Environmental Management Technology Demonstration and Commercialization Under the METC–EERC EM Cooperative Agreement

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I. Introduction

The task of restoring nuclear defense complex sites under the U.S. Department of Energy (DOE) Environmental Management (EM) Program presents an unprecedented challenge to the environmental restoration community. Effective and efficient cleanup requires the timely development or modification of novel cleanup technologies applicable to radioactive wastes. Fostering the commercialization of these innovative technologies is the mission of EM-50, the EM Program Office of Science and Technology. However, efforts are often arrested at the "valley of death," the general term for barriers to demonstration, commercialization, and deployment. The Energy & Environmental Research Center (EERC), a not-for-profit, contract-supported organization focused on research, development, demonstration, and commercialization (RDD&C) of energy and environmental technologies, is in the second year of a cooperative agreement with the DOE Morgantown Energy Technology Center (METC) designed to deliver EM technologies into the commercial marketplace through a unique combination of technical support, real-world demonstration, and brokering. This paper profiles this program and the part it is playing in the ongoing development and commercialization of several promising environmental technologies.

II. METC–EERC EM Cooperative Agreement: Concept and Approach

The "valley of death" takes many forms. For the small business technologist, commercialization prospects are hampered by limited testing and demonstration capabilities, limited capital, and, specific to the EM program, a limited knowledge of DOE and EM site needs. Successful commercialization and deployment may hinge on the successful resolution of technical issues outside the traditional focus of the technology developer. Deployment of the technology depends on scientifically sound, representative field tests coupled with knowledge of the market within the DOE complex and access to cleanup sites.

Activities under the METC–EERC EM Cooperative Agreement are designed to minimize commercialization barriers, particularly for the small business technologist, through an active process involving focused technical assistance, partnership brokering, and real-world demonstration. In order to realize this goal, the program uses a mix of core funding from DOE and joint venture capital from the private sector to support its activities and to ensure stakeholder involvement. DOE funding of the METC–EERC EM Cooperative Agreement provides seed money for commercialization

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activities. The EERC works to expand and supplement this core funding by pursuing funding under other research programs and in the private sector. The development of joint private sector–public funding partnerships is the cornerstone of the program, which brings government and private sector interests together to facilitate commercialization and ensure a private sector stake in the technology.

METC–EERC EM Cooperative Agreement seeks to work with select technologies nearing commercialization. Once a promising technology is identified, EERC activities under the Cooperative Agreement include the following:

- Partnerships are developed with small business technologists and technology vendors.

- Key technology commercialization barriers are identified, and a strategy is developed to address those barriers.

- Focused technical support is applied to resolve key technical barriers. The EERC brings to the program a wide range of technical expertise and state-of-the-art facilities for investigating chemical, thermal, and physical processes. The EERC facilities are capable of testing and demonstrating technologies from laboratory to pilot scale and are suitable to conduct tests representing a wide range of physical conditions. An evaluation of the EERC core expertise with respect to EM-50 technology needs is illustrated in Table 1. Core competency is particularly strong for extraction/analysis, treatment, and separations, which translates into strengths in the crosscutting technology areas of separations and treatment. Matches for EM focus areas are particularly strong for plumes, tank wastes, and decontamination and decommissioning.

- Field testing needs are evaluated, and field test design and site access are addressed. Because of regulatory constraints and liability concerns, access to field test sites can be a formidable obstacle to the demonstration of promising EM technologies for inexperienced technology providers. The EERC's growing family of industrial partners provides the potential for access to a wide variety of technology demonstration sites. For example, the EERC has access to a remediation demonstration site in Alberta, Canada, through a relationship with the Canadian Association of Petroleum Producers, Gulf Canada, and the DOE Jointly Sponsored Research Program. Further, the EERC has an established track record for scientifically sound field test design, oversight, and evaluation.

Creating a marketable technology to address EM cleanup needs accomplishes only part of the EM-50 mission. Technologies must be successfully deployed at EM sites to justify the public and private investment. A variety of cultural, institutional, and communication barriers within the DOE complex must be addressed to achieve effective deployment. Under the Cooperative Agreement, the EERC works as an active partner to understand client site issues and technology needs, to support development of the information packages required by client sites for the evaluation and deployment of innovative cleanup technologies, and to support the brokering of technology access.

III. Commercialization Activities

The METC–EERC Cooperative Agreement is currently facilitating the EM deployment of the eight innovative environmental technologies profiled on Table 2. The choice of these candidate technologies reflects the commitment to ensuring fully applicable commercial EM cleanup technologies. First, the technologies were a solid match with the needs of EM site cleanup. As illustrated in Table 1, these technologies have primary applications in the Mixed Waste, Tank Waste, and Decontamination and Decommissioning focus areas. Application potential is high in other focus areas for most of the technologies. Second, these technologies represent a solid match with the EERC's core technical strengths; that is, the EERC can provide solid technical support. As shown on Table 1, the activities fall under the Extraction/Analysis, Thermal Conversion, and Separations core strength areas. Third, the technologies either came from the private sector or were determined, based on preliminary inquiries, to have a high probability of attracting private sector partners. In other words, the technologies were judged to be marketable in the private sector. At the time of this writing, as shown in Table 2, all of the technologies have a private sector partner, or private sector partnerships are pending. The candidate technologies represent a mix of private sector technologies and technologies developed at the EERC. Appropriate steps have been taken to address conflict of interest concerns.

In the following sections the role of the EERC program in commercialization and deployment strategies is described for eight technologies. The activities described for A–D are under way and the remaining activities are proposed for Year 3 of the program.

A. Centrifugal Membrane Filtration

Large volumes of liquids contaminated with heavy metals radionuclides and other contaminants exist at DOE and Department of Defense sites. Pretreatment of the liquids is often required to remove suspended and colloidal solids to improve the operation and efficiency of selected treatment technologies. SpinTek Membrane Systems, Inc., has developed a novel centrifugal membrane filtration process to accomplish difficult separations under harsh conditions. The SpinTek technology provides an effective means of waste separation and waste volume reduction, while producing a solids-free effluent and low-volume concentrate stream.

The EERC has recently completed a number of tasks to support rapid technology deployment, including 1) a problem definition and opportunity assessment survey, 2) process performance verification, 3) membrane screening and selection specific to radioactive tank wastes, 4) process performance evaluation using a surrogate tank waste, and 5) development of process data to allow optimization of the technology for appropriate DOE waste stream remediation.

Based on the successful demonstration of the SpinTek process, the technology has excellent potential to meet EM cleanup needs for a variety of applications to liquid waste streams, including tank wastes, process liquids, secondary liquid waste streams, and contaminated groundwaters. Continued testing of the SpinTek system will focus on modifications to enhance the shear pattern across the membrane surface to effect improved long-term performance.

B. Thermal Treatment of Organics in Mixed Waste

The diverse properties of mixed-waste plastics and resins have thwarted application of conventional methods for their reprocessing to yield recyclable chemical feedstocks or safely disposable materials. Because of their unique chemistry, polyethylene terephthalate (PET) and polyvinyl chloride (PVC) pose particular reprocessing challenges for plastics, and the presence of radionuclides compounds the challenge. The EERC, in partnership with the American Plastics Council, DOE, and other U.S. companies, has developed an innovative technology to thermally decompose conventional organic waste streams, including automotive shredder wastes and chemical spill residuals. This process, which utilizes a low-temperature thermal depolymerization technology, is being modified to form the basis of a commercially viable recycling process able to accommodate a wide variety of mixed- waste organics from laboratory and production facilities that handle low-level nuclear materials. The EERC has provided testing facilities, technical support, support for private sector partnership development, access to EM site sample materials, and support for EM site deployment.

The EERC has contracted with Stone & Webster Environmental Technology & Services (S&W) for assistance in technology assessment and has initiated discussions with other commercialization partners regarding technical and economic evaluation of the EERC process as a commercial treatment option. These discussions have indicated that initial commercialization efforts should be targeted at application of the process to spent (fully loaded) ion-exchange resins used to remove radionuclides from aqueous solution at nuclear power facilities. Process demonstration work has focused on tests conducted with commercial ion-exchange resin loaded at the EERC with saturation levels of nonradioactive cesium. Tests have also been conducted with surrogate-spiked postconsumer plastic waste containing weighed amounts of polycarbonate, Tyvec®, nylon, and acrylonitrile butadiene styrene (ABS), which are significant components of nuclear industry laboratory waste streams. For both the resin and waste plastic tests, analytical detection limits have been lowered to 5–50 ppb to provide a more definitive demonstration of process performance.

C. Laser Cleaning of Contaminated Painted Surfaces

Paint contaminated with radionuclides and other hazardous materials is common in DOE facilities. Facility decommissioning and decontamination requires the removal of contaminated paint. Paint removal technologies include laser- and abrasive-based systems. F2 Associates are utilizing a pulsed-repetition CO_2 laser that produces a 2.5-cm diameter beam which can be scanned across a 30- × 100-cm raster and, when placed on a robot, can be designed to clean any surface that the robot can be programmed to follow. Causing little or no damage to the substrate (concrete, steel, etc.) the laser ablates the material to be removed from a given surface. Ablated material is then pulled into a filtration and collection (VAC-PAC) system to prevent the hazardous substances from entering into the atmosphere. The VAC-PAC system deposits the ablated material into 23-gallon waste drums, which may be removed from the system without compromising the integrity of the seal, allowing a new drum to be set up for collection without leakage of the ablated material into the atmosphere.

The EERC is supporting F2 Associates development activities for their laser-based coating removal system in the areas of 1) on-line sensors for cleaning optimization, 2) the development of a surface cleaning cost model to facilitate the comparison of competing decontamination technologies, and 3) the development of an engineering handbook to facilitate design modifications for improved unit decontamination.

In the near term, activities are focused on the development of strategies for on-line sensors and preliminary work on the cost analysis model. The addition of on-line sensors is particularly noteworthy, because it provides essential capabilities while resulting in significant operational cost savings. First, on-line sensors optimize the cleaning process by allowing a smaller number of iterations on the survey-clean-survey cycle typically employed in the removal of contaminated coatings from floors and walls in DOE facilities. Second, on-line sensors offer the potential for real-time, in-situ chemical analysis of coatings, including radioactive components, resulting in reduced assay costs for waste materials collected by the VAC-PAC system. Work on the design for an easy decontamination handbook will take place in Year 3.

D. SFE–IR/FT-IR Rapid Organics Field Screening Unit

Obtaining cost-effective, accurate, and precise analyses for organic contaminants in soils presents a major challenge to site cleanup.

Field determination of organic pollutants in soils is usually limited by extraction methods needed prior to analysis. Supercritical fluid extraction (SFE) is fully portable and can be used to extract samples for conventional chromatographic analysis or can be combined with IR to make an on-line extraction–detection system.

An inexpensive, simple-to-operate field instrument, consisting of SFE coupled with IR, intended for the extraction and analysis of organics at ppm detection levels, is being developed at the EERC. This field method, based on SFE with CO_2, is highly accurate, rapid, and nonpolluting. The unit has applications in several EM focus areas, including Mixed Wastes, for characterization and sensing and is expected to be particularly useful as a screening tool. The EERC has provided testing facilities, technical support, support for private sector partnership development, access to field sites, field testing, and deployment support.

On-line SFE has been coupled with Fourier transform infrared (FT-IR) detection, based on a fiber-optic interface in a prototype unit. An agreement has been reached with Suprex Corporation of Pittsburgh, a major SFE instrument company, to commercialize the fiber-optic interface. The technology will be turned over to Suprex by June 1997.

E. Preparation of Sampling, Analysis, and Availability Assurance Plans for the Vortec Vitrification Demonstration Plant (Proposed)

Vortec Corporation of Collegeville, Pennsylvania, has a contract with METC to construct an $11 million dollar, 30-ton/day vitrification demonstration plant at the Paducah Gaseous Diffusion Plant in Paducah, Kentucky. Construction, initiated in the summer of 1996, is slated to last through the summer of 1997. The EERC is proposing to utilize its expertise in large-scale quality assurance/quality control (QA/QC) planning to develop a QA/QC sampling and analysis plan for the Paducah plant to ensure that the emissions and the leachability of vitrified process products fall within EPA guidelines. In addition, the EERC is proposing to develop a plan for thermochemical equilibrium modeling and laboratory testing to ensure that specific subsystems operate as smoothly as possible. The plan will address several key areas, including glass viscosity measurement and prediction, refractory corrosion, and deposit formation in both gas and quench water recycle loops.

F. Calibration and Field Testing of a Fiber Optic/Cone Penetrometer System for Subsurface Heavy Metals Detection (Proposed)

The characterization of contaminated soil for heavy metals can be expensive and time- consuming because of the high number of samples required to effectively evaluate a site and the utilization of laboratory chemical analysis techniques. Science and Engineering Associates, Inc. (SEA), a METC industry partner, is undertaking the development and demonstration of a heavy metal sensor, based on the integration of fiber-optic laser-induced breakdown spectroscopy (LIBS) and cone penetrometry, that can analyze the heavy metal content of the subsurface in real time in situ. A prototype is being constructed in the fall of 1996, and field testing is scheduled for the fall of 1997. A Gate 5 technology will result.

The EERC is proposing to provide 1) laboratory calibration and validation of the LIBS probe, 2) development of multivariate models for subsurface matrix effects on the LIBS calibration, 3) field testing of the LIBS/CPT system, and 4) comparison of the LIBS data with data from conventional techniques. EERC core competency includes laboratories and facilities, LIBS expertise, and data and expertise developed from dealing with heavy metal-contaminated sites.

G. Bubbleless Gas-Transfer Technology for the in Situ Remediation of Chlorinated Hydrocarbons (Proposed)

Chlorinated hydrocarbons have been widely distributed in the environment, particularly in groundwater, and constitute an important class of pollutant at DOE sites. The EERC, with its industrial partner Baumgartner Environics Incorporated, plans to develop and test an effective reductive dehalogenation technology for the in situ remediation of chlorinated hydrocarbons and in particular highly chlorinated aliphatics, the most recalcitrant form of chlorinated hydrocarbon. Bubbleless gas-transfer technology, developed by Baumgartner, is superior to similar technologies because 1) it uses gas efficiently and 2) it performs without the generation of bubbles, which tend to block the aquifer.

Phase 1 work, proposed for Year 3, will consist of laboratory testing with columns utilizing aquifer sediments and batch testing to determine kinetics, and will produce a Gate 4 technology. Phase 2, in FY 98, will include a field demonstration and will result in a Gate 5 technology.

H. Remediation of Organically Contaminated Soil Using Hot/Liquid (Subcritical) Water (Proposed)

Semivolatiles constitute an important class of pollutants on DOE sites, but current characterization and remediation technologies are expensive, time-consuming, and often result in additional waste. The EERC has developed a cost-effective, clean technology utilizing hot/liquid (subcritical) water for the remediation of soils contaminated with organics such as PAHs, PCBs, and pesticides.

Using the knowledge gained in laboratory tests, the EERC is proposing a pilot-scale demonstration (20–40 kg) of this technology. Flow rates, contact times, and optimal temperatures will be determined in additional laboratory studies. The work will produce a Gate 4 technology suitable for field testing and provide the performance background needed to attract a commercial partner.

IV. Summary

Under an EM Cooperative Agreement with METC, the EERC has instituted "hands-on" focused technical support, partnership brokering, and field demonstrations that provides a vehicle for rapid commercialization and deployment. The EERC plays a vital role in this process through its technical expertise, state-of-the-art facilities, growing family of government and commercial partners, and access to field demonstration sites. This approach removes the barriers between government and the private sector and between the technologist and the client EM sites. As a result, parties in the public and private sectors can function as true partners in the commercialization and deployment process. The search for additional candidate technologies and commercial partners is ongoing.

V. Acknowledgments

We wish to acknowledge Venkat Venkataraman, our METC Contracting Officer's Representative, and Madhav Ghate, Director of METC's Technology Base Projects Management Division. Key components of commercialization activities in the EM program include knowledge of the marketplace, technical expertise, and the ability to forge partnerships with industry and government.

Table 1. Matrix of EERC Core Expertise and EM Technology Needs

EERC Core Expertise	EM Focus Areas 1	2	3	4	5
Extraction/Analysis	■	■		■	
Cementation					
Vitrification					
Leaching Assessment		■			
Catalysis					
Thermal Conversions (liquefaction, pyrolysis, FBC)		■			
Plasma					
Biotreatment	■				
Carbon Sorbents					
Separations		■	■		
Sensors	■			■	
Systems Analysis	■	■	■	■	

1 Subsurface Contaminants

2 Mixed-Waste Characterization, Treatment, and Disposal

3 Radioactive Tank Waste Remediation

4 Facility Stabilization, Decommissioning, and Final Disposition

5 Plutonium Stabilization and Immobilization

■ Technology Tasks

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Table 2. Current (Year 2) and Additional Activities Proposed for Year 3 Under the METC–EERC EM Cooperative Agreement

Technology/Facility	**Commercial Partner**	**Activity**
Centrifugal membrane filtration	SpinTek Membrane Systems, Inc.	Testing and assessment; turbulence promoter component design
Field-portable unit for the thermal decomposition of organic mixed wastes, including resins	To be determined	Development, testing, and demonstration
Automated laser-based unit for removal of contaminated surface coatings	F2 Associates	Development of on-line analytical sensor systems for trace metals; economic assessment; laser unit decontamination design
Field SFE–IR and field SFE/FT-IR for extraction and analysis of organic pollutants	Suprex Corporation	Development, testing, and demonstration of SFE/FT-IR systems and a fiber-optic interface between the SFE and FT-IR instruments to allow real-time analysis in the field.
Vitrification demonstration plant, Paducah, KY	Vortec Corporation	Quality assurance plans for sampling, analysis, and availability assurance plans (proposed)
Fiber-optic cone penetrometer system for subsurface metal detection	Science & Engineering Associates	Calibration and field testing (proposed)
Bubbleless gas-transfer technology for in situ bioremediation of chlorinated hydrocarbons	Baumgartner Environics, Inc.	Testing and demonstration (proposed)
Subcritical (hot/liquid) water technology for remediation of soils contaminated with semivolatile organic pollutants	To be determined	Testing and demonstration (proposed)