DOE INTEGRATED PROGRAM FOR CHARACTERIZATION, MONITORING AND SENSOR TECHNOLOGY (CMST-IP)

C.W. Collier and D. Roelant
BDM International, Inc.
12850 Middlebrook Road
Germantown, Maryland 20874

S.M. Wolf and C. Purdy
Office of Technology Development
U.S. Department of Energy
12800 Middlebrook Road
Germantown, Maryland 20874

W.J. Haas and M.C. Edelson
Ames Laboratory
7 Spedding
Iowa State University
Ames, Iowa 50011

ABSTRACT

To ensure that new and effective characterization, monitoring and sensor technologies (CMST) are provided to the DOE remediation efforts, the DOE Environmental Management (EM), Office of Technology Development (OTD) has established a CMST Integrated Program (CMST-IP). This Integrated Program will focus in the short-term on matching and adapting available CMST technologies to DOE site and waste remediation. In the long-term it will aim to stimulate, coordinate and sponsor relevant research and development; and promote and publicize the development and/or adaptation of newly emerging technologies for remediation. Emphasis will be placed on field deployable instrumentation and noninvasive methods. This paper discusses the initial efforts of the CMST-IP. There are other complementary efforts in the Office of Technology Development.

INTRODUCTION

Early efforts and planned activities will be described in this paper for the Integrated Program on Characterization, Monitoring and Sensor Technology (CMST-IP), which was initiated in FY 1991. The program conceives, supports and manages research, development, demonstration, testing and evaluation (RDDT&E) to characterize waste and monitor its processing. This program is designed to increase the effectiveness of known remediation approaches, and the viability of new options now limited by unacceptable characterization. A strategy is being developed to evaluate and establish priorities for rapid development, demonstration and transfer of technologies, and to evaluate criticality of needs, cost savings, risk level, and regulatory concerns.

The focus of the program is to extend existing technologies, and develop emerging techniques, to provide field deployable instrumentation and noninvasive methods which address an identified need at a specific U.S. Department of Energy (DOE) site, and are transferable to other waste streams and sites in the DOE complex. Research and development emphasis has been placed on remote and minimally-intrusive characterization, in situ measurements, and field deployable instrumentation. The program also coordinates information and RDDT&E on characterization within OTD to facilitate the transfer of results to industry and to applications throughout the DOE complex.

Characterization is not only the key first step in any environmental remediation activity, it is at the heart of each step in the remediation process. Characterization and monitoring must be conducted in a timely and cost effective manner, to enable the DOE complex to meet its deadline for complete remediation by the year 2019.

Overcoming a Multitude of Barriers

Regulatory issues, costs and lack of available technologies all combine to form a formidable barrier to successful remediation in general, and characterization and monitoring in particular.

Most important is regulatory approval. Each site operates under multiple-agency guidelines - DOE, EPA, and state and local offices. EPA specifies approved analytical chemistry methods for waste characterization for most remediation steps. Many of these tests are costly and time-consuming, taking days to get results. A major goal of OTD is to develop approved field deployable methods with substantially lower ($<10\%$) cost and turnaround time compared to present methods. Regulatory barriers to effective characterization are found primarily in the areas of deciding what analytical methods and detection limits are required, and what percentages and numbers of samples must be run by these methods. Established methods usually require central lab analysis. Minimal precedent exists for rapid approval of modified analytical methodology. Approval cannot be obtained without substantial background information under a number of sampling/analysis conditions, requiring a patient, committed sponsor willing to work closely with EPA committees.

Economic barriers to characterization are especially apparent in the area of analytical costs. Laboratory analytical

costs, including associated sampling expenses, can consume 30% or more of a total cleanup budget. An important role of the CMST-IP will be to assist in developing instrumentation and associated data bases which in turn will assist in establishing an adaptive or iterative approach to characterization, in which previous results are employed to provide guidance for the next step. This is called observational characterization. Life-cycle costs must be considered, and this requires careful specification and integration of a range of test data.

The third issue is the availability of technology on a commercial basis. Accuracy, reliability, durability, reproducibility and sensitivity are all key concerns. Technical barriers are addressed in the following section. Major opportunities exist to overcome regulatory, economic and technical barriers.

Much of this paper addresses RDDT&E activities. It is important to mention the Laboratory Management Division in the OTD's Office of Program Support. This division supports two key functions of characterization: gaining regulatory approval of new methods; and fostering technology transfer of new methods by compilation, publication, dissemination, and maintenance of a "Methods Compendium." The Robotics Program and the CMST-IP both share a fundamental need for advanced sensors. For this reason the programs are collaborating in the areas of waste facility operations, buried waste remediation, decontamination and decommissioning, storage tank characterization and retrieval and contaminant analysis automation. Also, each Integrated Demonstration (ID) supports characterization activities specific to its needs.

Technical Barriers

Technical barriers to adequate characterization include the following:

- Drum Scanning
- Geophysical and Hydrological Problems
- Detection Limits for U and Pu in Surface Soils and Surface Water
- Resolution of Pit and Trench Boundaries and of Buried Objects
- Detection and Monitoring of Groundwater Plume Movement
- Real-time Monitoring of Process Effluent Streams
- Longevity and Reversibility of Embedded Monitoring Sensors
- Analytical Turnaround Time

Drum Scanning

Radioactive TRU and low level wastes are stored in 55-gallon drums at numerous DOE sites, including Idaho National Engineering Laboratory (INEL), Savannah River, Oak Ridge, Richland, and Rocky Flats. In all, there are over 400,000 drums suspected of containing TRU waste throughout the DOE complex. Some drums contain TRU waste, the remainder contain low level radioactive wastes. Many of the drums also contain hazardous organic wastes. Current regulatory procedures require that each drum be individually inspected for presence of TRU waste and hazardous waste. Current assay methods for distinguishing between TRU versus LLW are slow and expensive. Current procedures cannot detect solid organic waste and provide no information on the nature of liquid hazardous organics.

Hydrological Problems

The extent, nature and variation of fissures above and within aquifers subject to potential contaminant migration is extremely difficult to estimate with current techniques. In addition, new pathways for potential migration of contaminants are opened by the invasive drilling techniques which must be used.

Detection Limits for U and Pu in Surface Soils and Surface Water

Characterization of soils contaminated with U and Pu from weapons testing and from weapons production facilities is stymied for lack of a rapid and sensitive detection method. At Rocky Flats, a Colorado State Construction Advisory, aimed at worker protection, requires analysis of soil samples to a level of 0.9 pCi/gram. Laboratory analyses for such samples require counting times upwards of 24 hours. It is hoped that field deployable inductively coupled plasma-mass spectrometry (ICP-MS) instruments will help resolve this problem.

Resolution of Pit and Trench Boundaries and of Buried Objects

Methods to determine pit and trench boundaries using noninvasive techniques do not have adequate depth penetration or resolution capabilities. Preliminary flyovers at INEL using infrared imagery, airborne high resolution magnetic and helicopter electromagnetic geophysical surveys have generated promising images. However, a 3-D spatial positioning of buried objects and boundaries with the needed 1 - 3 foot resolution will require further research.

Detection and Monitoring of Ground Water Plume Movement

With the exception of volatile organic compound (VOC) sensors, which can be placed in wells surrounding sites of interest, sensors for heavy metals, radionuclides, and other organics are either too large or lack adequate reversibility or sufficient sensitivity to be useful. Currently no noninvasive methods exist for monitoring ground water plumes of any kind, especially the priority contaminants: tritium and VOCs.

Real-time Monitoring of Process Effluent Streams

Process effluent streams from all ongoing and future nuclear production operations will require real-time monitoring if current DOE goals of reducing hazardous waste to 80% of the current rate of production by the year 2000 are to be met. To accomplish this, real-time sensors must be employed and used in process feedback control loops. EPA requirements for RCRA wastes also specify monitoring for leakage of liquids from storage tanks prior to required treatment under current Land Disposal Restrictions (LDRs). Likewise, Clean Air Act regulations will require continuous off-gas monitoring of thermally-based treatment technologies, such as incineration.

TABLE I

Consolidated Listing of Priority DOE Site Characterization (excluding Decontamination and Decommissioning)

- Development of a uniform approach for data quality objectives
- Non-intrusive methods to determine boundaries of buried waste areas, waste forms, and utility conduits
- Better methods to characterize subsurface geology
- Methods for locating DNAPLs (dense non-aqueous phase liquids) and other contaminant plumes
- Improved drilling technologies
- Improved means of collecting deep groundwater samples for VOCs and other contaminants
- Improved remote sampling techniques (including robotics and probes) for tank sludges and other media that may contain high-level wastes
- Methods for sampling soil under/near structures, piping, and trees
- Continuous waste remediation treatment monitoring (total alpha, beta/gamma during treatment)
- Off-gas monitoring for organics and NOx
- Real-time field analysis equipment
- Road-transportable field screening analytical laboratory
- Fixed-base laboratories to provide faster turnaround time
- Remote systems for analyses in isolated or hazardous areas (chem sensors) (flow sensors)
- Improved methods to evaluate tank integrity and to identify leaks in tanks
- Equipment for in situ measurement of physical properties of tank waste
- Methods for locating perched groundwater and contaminant plumes
- Improved methods to measure hydrogeologic properties, including fracture flow and discrete groundwater flow
- Miscellaneous physical characterization methods
- Improved downhole geophysical techniques
- Improved modelling codes for groundwater contaminants and sediment

Longevity and Reversibility of Embedded Monitoring Sensors

Sensors placed in wells or buried in the vadose zone must have long lifetimes, require no maintenance, have minimal hysteresis effects, be immune to poisoning, and be fully reversible. Most currently available sensors lack one or more of these characteristics.

Underground Tank Waste

Under current practices the cost for obtaining and analyzing a core from high-level waste underground storage tanks are $400,000 - 1 million. Hanford has 149 single shell waste tanks and current consent agreements require analysis of 2 cores per tank by 1998. The contents of many of the tanks are very heterogeneous and consist of liquids, sludges and salt cakes. Noninvasive methods to characterize these wastes in various locations within the tank are needed. Also, in situ sensors, "hardened" to the effects of radiation and high temperatures, are needed to monitor for key chemical, radiological and physical properties. This includes sensors capable of real-time monitoring for explosive levels of off-gases.

Analytic Turnaround Time

Typical times between collection of a sample and reporting on the results of laboratory analysis range from a day to weeks. During active site cleanup operations, deployment of personnel and equipment is scheduled in minutes and hours. This disparity causes severe slowdowns in remediation times. For many sites, cost-effective cleanups will be impossible until rapid field-deployable analysis instrumentation becomes available.

ACCOMPLISHMENTS, CURRENT ACTIVITIES AND FUTURE PLANS

Two major efforts have been undertaken to develop the CMST program area. First has been the synthesis of a consolidated list of characterization needs throughout the DOE complex. This listing is based on a composite of two independent needs surveys, including information obtained by visits to all major DOE sites, and interaction with technical personnel associated with identifying characterization needs of mixed waste, buried waste and underground storage tank remediation programs. This extensive list of needs (see Table I.) is being validated by characterization specialists throughout the DOE complex and is the basis of priorities for the IP.

The second effort has been the development of the IP Program Strategy. The key strategic goal of the IP is to deliver, in a timely fashion, appropriate characterization, monitoring, and sensor technologies to DOE clients charged with environmental restoration and waste management. The R&D priorities are being established at this time. These include:

- Remote Sensing Systems Development and Application
- Noninvasive Geophysical Characterization Technology
- Field-Deployable Instrumentation for Organic and Radioactive Contaminants

- In-ground Chemical and Radiochemical Sensors for Monitoring of Organics, Transuranics, and RCRA Metals
- Real-time Analytical Techniques for Characterization of Storage Tank Waste Systems
- Continuous Air Monitor Improvement
- Data Fusion
- On-line Waste Processing Diagnostics and Controls

The CMST-IP also acts as an information resource throughout the Office of Technology Development. It has assisted the Integrated Demonstrations in initiating and conducting Characterization Technology Support Groups. The CMST-IP will concentrate on developing and promoting the development of emerging technologies and act as a referral service for information on existing and applicable technologies.

Major Technical Activities

To date, major technical activities have been conducted in the area of nonintrusive testing and evaluation. Jointly with Los Alamos National Laboratories and Ames Laboratory, the CMST-IP conducted a Workshop on Geophysics Nonintrusive Characterization Technology Development Planning. The high priority items from this workshop were data fusion and selected extension of some technologies such as seismic and ground-penetrating radar.

At INEL, the CMST-IP has assisted the Buried Waste Integrated Demonstration in planning for two helicopter flyovers equipped with remote sensing instrumentation. One of these involved infrared thermographic remote imaging, and the other used magnetic and electromagnetic sensing devices to locate and identify buried metal objects. A preliminary review of the data looks promising. A comprehensive review is underway.

Promising Technologies

CMST-IP personnel from the Ames Laboratory have recently completed an independent peer review and prioritization of five methods of nondestructive analysis (NDA) for drum scanning in the INEL Buried Waste Integrated Demonstration. From this review, two promising technologies were selected for future research funding to provide the capability of determining the radioactive components and levels present in contact-handled waste drums and in turn for categorizing the waste as TRU or LLW. The integrated system would also be capable of determining the amount of weapons grade Pu equivalents in a waste drum without prior source distribution information, and would be amenable to quality controls commensurate with the Waste Isolation Pilot Plant (WIPP). Both proposals would use multiple detectors to provide imaging, so that spatial information can be used to improve NDA accuracy. One of the proposed devices would require only 15 minutes to scan a single drum.

A related activity is the design and construction of a prototype scanner capable of scanning individual 55-gallon drums in a period of a few minutes. This activity is being conducted by EG&G, Santa Barbara, California. High energy neutrons will be used to penetrate the drums, exciting elements, which in turn decay and emit gamma rays with unique characteristic energies. If successful, this technique will allow for rapid three-dimensional scanning, yielding both spatial and elemental distribution information on drum contents. The scanner is expected to be sensitive to hydrogenous materials, thus identifying the presence or absence of liquid and solid organic compounds.

If only 1% of the steel waste drums are found to be free of organics, these drums can be qualified as LLW and not mixed waste. An overall disposal savings of $50-100M could be accomplished.

The CMST-IP, in collaboration with the EM Office of Waste Operations, is beginning to evaluate field deployable mass spectrometry instrumentation at Hanford's Underground Storage Tank site. Around one tank, organic vapors are being released which may affect work conditions in the area. The confidence in prior sampling and analysis techniques has been questioned.

SUMMARY

The CMST-IP is rapidly becoming a multifaceted program, serving a wide variety of DOE clients addressing diverse characterization, monitoring and sensor technology needs. The RDDT&E component has stressed noninvasive technologies such as ground-penetrating radar. The program also provides a mechanism to match existing DOE Office of Environmental Restoration and Waste Management (ERWM) needs with best available and emerging technologies. Finally, the CMST-IP provides information dissemination and technical transfer to those outside ERWM.