CHARACTERIZATION, MONITORING, AND SENSOR TECHNOLOGY

CROSSCUTTING PROGRAM

Genesis and History of the CMST-CP Program*

a decade of progress

*Excerpted from the CMST-CP Technology Summary FY 2000

OFFICE OF SCIENCE AND TECHNOLOGY

OFFICE OF ENVIRONMENTAL MANAGEMENT

U.S. DEPARTMENT OF ENERGY

GENESIS AND HISTORY OF THE CMST PROGRAM

DOE ENVIRONMENTAL GOAL (Set November 1, 1989)

Former U. S. Department of Energy (DOE) Secretary of Energy James D. Watkins established the Office of Environmental Restoration and Waste Management (ERWM) and Office of Technology Development (OTD) on November 1, 1989, and adopted a goal to clean up 80 percent of DOE nuclear sites by 2006 and the more challenging DOE sites by 2030. Achieving this goal in a cost-effective manner required the development and implementation of safer and more efficient technologies for *site characterization and remediation, facility deactivation and decommissioning*, and *waste treatment and disposal*. These paired cleanup objectives are essential to cleaning up and restoring DOE sites throughout the United States for subsequent use and development. As part of its Integrated Program to accomplish these objectives, the ERWM created the Characterization, Monitoring, and Sensor Technology (CMST) program to be the focal point and integrator of environmental characterization and contaminant measurement technology development efforts.

NEED FOR ENVIRONMENTAL RESTORATION TECHNOLOGY DEVELOPMENT

To achieve its environmental cleanup objectives, ERWM first needed to characterize the waste inventory that had been accumulating for over 40 years at DOE sites, including thousands of contaminated facilities, contaminated equipment, soil contaminated by spills, waste disposal sites, and contaminant migration in the subsurface. Many of the environmental remediation technologies available in FY 1990 were inadequate or not economically feasible to implement at DOE sites. Some existing technologies were not capable of accurately assessing or characterizing the environmental status, defining specific cleanup requirements, or quantifying remediation success. In many cases, the technologies or strategies needed to deal with the diverse assortment of contaminated sites, with their unique combinations and levels of contaminants that include both radioactive and toxic materials, did not even exist. In addition, DOE needed a team approach that transcended organizational boundaries to evaluate and coordinate the development of technologies and methodologies to efficiently and cost-effectively achieve the following objectives.

Site Characterization and Remediation

The first set of cleanup objectives is to characterize contaminated sites in sufficient detail to make possible efficient, reliable, and defensible remediation. To achieve these objectives in a timely manner, DOE needed faster, less costly, and less environmentally intrusive methods for characterizing subsurface contamination and its potential for moving within the subsurface environment. DOE also needed technologies to monitor remedial processes in real time as well as to measure the effectiveness of remediation. In cases where complete remediation and restoration are not viable options, DOE needed technologies to contain or immobilize (stabilize) contaminants and to monitor the long-term effectiveness of those solutions.

Conventional remediation technologies were not designed to safely retrieve and treat extremely corrosive and/or highly radioactive wastes stored in surface and underground tanks or in waste lagoons, or to recover buried wastes (some of which are explosive, spontaneously ignite, and/or contain high levels of radioactivity, heavy metals, and hazardous organic solvents). In other instances, where large volumes of soil contain unacceptable levels of radionuclides, heavy metals, or hazardous organic compounds, conventional technologies that rely on excavation, treatment, and re-disposal clearly are neither cost-effective nor environmentally acceptable and expose workers to health and safety hazards. Significant technological advances in remediating groundwater are also necessary, especially for situations involving dense non-aqueous phase liquids and for nitrates in deep aquifers.

Facility Deactivation and Decommissioning

The second set of cleanup objectives is to close down, dismantle, decontaminate, and dispose of facilities and their contents at DOE sites to make decommissioning possible. Technology development was needed to ensure that the deactivation and decommissioning processes used at DOE sites were cost-effective and that they met all health, safety, and environmental regulations. Since many available decontamination processes were expensive, created excessive waste, and required modifications to satisfy existing regulations, innovative technologies and approaches were needed to meet requirements and to conserve resources.

The DOE facilities that need to be decontaminated, dismantled, and disposed of range from underground storage tanks and hot cells to mammoth uranium enrichment and plutonium processing plants. Each facility has radioactive contaminants and, in some instances, toxic substances contained in or on equipment that is difficult to remove because of its unique and complex design. DOE facilities slated for deactivation and decommissioning also include uranium enrichment and fabrication facilities, nuclear production reactors, and fuel reprocessing plants that have massive contaminated structures. Innovative technologies are needed to safely survey and distinguish the various contaminants on the surface and within equipment, pipes, and other facility materials, to reduce worker exposure and minimize waste.

Waste Treatment and Disposal

The third set of cleanup objectives is to treat, minimize, and dispose of contaminated materials and to recycle clean materials. In the process of remediating a site, contaminated soil and substances, including groundwater, are separated from clean soil and groundwater; the clean soil and groundwater are recycled. The extracted waste and contaminated solids are typically packaged in steel drums and deposited in a landfill. Non-destructive assay technologies are needed to confirm that the contents of the drums conform to landfill disposal requirements/regulations prior to delivery and burial.

Specially designed technologies are needed for characterizing, removing, and treating the contents of underground storage tanks and wastewater lagoons. Waste tanks and lagoons often contain significant quantities of highly radioactive wastes mixed with heavy metals, corrosive chemicals, and/or hazardous organic compounds that make personnel entry unacceptable. Remotely operated instrumentation and analysis systems are needed to reduce radiological exposure to workers and to monitor waste extraction conduits, such as pipelines, and treatment processes, such as vitrification and stabilization.

Continuous emissions monitors (CEMs) are needed at incinerators to replace existing emission sampling technologies that rely on periodically sampling and analyzing stack emissions with data becoming available only after a substantial time lapse. Similar requirements are anticipated for monitoring the alternative oxidation treatment processes expected to supplant incineration as well as off-gas effluents from other treatment processes. CEMs must be capable of continuously analyzing what is in the emissions and measuring the amounts of those substances. In particular, CEMs must be capable of measuring, in “real time” and under adverse conditions, emissions containing low levels of the metals specified in the Resource Conservation and Recovery Act (RCRA), hazardous chemical compounds, and radioactive elements from, for example, the incineration of mixed wastes. CEMs must also provide facility operators with the real-time data needed to prevent violation of regulatory standards.

NEED FOR AN INTEGRATED TECHNOLOGY DEVELOPMENT PROGRAM

Technology development is proceeding at a rapid pace at various commercial, academic, and federal laboratory organizations. The diversity of those development activities make it desirable to have a team devoted to overseeing and coordinating DOE-sponsored technology development to avoid duplication of effort to provide expertise, bring in technologies and strategies from other government agencies, and to help refine and then satisfy the environmental technology needs of DOE sites. Indeed, a characterization, monitoring, and sensor technology program driven by DOE needs is essential for sensible and cost-effective resource allocation and management. Furthermore, in addition to efficient

resource utilization, there is great potential to improve worker safety and to lessen environmental impacts.

ERWM made its CMST program the focal point for developing the environmental characterization and measurement technology needed for site cleanup. In its role as an integrator of technology development, CMST employed the participation of Characterization Technical Support Groups and Integrated Program Technology Support Groups. In an effort to further focus resources and address technology development opportunities, ERWM implemented Integrated Programs and Integrated Demonstrations, which were described as follows:

> *An Integrated Program focuses on technologies to solve a specific aspect of a waste management or environmental problem; the technology solution can be either unique to a site or common to many sites. An Integrated Program supports applied research to develop innovative technologies in key application areas organized around specific activities required in each stage of the remediation process (e.g., characterization, treatment, and disposal).*
>
> *An Integrated Demonstration is the cost-effective mechanism that assembles a group of related and synergistic technologies to evaluate their performance individually or as a complete system in correcting waste management and environmental problems from cradle to grave.*

The CMST program was an active participant in the Integrated Programs and Integrated Demonstrations.

THE EARLY YEARS OF THE CMST INTEGRATED PROGRAM (FY 1990 TO 1994)

Initial Characterization, Monitoring, and Sensor Technology (CMST) activities began in FY 1990. The early focus of the CMST was to identify the environmental restoration and waste management technology needs of the DOE sites, and to conduct a research and development program to satisfy those needs. From its inception through March 1992, it was managed directly by OTD at DOE Headquarters (HQ) with the assistance of BDM International, Ames Laboratory, and Los Alamos National Laboratory.

During the OTD Mid-Year Review in March 1992, Ames Laboratory was designated the primary field organization for CMST supporting the HQ Program Manager. OTD also adopted the Strategic Plan developed by Ames Laboratory in collaboration with other CMST program participants. Ames Laboratory, as the primary field support organization, was responsible for bringing together and utilizing the expertise needed for evaluating technology development proposals and the merits and progress of ongoing projects, and for collecting information and documenting CMST research and development projects in support of numerous ERWM activities throughout the DOE Complex.

SCOPE AND MANAGEMENT OF THE CMST INTEGRATED PROGRAM

The scope of CMST encompassed the broad spectrum of chemical and physical measurement and analysis technologies for the characterization and monitoring of contaminant materials, waste streams, and environmental contamination at DOE sites. The environmental media to be characterized and quantitated included air, soil, groundwater, waste forms, and waste containers. The activity range extended from identification and analysis of needs to the delivery and post-application evaluation of technology performance. The initial CMST program development and application areas were:

- Technologies that characterize, monitor, and sense mobile contaminants and define mobile contaminant pathways.
- Tools and strategies to provide better and more cost-effective site and waste and waste form characterization.
- Characterization of buried waste, the contents of underground storage tanks, and facilities to be decontaminated and decommissioned.
- Remediation process and waste treatment process monitoring.

- Characterization of high-level, transuranic, and mixed waste, and contaminated soil, material, and equipment for final disposition.

CMST Management Policies and Strategies

Since the success of OTD programs depended on the cooperation of many organizations working in concert, the following strategic management policies were adopted by OTD in March 1992.

- Work with the DOE ERWM Office of Waste Management (EM-30) and Office of Environmental Restoration (EM-40) by participating in the following technology exchange activities: Technology Integration, Technology Diffusion, Technology Transfer, and Technology Adaptation and Adoption. Obtain and validate information about their needs and schedule requirements.
- Work with the Integrated Demonstration and Integrated Program Technical Support Groups (Chemical Waste Landfill/Mixed Waste Landfill, Underground Storage Tanks, Buried Waste, Uranium in Soil, Plutonium in Soil, Volatile Organic Compounds in Non-Arid Soil and Groundwater, and Volatile Organic Compounds in Arid Soil and Groundwater) to share expertise and gain intimate knowledge of DOE EM technology needs and deficiencies. Capture planning and schedule requirements for Integrated Demonstrations and Integrated Programs so that the CMST program can accurately anticipate technology needs.
- Work in a manner that demonstrates open-mindedness and lack of bias. The CMST program must encourage the involvement of all DOE sites and laboratories, other federal agencies, and commercial and academic sectors, avoiding the tendency to support the DOE laboratories when more attractive alternatives exist.
- Prepare and distribute a newsletter that describes pertinent ERWM needs, identifies contact persons who are responsible for supplying information about available technologies that address those needs, and provides “snapshots” of newly available or emerging technologies from all sources.

CMST Technology Development Priorities

The initial technology development priorities were categorized as follows:

Characterizing Contaminants and Contaminant Pathways

- Airborne Contaminants (stack monitors for organic compounds, radionuclides, heavy metals)
- Transport Properties of Media (continuity of clay layers, non-intrusive methods for monitoring subsurface contaminant migration, improved methods for obtaining hydrologic permeability, improved high-resolution surface-fielded geophysical methods to define shallow systems)
- Waterborne Contaminants (real-time monitoring of process effluents for targeted organic compounds, heavy metals, radionuclides; *in situ* monitoring of volatile organic compounds)
- Soil Contaminants (uranium, plutonium, or other heavy metals in soil, organic contaminants)
- Real-Time Monitoring (volatile organic compounds, radionuclides, heavy metals, particulates)

Site Characterization Strategies

- Improved Sampling Strategies (use of *a priori* information, dynamic sampling strategies, quantification of the influence of uncertainty)
- Development and Application of Appropriate Data Quality Objectives

Waste Characterization Strategies

- Location of Buried Waste Containers and Objects (location of buried drums, resolution between buried metallic objects)
- Underground Storage Tanks (integrity and contents of underground storage tanks)
- Contents of drums (transuranic waste versus mixed wastes).

- Characterizing the Integrity of Waste Containers (field test methods for integrity of 55-gallon drums and Waste Isolation Pilot Plant waste packages)

CMST Technology Development Initiatives

The CMST program technology development initiatives included:

- Field Deployable, Rapid-Turnaround Chemical Characterization Instrumentation (advanced technology mass spectrometric, electrochemical, and spot test instrumentation for volatile organic compounds, inorganic pollutants, and radioisotopes in soil, groundwater, and storage tanks)
- Complex-Wide Protocol for the Establishment of Data Quality Objectives (characterization data and data quality required to support regulatory and other decisions regarding environmental restoration and waste management)
- Field Deployable, Data Driven, Adaptive Characterization Guidance Package (improved, timely guidance for field personnel on where to sample next for maximum return on pollutant distribution based upon spatial statistical analysis of all previously obtained characterization results)
- Large Area Imaging Sensor System for Surface Contamination Mapping (needed for mapping radioactively contaminated surfaces in facilities and surface soil contamination)
- Advanced Technology Continuous Emissions Monitors (needed to monitor and characterize metals and particulates)
- Advanced Technology Chemical Sensor and Sensor Placement Systems for Post-Closure Monitoring (volatile organic compounds, chromate ions, mercuric ion, and elemental mercury)
- System for Visualization and Analysis of Combined Data Streams from Geographical Location and Multiple Characterization Technologies (to improve the usefulness and total value of data from separate characterization techniques, including the whole array of surface and remote geophysical and other sensing technologies as well as the whole array of field and laboratory chemical analysis techniques)
- Advanced Near-Surface and Borehole Seismic and Other Non-Intrusive Geophysical Technologies for Location and Characterization of Buried Waste (present methods are inadequate)
- Non-Destructive Assay/Non-Destructive Evaluation Technologies (needed for determining the contents of waste drums
- Integration and Application of Chemical and Radioactivity Sensors in Robotic Characterization, Retrieval, Decontamination, and Waste Processing Systems (needed for characterization of underground storage tanks, spent fuel retrieval and reprocessing, and deactivation and decommissioning not presently being addressed)
- Airborne Remote Sensing

A NEW APPROACH TO TECHNOLOGY DEVELOPMENT (FY 1994 to 1999)

Although technology research and development efforts were quite successful, it became apparent that a better approach was needed to overcome some obstacles and to speed up DOE site cleanup. Consequently, in August 1993, the Assistant Secretary of Environmental Management established a Working Group to develop and implement a new management approach to environmental research and development within the entire ERWM.

During FY 1994, the Working Group established a framework and strategy for coordinating efforts among DOE organizations, Management and Operations (M&O) contractors, the national laboratories, other government agencies, the scientific community, industry, academia, and the affected public. Full implementation of the new approach occurred in FY 1995. Concurrently, in FY 1995, the CMST-Integrated Program (CMST-IP) was transformed into the Characterization, Monitoring, and Sensor Technology Crosscutting Program (CMST-CP).

In FY 1995 the ERWM was transformed into the Office of Environmental Management (EM) and the OTD was transformed into the Office of Science and Technology (OST). The newly formed organizations aimed to build upon existing programs and to seek continual improvement of all DOE EM operations and

processes. To assist in this endeavor, Site Technology Coordination Groups (STCG) were established at each major DOE site to identify their technology development needs.

The objectives of the new EM/OST management approach included better prioritizing research projects and fostering an enhanced level of technology development by involving academia and private industry. Another objective was to overcome obstacles to DOE site cleanup by focusing efforts on the specific needs of customers, users, regulators, and stakeholders and by keeping them informed of progress. Key features of the approach were:

- Establishing five Focus Areas and three Crosscutting Programs to address the most pressing environmental cleanup problems at DOE sites.
- Focusing technology development activities on major environmental management problems.
- Coordinating management of scientific and development activities in support of environmental management in the five Focus Areas.
- Teaming with internal DOE customers to identify, develop, and implement needed technologies.
- Focusing resources in national laboratories more effectively.
- Involving industry in developing and implementing solutions (including technology transfer *into* DOE and *from* DOE to the private sector).
- Coordinating basic research by involving academia and other research organizations to stimulate technological breakthroughs.
- Enhancing the involvement of regulators and stakeholders in implementing new technologies.

Benefits of the New Approach

A keystone for implementation of the new approach was to encourage the development of technologies that were better, faster, safer, and more cost-effective than those currently available. More importantly, the new approach was adopted to foster implementation of new and innovative environmental technologies, thereby facilitating the national commitment to achieving long-term environmental, energy, and economic goals. An important benefit of the new approach was the creation of investment returns for developing new technologies--technology dividends. These technology dividends result from partnerships and leveraging *within* government and *between* government and the private sector. The partnerships could consist of technology developers, technology users, problem holders, and problem solvers. EM technology dividends included:

- Cleanup of sites posing the greatest threats to human health, safety, and the environment.
- Materials reused and recycled, instead of thrown away or freshly contaminated.
- Pollution prevented.
- More effective and efficient industrial processes, leading to greater U.S. global competitiveness.
- Technology transfer to other countries.
- Employment opportunities with new businesses and existing businesses.

Establishment of Focus Areas in FY 1995

Five Focus Areas were established to target major remediation and waste management problem areas within the DOE Complex. These problem areas were targeted on the basis of risk, prevalence, or need for technology development to meet environmental requirements and regulations. The following are the Focus Areas established in FY 1995 with their original descriptions:

Contaminant Plume Containment and Remediation Focus Area

Unconfined hazardous and radioactive contaminants in soil and groundwater exist throughout the DOE Complex. There is insufficient information at most sites on the distribution and concentration of contaminants. The migration of some contaminants threatens water resources and, in some cases, has already had an adverse impact on the off-site environment. Many current characterization, containment,

and treatment technologies are ineffective or costly. Improvements are needed in characterization and data interpretation methods, containment systems, and *in situ* treatment.

Mixed Waste Characterization, Treatment, and Disposal Focus Area

DOE faces major technical challenges in the management of low-level radioactive mixed waste. Conflicting regulations together with a lack of definitive mixed waste treatment standards hamper mixed waste treatment and disposal. Disposal capacity for mixed waste is expensive and severely limited. DOE now spends millions of dollars annually to store mixed waste because of the lack of accepted treatment technologies and disposal capacity. In addition, currently available waste management practices require extensive and costly waste characterization before disposal. Therefore, DOE must pursue technology that leads to better and less expensive characterization, retrieval, handling, treatment, and disposal of mixed waste.

Radioactive Tank Waste Remediation Focus Area

Across the DOE Complex, hundreds of large storage tanks contain hundreds of thousands of cubic meters of high-level mixed waste. The primary areas of concern are deteriorating tank structures and consequent leakage of their contents. Research and technology development activities must focus on the development of safe, reliable, and cost-effective methods for characterizing, retrieving, treating, and permanently disposing of the wastes.

Landfill Stabilization Focus Area

Numerous DOE landfills pose significant remediation challenges. Some existing landfills have contaminants that are migrating, and require interim containment prior to final remediation. Materials buried in retrievable storage pose another problem. Retrieval systems must be developed to reduce worker exposure and secondary waste quantities. Another high-priority need is to develop *in situ* methods for containment and treatment.

Decontamination and Decommissioning Focus Area

The aging of DOE weapons facilities, along with the reduction in nuclear weapons production, has resulted in a need to transition, decommission, deactivate, and dispose of numerous facilities contaminated with radionuclides and hazardous materials. While building and scrap materials at the sites are a potential resource with a significant economic value, current regulations lack clear release standards. This indirectly discourages the recovery, recycling, and/or reuse of these resources. The development of enhanced technologies for the decontamination of these materials, and effective communication of the low relative risks involved, will facilitate the recovery, recycling, and/or reuse of these resources. Improved material removal, handling, and processing technologies will enhance worker safety and reduce cost.

The Focus Areas were redefined in FY 1997. Two Focus Areas related to soil and groundwater, Contaminant Plume and Remediation Focus Area and Land Stabilization Focus Area, were combined into the Subsurface Contaminants Focus Area and a new Plutonium Focus Area was added. In FY 1999 the Plutonium Focus Area was enlarged in scope and renamed the Nuclear Materials Focus Area. In FY 2000 the Mixed Waste Focus Area was enlarged to include transuranic wastes and was renamed the Transuranics/Mixed Waste Focus Area (TMFA).

Establishment of Crosscutting Programs in FY 1995

Three Crosscutting Programs were established in FY 1995 to manage the development of technologies that overlap individual Focus Areas:

Characterization, Monitoring, and Sensor Technology Crosscutting Program

DOE is required to characterize more than 3,700 contaminated sites, 1.5 million barrels of stored waste, 385,000 cubic meters of high-level waste in tanks, and from 1,700 to 7,000 facilities before remediation, treatment, and facility transitioning commence. During remediation, treatment, and site closure, monitoring technologies are needed to ensure worker safety and effective cleanup. Cost-effective technologies are needed for all DOE environmental characterization requirements.

Efficient Separations and Processing Crosscutting Program

Separation and treatment technologies are needed to treat and immobilize a broad range of radioactive wastes. In some cases, separation technologies do not exist; in others, improvements are needed to reduce costs, reduce secondary waste volumes, and improve waste form quality. Separation technologies are also needed for the environmental restoration of DOE sites, for groundwater and soil cleanup, and for the decontamination and decommissioning of facilities. Many separation agents developed for waste treatment can be adapted for environmental restoration needs.

Robotics Technology Crosscutting Program

DOE waste disposal efforts have particular issues--access, safety, final disposal, and cost efficiency. Due to hazardous radiation, massive waste loads, and restricted entryways, many sites are inaccessible for human labor. It is unsafe to expose humans to radiation, harmful chemicals, and injurious mechanical objects. Human labor requires higher compensation, the need for expensive protective clothing, and stringent decontamination procedures. Robotic systems are safe, efficient, and cost-effective means to automate the handling and processing of mixed waste and characterizing and/or retrieving storage tank waste. Systems can also be designed for surveillance, characterization, cleanup, and decommissioning of retired DOE facilities.

MANAGEMENT OF THE CMST CROSSCUTTING PROGRAM (FY 1990 to Present)

While the fundamental technological objectives of the CMST program have remained essentially the same since its inception, the management approach has changed several times. As stated earlier, during the initial phase from FY 1990 through March 1992, CMST program activities were managed entirely by DOE HQ with the support of BDM International, Ames Laboratory, and Los Alamos National Laboratory. From mid-March 1992 until FY 1996, Ames Laboratory was the primary Field organization coordinating CMST Program activities for HQ. During FY 1996 OST designated the DOE Nevada Operations Office (NV) the CMST Field Coordinator organization, and NV became the CMST Field Lead organization in FY 1998. In FY 2000, the management role of the OST Crosscutting Programs, including CMST-CP, was changed to a Focus Area Centered approach.

CMST PROGRAM MANAGERS AND COORDINATORS

The following time periods are approximate. The period(s) an individual served is given by fiscal year. This may not fully represent the entire time period an individual served.

Stanley Wolf, DOE/OTD
CMST HQ Program Manager, FY 1990-1992

David Roelant, BDM International/ Professional Analysis, Inc. - Bechtel Nevada
CMST HQ Contractor Lead, FY 1991-FY1997
CMST Field Program Coordinator, FY 1997-1999

William Haas, Ames Laboratory
CMST Field Program Coordinator, FY 1992-1993

Caroline Purdy, DOE/OTD/OST
CMST HQ Program Manager, FY 1992-1997

Paul Wang, Ames Laboratory
CMST Field Program Coordinator, FY 1994
CMST Field Program Technical Coordinator, FY 1995
CMST Field Technical Coordinator, FY 1996-1998

John Jones, DOE/NV
CMST Project Manager (on assignment to HQ), FY 1996
CMST Field Program Manager, FY 1996-1997
CMST Field Technical Manager, FY 2000
CMST Field Manager, FY 2001-***Present***

Charles Nalezny, DOE/OST
CMST HQ Program Manager, FY 1998-1999

David Hippensteel, DOE/NV
CMST Field Program Manager, FY 1997-1998

Dirk Schmidhoffer, DOE/NV
CMST Field Program Manager, FY 1998-1999

Joseph Ginanni, DOE/NV
CMST Field Program Manager, FY 1999-2000

Edward Rizkalla, DOE/OST
CMST HQ Point of Contact, FY 2000

Charles Davis, Professional Analysis, Inc. - Bechtel Nevada
CMST Field Program Coordinator FY 1999-***Present***

Beth Moore, DOE/OST
CMST HQ Point of Contact, FY 2000-***Present***

CURRENT PROGRAM STATUS AND FUTURE OUTLOOK

CMST-sponsored research and development has resulted in the evaluation, development, and application of many characterization, monitoring, and sensor technology solutions to environmental restoration and waste management problems at DOE sites. The CMST program develops technologies to satisfy specific needs identified in Need Statements made by the DOE Site Technology Coordination Groups, striving to develop technologies that are safer, faster, less costly, more efficacious, and less physically invasive than previously used approaches. The CMST program also develops innovative technologies to solve Site Environmental Restoration and Waste Management problems where no suitable technologies previously existed.

CMST projects have made major technological advances in methods used for site, facility, and waste characterization. They have made a major impact in the areas of real-time *in situ* monitoring for site characterization, waste stream and thermal treatment process control, and surveying contaminated facilities and equipment.

At present approximately 120 CMST program technologies have been evaluated and/or developed, demonstrated, and applied to DOE EM problems at DOE sites. Approximately 40 technologies developed by the CMST program are commercially available. Nevertheless there remain dozens of environmental problems that need new solutions.

Accurate characterization of the nature and extent of soil, groundwater, and facility contamination can have a dramatic effect on the amount of material that is ultimately subjected to remediation, stabilization, and/or disposal. The treatment options depend to a large extent on accurately determining the distribution and concentrations of various contaminants. Similarly, real-time control and optimization of waste treatment systems can be accomplished only if reliable, real-time monitors are available, thus enabling continuous monitoring and adjustments for changing waste conditions. Finally, DOE EM will need to validate system performance upon completion of site remediation and waste disposal as part of its environmental restoration and site stewardship responsibilities. Sensitive and reliable sensors and monitoring programs will be critical to protecting public health and assuring the necessary high confidence in engineered solutions.

In the recent report entitled “Research Needs in Subsurface Science,” prepared by the National Research Council (2000) certain of the sensor and monitoring technology needs are specifically identified:

> *Development of methods for designing monitoring systems to detect current conditions and changes in system behaviors. These methods may involve the application of conceptual, mathematical, and statistical models to determine the types and locations of observation systems and prediction of the spatial and temporal resolutions at which observations need to be made.*
>
> *Research to support the development of methods to monitor fluid and gaseous fluxes through the unsaturated zone, including both direct (e.g., in situ sensors) and indirect (e.g., using plants and animals) over long time periods. Included is research addressing physical instrumentation as well as measurement techniques, the latter including measurement strategies and data analysis (including statistical) approaches.*

Research and development continues to be needed to design both *in situ* and remote sensors that can discriminate more effectively, have greater sensitivity, and enable real-time or near real-time continuous assessments of changing conditions spanning many channels of input (corresponding to many contaminants under observation). Corresponding applied and developmental research is needed to transform the findings of basic research and innovative concepts into functioning, reliable instruments and methodologies for confronting the challenges and demands of *in situ* applications both in the field or within active or closed facilities.

The ability to accurately characterize and monitor the existence and migration of contaminants is paramount to cost-effective environmental restoration and waste management strategies. An improved ability to detect and assess the spatial distribution of different types of contaminants will enable more precise, tailored approaches to different conditions at each DOE site. Similarly, in the treatment of wastes, such as those from Deactivation and Decommissioning, the ability to accurately scan wastes in real time or near real time and to perform appropriate separation and segregation could result in significant life cycle cost savings. And, in pursuit of final disposal and site stewardship options, improved sensors will increase confidence and provide a more sensitive, early warning when system failures occur. The CMST team has the experience and technical capability to deliver innovative technologies to satisfy DOE site characterization, monitoring, and sensor technology needs.

A list of the technologies evaluated and/or developed by the CMST program during the past decade are presented in Appendix A.

APPENDIX A

CMST PROGRAM TECHNOLOGY PROJECTS

The following CMST Program Technology Projects are presented by Fiscal Year (FY).

FY 1990

Projects Outside Program – Related to CMST

- *In Situ* Characterization by Ion Trap Mass Spectroscopy (*Tech ID 1297)
- Laser Spark Analysis of Soils for Contaminants (Tech ID 434)
- Remote Handled Non-Destructive Assay Development
- Mobile Inductively Coupled Plasma Optical Emission Spectroscopy (Tech ID 602)
- Improvements in Inductively Coupled Plasma Mass Spectroscopy (Tech ID 133)
- Portable Infrared Analyzer (Tech ID 711)
- Characterization of Underground Storage Tanks
- Sensor System Development for Remote Sensing (Tech ID 208)
- Electromagnetic Underground Imaging - Electrical Resistance Tomography (Tech ID 17)

FY 1991

CMST Projects

- *In Situ* Characterization by Ion Trap Mass Spectroscopy (Tech ID 1297)
- Improvements in Inductively Coupled Plasma Mass Spectroscopy (Tech ID 133)
- Sensor System Development for Remote Sensing (Tech ID 208)

Projects Outside Program – Related to CMST

- Defense Low-Level Waste Technical Support - Lysimeters: Groundwater Studies (Tech ID 715, 2365)
- Portable Infrared Analyzer (Tech ID 711)
- Analysis of a Plume at INEEL: Commercial, Airborne Thermal and Electromagnetic Flyovers and Soil Characterization Activities (Tech ID 733, 2946)

FY 1992

CMST Projects

- Non-Invasive Site Characterization Phase I (Meeting, Study)
- Improvements in Inductively Coupled Plasma Mass Spectroscopy (Tech ID 133)
- Portable Infrared Analyzer (Tech ID 711)
- Volatile Organic Compounds in Vadose Zone Groundwater Characterization
- Cone Penetrometer Truck Vadose Zone Testing for Subsurface Contaminants (Initial Studies with Commercial CPT Before Building SCAPS) (Tech ID 243)
- *In Situ* Secondary Ion Mass Spectroscopy Analysis (Tech ID 135)
- Sensor System Development for Remote Sensing (Tech ID 208)
- Martin Marietta Energy System Corp. Thermal Measurements – Flyover (Thermal Anomaly Found) (Tech ID 733, 2946)

*****DOE OST Technology Management System (TMS) Tech ID Number; see DOE Office of Environmental Management Internet site [http://ost.em.doe.gov/IFD/OSThome.htm] for accessing TMS and other information sources. Since the TMS did not exist from the inception of CMST, the corresponding TMS numbers have been added retroactively.

- Associated Particle Imaging (Tech ID 413)
- Defense Low-Level Waste Technical Support - Lysimeters (Water Sample Collections) (Tech ID 715, 2365)

FY 1993

Projects for Expedited Site Characterization

- Expedited Site Characterization: Application and Continued Development of Rapid, Focused Site Characterization Methodology for Federal Facilities (Tech ID 77)
- Innovative Directional and Position Specific Sampling Technique (Tech ID 8)
- Direct Sampling Ion Trap Mass Spectrometry Instrumentation for Organics in Water, Soil, and Waste (Tech ID 69)
- Field-Deployable Volatile Organic Compound (VOC) Analyzer: On-Site, Real-Time VOC Analyzer Systems for Air, Soil, and Water (Tech ID 711)
- Field-Usable Portable Analyzer for Chlorinated Organic Compounds (Tech ID 313)
- Improvements in Inductively Coupled Plasma Mass Spectrometry (Tech ID 133)
- Direct Measurement of Strontium-90 in Surface Soils (Tech ID 70)
- Road Transportable Analytical Laboratory System (Tech ID 292)
- *In Situ* Secondary Ion Mass Spectrometry (SIMS) Analysis: Development and Evaluation of a Transportable Ion Trap SIMS Instrument for the Direct Analysis of Low Volatile Organic Compounds (Tech ID 135)

Projects for Contaminants in Soils and Groundwater

- Spectroelectrochemical Sensors for DOE Site Characterization (Tech ID 744)
- Improved Reversible Carbon Tetrachloride Sensor for On-Line and Down-Well Measurements (Tech ID 103)
- Chlorinated and Aromatic Hydrocarbon Thin Film Chemical Sensors (Tech ID 16)
- Remote Sensing Systems Development (Several Technologies at DOE/STL)

Projects for Geophysical and Hydrogeologic Measurements

- Zero-Tension Lysimeters: An Improved Design to Monitor Colloid Facilitated Contaminant Transport in the Vadose Zone (Tech ID 715)
- A New Generation Pulsed-Neutron Induced Gamma-Ray Multi-Spectral Logging System for *In Situ* Mapping of Contaminants (Tech ID 382)
- High-Resolution Subsurface Imaging and Neural Network Recognition: Non-Intrusive Buried Substance Location (Tech ID 314)
- Geophysical Data Fusion For Subsurface Imaging (Tech ID 290)
- Data Fusion Workstation (Tech ID 290)
- Historical Imagery Applications for Environmental Restoration and Waste Management

Projects for Mixed Wastes in Drums, Burial Grounds, and Underground Storage Tanks

- Associated Particle Imaging Development (Tech ID 413)
- Field Raman Spectrograph for Environmental Analysis (Tech ID 1544)

Projects for Remediation, Deactivation and Decommissioning, and Waste Process Monitoring

- Novel Mass Spectrometric Instrument for Gaseous and Particulate Characterization and Monitoring
- Air Quality Site Boundary Monitoring for Volatile Organic Compounds by Preconcentration/Membrane (Tech ID 670)
- Ion Trap Mass Spectrometry (Tech ID 69)
- Continuous Emission Monitor for Incineration (Tech ID 18, 411, 1564, 2029, 2305)
- Infrared Analysis of Wastes: Novel Lab and On-Line Measurements by Photoacoustic and Transient Infrared Spectroscopies (Tech ID 215)

- Development of a Long-Term Post-Closure Radiation Monitor (Tech ID 288)
- *In Situ* Vitrification Field Data Collection at Arnold Air Force Base and Parsons Superfund Site (Tech ID 749)

FY 1994

Projects for Contaminants in Soils and Groundwater

- Expedited Site Characterization at DOE Facilities (Tech ID 77)
- Ames Laboratory Expedited Site Characterization Project (Tech ID 77)

Projects for Sensors and Field Analysis Equipment

- Ames Mobile Laboratory Project (Tech ID 717)
- Site Characterization and Penetrometer System (Tech ID 243)
- Time Domain Reflectometry and Fiber Optic Probes for the Cone Penetrometer (Tech ID 141)
- Airborne Miniature Platforms (Tech ID 76)
- Development of Screening and Quantitative Field Methods Coupled to the Cone Penetrometer (Tech ID 219)
- Secondary Ion-Mass Spectrometry Analysis: Development and Evaluation (Tech ID 135)
- Miniaturized Chemical Flow Probe Sensor Development (Tech ID 218)
- Multi-analyte, Single-Fiber Optical Sensor (Tech ID 383)
- Sol-Gel Indicator Program (Tech ID 384)
- Portable, Real-Time Monitoring Systems for Volatile Organics (Tech ID 711)
- Chlorinated and Aromatic Hydrocarbon Thin Film Chemical Sensors (Tech ID 16)
- Air Quality Site Boundary Monitoring for Volatile Organic Compounds by Preconcentration/Membrane (Tech ID 670)
- Direct Sampling Ion Trap Mass Spectrometry Instrumentation (Tech ID 69)
- Multisorbent Arrayed Sampler for Collection of Vadoze Zone Organic Contaminants (Tech ID 461)
- Multi-Spectral Neutron Logging (Tech ID 382)
- *In Situ* RCRA Metals Analysis (Tech ID 434)
- Air-Quality Monitoring for Alpha Contamination - Long Range Alpha Detector (Tech ID 596)
- Direct Measurement of Strontium-90 in Surface Soils in Real Time (Tech ID 70)
- LA-ICP-AES Using a High-Resolution Fiber Optic Interferometer (Tech ID 430)

Projects for Characterization Decision Support Tools

- Data Fusion for Characterization and Monitoring (Tech ID 290)

Projects for Geophysical and Hydrogeologic Measurements

- Three-Dimensional/Three-Component Seismic Reflection for Site Characterization (Tech ID 174)
- Crosshole Compressional and Shear Wave Seismic Tomography (Tech ID 623)
- Zero-Tension Lysimeters: An Improved Design to Monitor Colloid-Facilitated Contaminant Transport in the Vadoze Zone (Tech ID 715)
- Analog Site for Characterization of Fractured Rock (Tech ID 216)
- Rabbit Valley Geophysics Performance Evaluation (Tech ID 427)
- International Environmental Assessment of Contaminant Transport Studies of Russian Sites (Tech ID 775)
- Electrical Resistance Tomography for Subsurface Imaging (Tech ID 17)

Projects for High-Level Waste Tanks

- Moisture Measurement by Electromagnetic Induction (Tech ID 398)
- In-Tank Interface Detection Using Time Domain Reflectometry (Tech ID 401)
- Transuranic Elements and Moisture Measurement in High-Level Waste Tanks by Neutron Activation (Tech ID 771)
- Sensing of Head Space Gases: Continuous *In Situ* Monitoring of Gaseous Components in Underground Storage Tanks Using Piezoelectric Thin Film Resonator Sensors (Tech ID 396)

- Raman Probe Radiation Study (Tech ID 1544)
- Infrared Analysis of Wastes: Novel Laboratory and On-Line Measurements by Photoacoustic and Transient Infrared Spectroscopies (Tech ID 215)
- Laser Ablation Mass Spectrometry Scanning of Waste Tank Core Samples (Tech ID 127)
- Imaging Through Obscuration During Sluicing (Tech ID 405)

Projects for Characterization, Treatment, and Disposal of Mixed Waste
- Development of a Continuous Emission Monitor for Incineration (Tech ID 1564)
- Associated Particle Imaging (Tech ID 413)

Projects for Remote Sensing
- Remote Sensing Systems Development (Tech ID 208)
- Laser-Induced Fluorescence Imaging (Tech ID 78, 1999)

FY 1995

Projects for the Contaminant Plume Containment and Remediation Focus Area

Expedited Site Characterization
- Expedited Site Characterization - Application to Federal Facilities (Tech ID 77)
- Ames Laboratory's Expedited Site Characterization Demonstrations (Tech ID 77)

Field Analysis and Instrumentation
- Time Domain Reflectometry and Fiber-Optic Probes for the Cone Penetrometer (Tech ID 141)
- Site Characterization and Analysis Penetrometer System (Tech ID 243)
- *In Situ* Measurement of Volatile and Semi-Volatile Organic Compounds in the Subsurface: Development of Screening and Quantitative Field Methods Coupled to the Cone Penetrometer (Tech ID 219)
- Miniature Pumps in the Cone Penetrometer Tip for Groundwater and Soil Gas Sampling (Tech ID 381)
- Nuclear Borehole Logging: Passive and Neutron-Induced Spectral Gamma-Ray Techniques for Mapping Contaminants *In Situ* (Tech ID 382)

Sensors
- Multi-Analyte Single Fiber-Optical Sensor (Tech ID 383)
- Sol-Gel Indicator Program (Tech ID 384)
- Miniaturized Chemical Flow Probe Sensor Development (Tech ID 218)
- Flow Probe Sensor Development - Center for Process Analytical Chemistry (Tech ID 218)
- Portable Acoustic Wave Sensor Systems for Volatile Organic Compounds (Tech ID 282)
- Surface Acoustic Wave Array Detectors (Tech ID 16)

Contaminant Transport
- Analog Site for Characterization of Contaminant Transport Through Fractured Rock (Tech ID 216)
- Integrated Geophysical and Hydrological Characterization of Transport Through Fractured Media (Tech ID 290, 2944)

Projects for the High-Level Tank Waste Remediation Focus Area

Safe Storage
- Sensing of Head Space Gases: Continuous In Situ Monitoring of Gaseous Components in Underground Storage Tanks Using Piezoelectric Thin Film Resonator Sensors (Tech ID 396)
- Electrical Resistance Tomography for Subsurface Imaging (Tech ID 17)
- Moisture Measurement by Electromagnetic Induction (EMI) (Tech ID 398)
- In-Tank Interface Detection Using Time Domain Reflectometry (Tech ID 401)

Waste Retrieval
- Acoustic Characterization of Wastes in Double Shell Underground Storage Tanks (Tech ID 175)
- Imaging Through Obscurations During Sluicing Operations (Tech ID 405)

Waste Sampling/Analysis
- Moisture Sensor in Cone Penetrometer for In-Tank Characterization (Tech ID 86)
- Infrared Analysis of Wastes (Tech ID 215)

Projects for the Mixed Waste Characterization, Treatment, and Disposal Focus Area

Waste Process Monitoring and Controls
- Diagnostic Instrumentation and Analysis Laboratory (Tech ID 207)
- Support for RCRA Metal and Air Stream Characterization

Off-Gas and Effluent Monitoring
- Continuous Emission Monitor for Thermal Treatment Systems (Tech ID 411, 2932)
- Metal Emissions Monitor for DOE Mixed Waste Thermal Treatment (Tech ID 18, 1564)

Projects for Decontamination and Decommissioning Focus Area
- Associated Particle Imaging Development (Tech ID 413)
- A Robust Radiation Detector for Rapid Waste Characterization (Tech ID 19)
- Development of a Portable Heavy Metal Detector Using X-Ray, K-Edge Analysis (Tech ID 134)

Projects for Landfill Stabilization Focus Area

Buried Waste Location/Characterization
- Remotely Piloted Vehicles and Miniaturized Sensors (Tech ID 76)
- Remote Sensing Systems Development and Application (Tech ID 208)
- Laser-Induced Fluorescence Imaging for Surface Uranium (Tech ID 1999)
- Rabbit Valley Geophysics Performance Evaluation Range (Tech ID 427)
- Three-Dimensional/Three-Component Seismic Surveys for Site Characterization (Tech ID 174)

Containment
- Laser Ablation-ICP-AES Using a High Resolution Fiber-Optic Interferometer (Tech ID 430)
- Inductively-Coupled Plasma - Mass Spectrometry (ICP-MS) for Analysis of Microliter Samples and Solids (Tech ID 133)
- Secondary Ion-Mass Spectroscopy Analysis: Development and Evaluation (Tech ID 135)
- RCRA Metals Analysis by Laser-Induced Breakdown Spectroscopy (Tech ID 434)

FY 1996

Projects for the Contaminant Plume Containment and Remediation Focus Area
- Integration of Innovative Expedited Site Characterization Techniques (Tech ID 77)
- Cone Penetrometer Support: Operation, Maintenance, and R&D Activity Conducted on the DOE Office of Technology Development Cone Penetrometer Vehicle (Tech ID 243)
- *In Situ* Measurement of Volatile and Semi-Volatile Organic Compounds in the Subsurface
- Flow Probe Chemical Analyzer (Tech ID 219, 237)
- Portable Acoustic Wave Sensor Systems for Volatile Organic Compounds (Tech ID 282)
- Surface Acoustic Wave Array Detectors (Tech ID 16)
- Analog Site for Characterization of Contaminant Transport Through Fractured Rock (Tech ID 216)
- International Environmental Assessment/JCCEM Contaminant Transport Studies (Tech ID 775)

Projects for the Radioactive Tank Waste Remediation Focus Area

- Electrical Resistance Tomography For Subsurface Imaging (Tech ID #140)
- Acoustic Characterization of Wastes in Double-Shelled Underground Storage Tanks (Tech ID 175)
- Infrared Analysis of Wastes (Tech ID 215)
- Neural Network Raman Cone Penetrometer Signal Extraction and Enhancement (Tech ID 242)
- In Situ Sensor Development: Ultrasonic Density Measurement Probe (Tech ID 214)
- Ultrasonic Sensors For In Situ Monitoring of Physical Properties (Tech ID 214)
- *In Situ* Viscosity and Density Monitoring Using Quartz Resonators (Tech ID 213)
- Process Monitoring and Control: Ammonia Measurements in Offgases (Tech ID 212)

Projects For Mixed Waste Characterization, Treatment, and Disposal Focus Area

- Diagnostic Instrumentation and Analysis Laboratory (Tech ID 207)
- Support for RCRA Metal, Forensic Geophysics, and Air Stream Characterization
- Metal Emissions Monitor for DOE Mixed Waste Thermal Treatment (Tech ID 18)

Projects for Decontamination and Decommissioning Focus Area

- A Robust Radiation Detector for Rapid Waste Characterization (Tech ID 19)
- Portable X-Ray, K-Edge Heavy Metal Detector (Tech ID 134)

Projects for Landfill Stabilization Focus Area

- Remotely Piloted Vehicles and Miniaturized Sensors (Tech ID 76)
- Airborne and Ground-Based, Laser-Induced Fluorescence Imaging (Tech ID 78, 1999)
- Three-Dimensional, Three-Component Seismic Imaging for Site Characterization (Tech ID 174)
- Inductively Coupled Plasma-Mass Spectrometry for Analysis of Microliter Samples and Solids (Tech ID 133)
- Secondary Ion Mass Spectroscopy Analysis (Tech ID 135)

FY 1997

Projects for the Subsurface Contaminants Focus Area

- New Environmental Measurement While Drilling (Tech ID 8)
- A Steerable/Distance Enhanced Penetrometer Delivery System (Tech ID 317)
- Cone Penetrometer Operations & Site Characterization and Analysis (Tech ID 243)
- Tomographic Site Characterization Using Cone Penetrometer, Electrical Resistivity Tomography, and Ground Penetrating Radar (Tech ID 17, 284)
- Internal Reflection Sensor (IRS) for the Cone Penetrometer (Tech ID 1723)
- *In Situ* Permeability Measurements with Direct Push Techniques (Tech ID 307)
- Joint Development of a Membrane-Based Rapid Water Sampler with 3M (Tech ID 1514)
- Field Raman Spectrograph for Environmental Analysis (Tech ID 873)
- Three-Dimensional Integrated Characterization and Archiving System (Tech ID 97)
- Environmental Remote Sensing for Monitoring Plant Health (Tech ID 1900)
- Laser-Induced Fluorescence (LIF) for Heavy Metals in Soils and Plants (Tech ID 78, 208)
- JCCEM Contaminant Transport Studies--Pacific Northwest National Laboratory (Tech ID 775)
- Electrical Resistance Tomography (ERT) for Subsurface Imaging of Barriers(Tech ID 140)
- Neural Network Raman Cone Penetrometer Signal Extraction and Enhancement (Tech ID 242)
- Characterization and Monitoring of Dense, Non-Aqueous Phase Liquids (DNAPLs) (Tech ID 237)
- Analog Site for Characterization of Fractured Rock (Tech ID 216)

Projects for the Radioactive Tank Waste Remediation Focus Area

- Portable Acoustic Wave Sensor Systems for Volatile Organic Compounds (Tech ID 282)
- *In Situ* Viscosity and Density Monitoring Using Quartz Resonators (Tech ID 213)
- Comparative Testing of Pipeline Slurry Monitors (Tech ID 2935, 2936, 2970)
- Ultrasonic Sensors for *In Situ* Monitoring of Physical Properties (Tech ID 214)

- Development of a Magnetic Resonance Monitor for Technetium-99 Column Breakthrough (Tech ID 1513)
- Robotic End Effector for Inspection of Storage Tanks (Tech ID 278)
- Development of an On-Line, Real-Time, Alpha-Radiation Measuring Instrument for Liquid Streams (Tech ID 312)
- Diagnostics and Data Fusion of Robotic Sensors (Tech ID 227)
- Automated Monitoring System for Fluid Level and Density in High-Level Waste Tanks (Tech ID 279)
- *In Situ* Sensor Development - Ultrasonic Density Measurement Probe (Tech ID 214)

Projects for the Mixed Waste Characterization, Treatment, and Disposal Focus Area
- Metal Emissions Monitor for DOE Mixed Waste Thermal Treatment (Tech ID 18, 1564)
- Diagnostic Instrumentation and Analysis Laboratory (Tech ID 207)
- Development of a Multielement Metal Continuous Emissions Monitor (Tech ID 18, 1564)
- Coherent Laser Vision System (Tech ID 94)
- An Advanced, Open-Path, Atmospheric Pollution Monitor for Large Areas (Tech ID 280)
- A Continuous Emission Monitor for Toxic Metals in the Offgases of Thermal Treatment Facilities (Tech ID 1564)
- Demonstration of Emerging Continuous Emissions Monitoring (CEM) Technologies (Tech ID 2034)

Projects for the Deactivation and Decommissioning Focus Area
- Real-Time Monitoring of Alpha Emissions (Tech ID 114)
- Portable X-Ray, K-Edge Heavy Metal Detector
- Characterization of Radioactive Contamination Inside Pipes with the Pipe Explorer™ System (Tech ID 74)
- Waste Inspection Tomography (Tech ID 259)
- Portable Sensor for Hazardous Waste (Tech ID 31)
- Nondestructive Examination and Assay of Drums Containing Transuranic Waste Associated Particle Imaging (Tech ID 413)
- Airborne and Ground-Based Laser-Induced Fluorescence Imaging (Tech ID 78, 1999)
- Radiation Sensors (Long-Range Alpha Detector) for Uranium Cylinders (Tech ID 1560)
- Remotely Piloted Vehicles and Miniaturized Sensors (Tech ID 76)

Projects for the Plutonium Focus Area
Real-Time Plutonium Monitoring (Tech ID 2004)

FY 1998

Projects for the Subsurface Contaminants Focus Area
- Sonic Cone Penetrometer Technology Testing (Tech ID 1686)
- Site Characterization and Analysis Penetrometer System Sensor Evaluation (Tech ID 243)
- JCCEM Contaminant Transport Studies (Tech ID 775)
- Environmental Monitoring While Drilling Sensor Delivery System (Tech ID 8)
- Alternative Landfill Cover Demonstration (Tech ID 10)
- Environmental Remote Sensing for Monitoring Plant Health (Tech ID 1900)
- Barrier Monitor Using Electrical Resistance Tomography (Tech ID 2120)
- Characterization and Monitoring of Dense Non-Aqueous Phase Liquids (Tech ID 237)
- Integrated Geophysical and Hydrological Characterization of Contaminant Transport Through Fractured Rock (Tech ID 216)
- Analog Site for Characterization of Contaminant Transport Through Fractured Rock (Tech ID 216)
- *In Situ* Permeability Measurements with Direct Push Techniques (Tech ID 307)
- Subsurface Barrier Validation with the SEAtrace™ Monitoring System (Tech ID 308)
- Specialized Sampling and Separations Using 3M Membrane Technology (Tech ID 1514)

Projects for the Radioactive Tank Waste Remediation Focus Area

- SEAlevel™ System for Monitoring Waste Levels in Tanks (Tech ID 279)
- Integrated Raman pOH Sensor for In-Tank Corrosion Monitoring (Tech ID 2015)
- Comparative Testing of Pipeline Slurry Monitors (Tech ID 2935, 2936, 2970)
- *In Situ* Monitoring of Physical Properties of High-Level Waste Slurries (Tech ID 213, 214)
- Magnetic Resonance Monitor for Technetium-99 Column Breakthrough (Tech ID 1513)
- Process Monitors for Cesium-137 Column Breakthrough (Tech ID 1515)

Projects for the Mixed Waste Characterization, Treatment, and Disposal Focus Area

- Multi-Element Metal Continuous Emissions Monitor for Compliance Monitoring (Tech ID 1564)
- Metal Emissions Monitor for Mixed Waste Thermal Treatment (Tech ID 18)
- Performance Testing of Multi-Metal Continuous Emissions Monitors (Tech ID 1564)
- Laboratory/Industry Nondestructive Assay Performance Demonstration (Tech ID 1574)

Projects for the Deactivation and Decommissioning Focus Area

- Portable Uranium Survey Tool Using Laser-Induced Fluorescence (Tech ID 78, 1999)
- Portable X-Ray K-Edge Heavy Metal Detector (Tech ID 134)

Projects for the Plutonium Focus Area

- Real-Time Plutonium, Curium, and Americium Monitor (Tech ID 2004)

Environmental Studies

- Current Practice of Environmental Characterization and Monitoring Technologies (Tech ID 712)
- Privatization Pilot Project for Expedited Site Characterization (Tech ID 77)

FY 1999

Subsurface Contaminants Focus Area

- Sonic Penetration Enhancement for Cone Penetrometer (Tech ID 1686)
- Site Characterization and Analysis Penetrometer System Techniques (Tech ID 243)
- Large-Scale Radioactive Contaminant Transport Methodology Validation (Tech ID 775)
- Environmental Monitoring While Drilling Sensor Delivery System (Tech ID 8)
- Alternative Landfill Cover Demonstration (Tech ID 10)
- Environmental Remote Sensing for Monitoring Plant Health (Tech ID 1900)
- Characterization and Monitoring of Dense Non-Aqueous Phase Liquids (Tech ID 237)
- *In Situ* Permeability Measurements with Direct Push Techniques (Tech ID 307)
- Subsurface Barrier Verification with the SEAtrace™ Monitoring System (Tech ID 308)
- Specialized Sampling Using 3M Membrane Technology (Tech ID 1514)

Radioactive Tank Waste Remediation Focus Area

- Raman and Electrochemical Noise Sensors for In-Tank Corrosion Monitoring (Tech ID 2015)
- SEAlevel™ System for Monitoring Fluid Levels in Waste Tanks (Tech ID 279)
- Comparative Testing of Pipeline Slurry Monitors (Tech ID 1547)

Mixed Waste Characterization, Treatment, and Disposal Focus Area

- Multi-Element Metal Continuous Emissions Monitor for Compliance Monitoring (Tech ID 1564)
- Environmental Sample Chemical Analysis Automation Project (Tech ID 72)

Deactivation & Decommissioning Focus Area

- Portable Uranium Survey Tool Using Laser-Induced Fluorescence Imaging (Tech ID 1999)
- Portable X-Ray, K-Edge Heavy Metal Detector (Tech ID 134)

Nuclear Materials Focus Area

- Real-Time Plutonium, Americium, and Curium Monitor (Tech ID 2004)