisors (e.g., EM Headquarters and field offices, national laboratories, SC, NE) is provided in the DOE EM *Applied Research and Technology Development Program Summary* (DOE 2011b). The scope of the initiatives will be reviewed each year as part of the program prioritization process.

IMPACT

Significant challenges and greater opportunities lie before us. Remediating the nation's legacy from nuclear weapons production and restoring the environment is a technological and financial challenge for our nation. During this time of difficult budget choices, the annual mortgage for the DOE's legacy waste sites is an undue fiscal challenge. DOE has an obligation to the public to achieve greater economic and social outcomes from investments in science and technology development and ensure our efforts are efficient and impactful. Technologically, these challenges demand innovative scientific and technical solutions and approaches that enable us to achieve environmental cleanup goals at a cost the nation can bear (Bredt et al. 2008; NRC 2009; Pierce et al. 2009; DOE 2010c; DOE 2011b). These values are embedded within the operating practices and applied research and technology development strategies of the EM program. Moreover, through integration, collaboration and communication these values are further fully embraced by our scientific and technical communities of practice.

The EM AR&TD program is assiduously working to address today's most pressing environmental challenges. Program activities are providing the scientific understanding, technical knowledge and technologies to enable successful completion of the EM mission, while developing the next generation of technical experts. Utilization of the resources developed by the program is providing holistic approaches to solve the remaining complex remediation requirements and reduce risks, costs and schedules for site cleanup and closure (DOE 2011b). Collaborative and integrated approaches to achieving these goals have demonstrated acceleration of site closure in the past, and are making future site closures possible.

Our response to today's challenges will leave an enduring new legacy as we work to reduce impacts from our past and build toward applying scientific knowledge to promote economic progress. Meeting our goals outlined in *Science and Technology to Reduce the Life Cycle Cost of Closure: Investing in Our Future: Technology Innovation and Development for Footprint Reduction* (DOE 2010c) is dependent upon our continued diligence and commitment to technical innovation. In the process, we will not only reduce the life-cycle costs, schedules and risks associated with site closure, but we will create enduring capabilities to meet national demands tomorrow.

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