Technology solutions

for the near and long terms



U.S. Department of Energy
Office of Environmental Management

Contents

The DOE Office of Environmental Management (EM) leads an aggressive national program of applied research and development. Our focus is on providing the science and technology necessary to achieve EM's cleanup mission. Whether it is through basic research, advances in scientific knowledge, or specific technology solutions, we're finding better ways to clean up the legacy of environmental waste left after the Cold War era.

Technology solutions for the near and long terms

The DOE Office of Environmental Management's (EM) Science and Technology program is making great strides in providing technology solutions that are targeted toward the specific needs identified by DOE sites.

EM is working to complete cleanup at most of its sites by 2006. Some sites will be turned over to new landlords, and other sites will continue pursuing DOE missions. In either case, the Science and Technology program is concentrating on quickly bringing the specific solutions needed to achieve EM's near-term cleanup goals. More and more, support also includes putting knowledgeable engineers and scientists on the ground at closure sites. These experts consult with the problem holders, and together they identify technical solutions that will meet immediate needs.

This report shows how technology advances and technical assistance are helping sites realize their near-term closure goals…

- Like at the Nevada Test Site, where research on less expensive ways to cap hazardous waste landfills is proving that the most effective solutions are not always the most elaborate.
- And at the Oak Ridge Reservation, where technologies are helping to completely close out the underground storage tanks.

In particular, the EM Science and Technology program is committed to ensuring that technical challenges will not stand in the way of two sites achieving their goal to close in 2006…

- At the Fernald Environmental Management Project in Ohio, innovative technologies are cleaning up the groundwater and characterizing the soil with cost savings measured in millions.
- And at the Rocky Flats Environmental Technology Site in Colorado, the Science and Technology program is providing decontamination and decommissioning technologies that can more safely tear down buildings so the site can be turned over to a new owner.

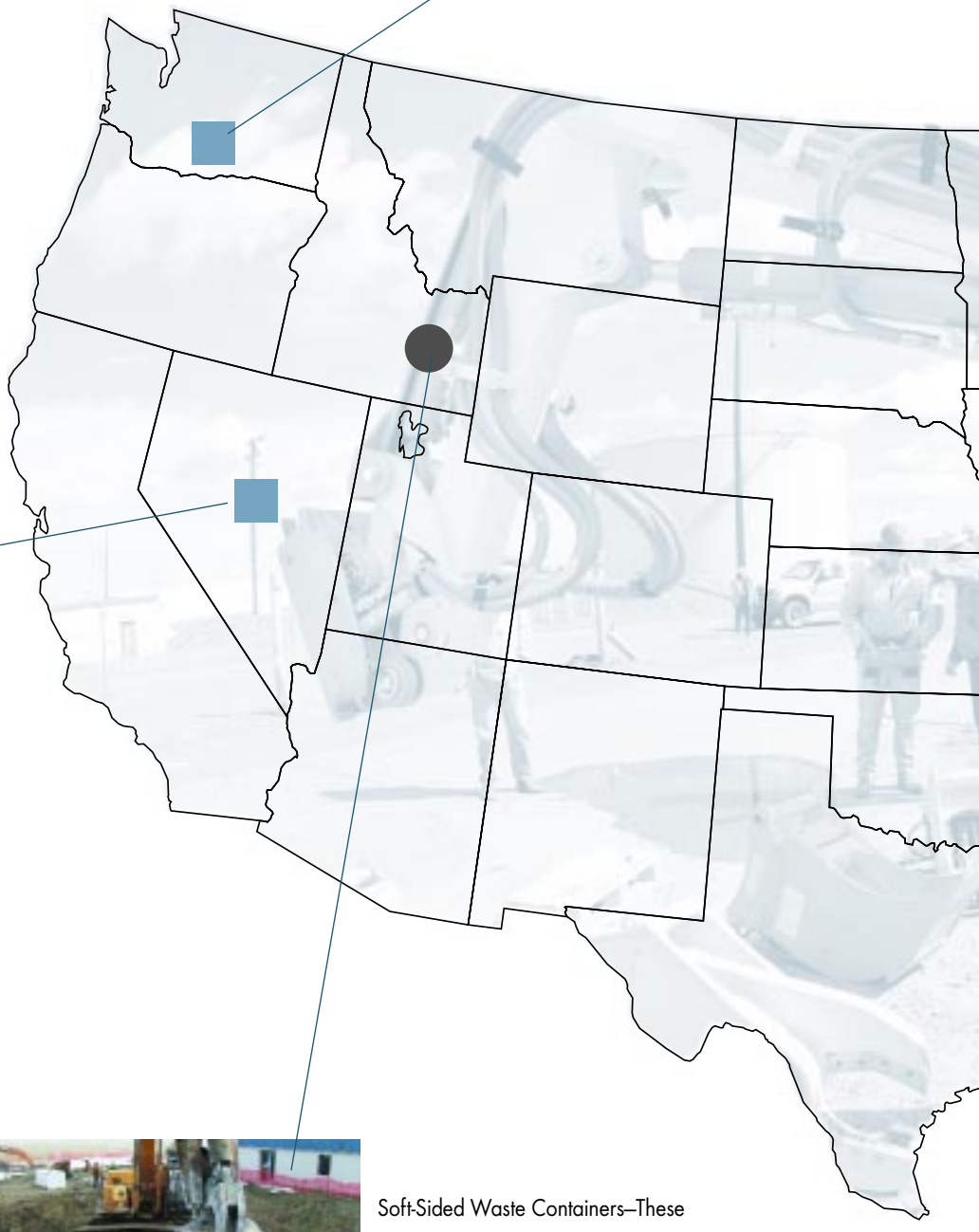
This report also highlights science and technology solutions with benefits for the four DOE offices where cleanup is projected to take several more decades: Idaho, Savannah River, Richland, and the Office of River Protection. Assistance at these sites covers a broad spectrum from deploying specific technologies that are already addressing tough environmental problems to conducting basic research that will one day result in huge advances in how cleanup is done…

- The Idaho National Engineering and Environmental Laboratory (INEEL) will benefit from what the Science and Technology program is learning about handling and evaluating the contents of transuranic waste drums bound for the Waste Isolation Pilot Plant (WIPP) in New Mexico.
- The Savannah River Site will benefit from an investigation into alternatives for removing cesium from salt waste, which will result in a less radioactive waste stream.

Selected accomplishments

The EM Science and Technology program continues to advance cleanup across the DOE complex through basic research, technology demonstrations, and technology deployments. Here are some examples.

Pit Viper–This system will reduce worker exposure, decrease decontamination costs, and enhance access for tank waste retrieval and transfer equipment.

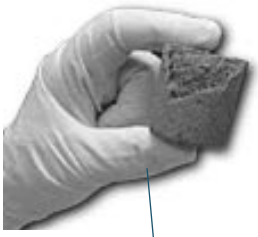


Alternative Landfill Covers–The EM Science and Technology program is continuing to evaluate data from a side-by-side comparison of caps for hazardous waste landfills.

Key

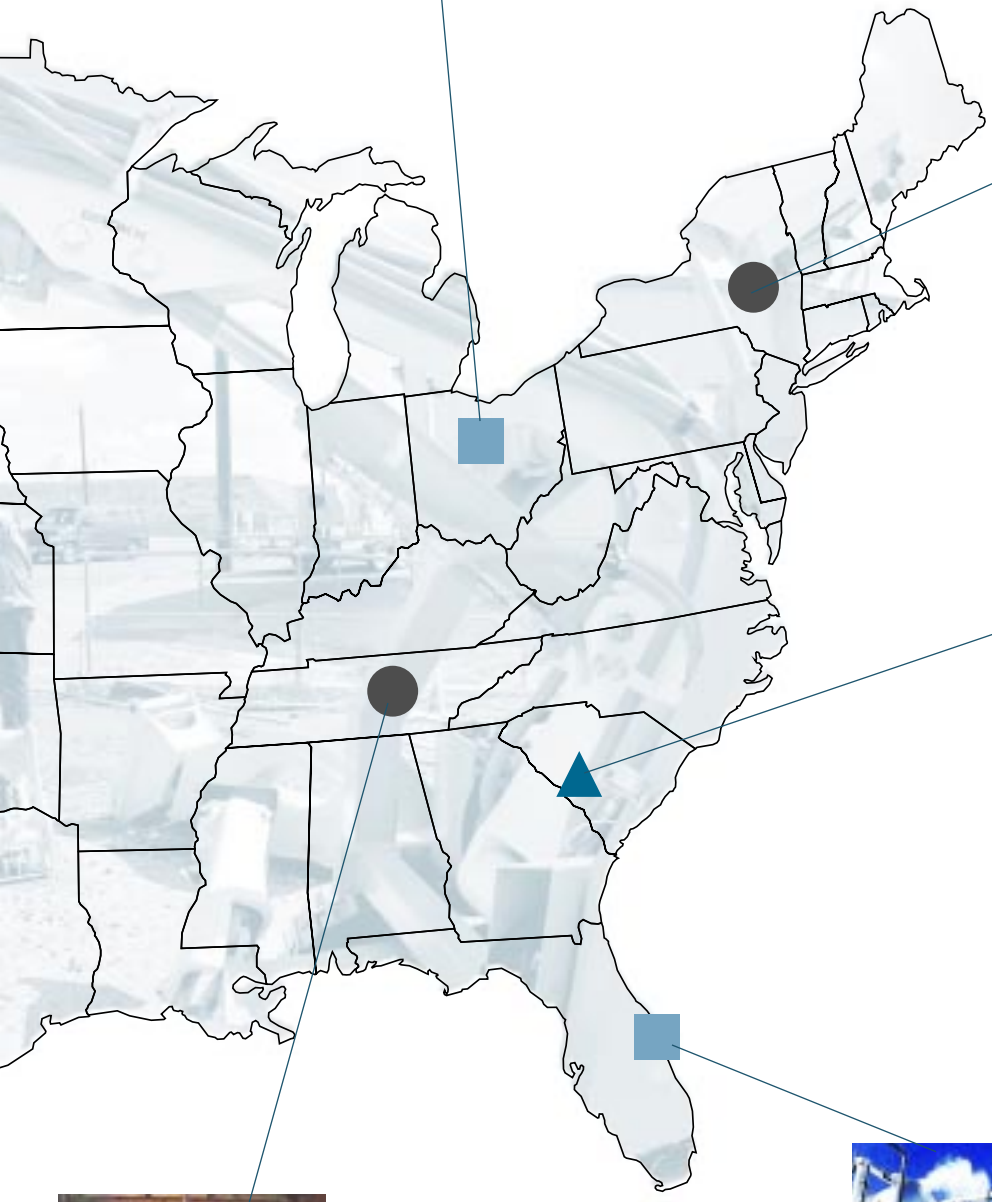
- Basic Science/Knowledge
- Demonstrations
- Deployments

Soft-Sided Waste Containers–These light and compact containers have become the waste container of choice for low-level waste at INEEL.



Gubka–Through an international partnership, the EM Science and Technology program brought a Russian technology to Fernald that can help stabilize waste for storage, shipping, and disposal.

Decontamination and decommissioning technologies–The EM Science and Technology program launched a large-scale demonstration and deployment project at West Valley. The project is focused on remote waste characterization, retrieval, processing, and packaging technologies.



Salt Processing Project–The EM Science and Technology program led the way in selecting a better way to separate cesium from salt waste. The recommended alternative will cut disposal costs.

Pulsating Mixer Pump–Through an international collaboration, DOE and Russian engineers have developed this high-capacity pump for mobilizing slurry within Oak Ridge tanks.

Dynamic Underground Stripping–EM has joined with other federal agencies to demonstrate a cleanup technology for a commonly shared and difficult environmental challenge.

An introduction to OST

Imagine fighting an illness without all the advancements in modern medicine–magnetic resonance imaging (MRI), laser instruments, and powerful drugs, for example. People want access to the best science and technology. DOE expects the same for its fight to restore and protect America's environmental health. DOE is responsible for the largest environmental management program in the world–cleaning up the legacy of 50 years of U.S. government nuclear operations and weapons production. Finding and creating the best environmental science and technology that will remove (or isolate) and dispose of these contaminants is an imposing challenge. That is the mission of the Office of Science and Technology.

Under DOE's Office of Environmental Management, the Office of Science and Technology (OST) is responsible for conducting basic and applied research and technology development, demonstration, and deployment assistance that is essential to complete timely and cost-effective cleanup and enable long-term stewardship of contaminated DOE sites. OST provides environmental research and cleanup technologies needed to achieve an end state for each site that returns as much land as possible to the public domain and unrestricted usage.

The contamination at many DOE sites is uniquely hazardous and chemically complex. Contaminants like spent nuclear fuel, liquid high-level radioactive waste, nuclear materials, and mixtures of hazardous and radioactive compounds are found in a wide range of contaminated media such as groundwater, soil, and nuclear production facilities. Much of the hazardous materials and contamination at DOE sites cannot be removed easily because many existing technologies are expensive and inefficient and may pose risks to human health or the environment. Moreover, due to the complex natural systems at DOE sites and the nature of pollutants there, contamination is frequently difficult to locate, characterize, and remediate.

Technology solutions deployed with OST's support are improving detection, characterization, and remediation of contamination; refining waste management; ensuring worker safety; minimizing risk, and significantly reducing cleanup schedules and expenses. OST also tackles complex technical issues for which there are only limited data and partial scientific understanding. This work is accomplished through support of peer-reviewed science and technology programs. Activities are performed through teams that address DOE's major environmental problem areas. Referred to as focus areas, these areas cover Deactivation and Decommissioning, Nuclear Materials, Subsurface Contaminants, Radioactive Tank Waste, and Transuranic and Mixed Waste.

The **Deactivation and Decommissioning Focus Area (DDFA)** is finding and creating technologies that will be used to deactivate more than 7,000 buildings contaminated with radiological/hazardous waste, and decommission more than 700 other surplus structures. These include reactor facilities, radionuclide separation facilities, and fuel and weapons component fabrication facilities. Over 600,000 tons of metal and 23 million cubic meters of concrete inside these buildings and 400,000 tons of metal currently in scrap piles must be disposed of or recycled. In addition to all of this D&D work, DDFA is currently emphasizing technologies to effectively support decontamination of surfaces and application of robotics and other remotely operated dismantlement systems.

The **Nuclear Materials Focus Area (NMFA)** supports the safe management and expeditious stabilization of nuclear materials and spent nuclear fuel stored in EM facilities or sites. Many of these materials and spent nuclear fuel are not considered waste. They are surplus assets that potentially could be recovered and reused. Some exotic isotopes, for example, can be used in nuclear medicine. Current NMFA activities include developing stabilization, packaging, transportation, and storage technologies.

The **Subsurface Contaminants Focus Area (SCFA)** is working on technological solutions for 5,700 known DOE groundwater plumes. Cleanup involves remediating 1.7 trillion gallons of contaminated groundwater, an amount equal to approximately four times the daily U.S. water consumption, and 40 million cubic meters of contaminated soil and debris, enough to fill approximately 17 sports stadiums. Three million cubic meters of leaching wastes buried in landfills, trenches, and spill areas continues to feed these plumes. Current activities are focused on dense, nonaqueous-phase liquids; source term containments and remediation; and metals and radionuclides in the vadose and saturated zones.

The **Tanks Focus Area (TFA)** is directed at removing and processing some 90 million gallons of high-level waste in the form of solid, sludge, liquid, and gas stored in 289 underground storage tanks across the DOE complex. Some of the waste has been stored for over 50

years in tanks that have exceeded their design lives. The challenge is to characterize and maintain these contents in a safe condition and continue to remediate and close each tank. Before closure, most of the radioactive waste must be retrieved. This task requires remotely controlled operations with tools able to enter underground tanks through small openings. TFA is currently developing technologies to improve waste retrieval and investing in tools to more effectively remove or pretreat problematic contaminants from tank contents.

The **Transuranic and Mixed Waste Focus Area (TMFA)** is concentrating on the treatment of 165,000 cubic meters of mixed and transuranic (TRU) waste at 36 sites. This waste is packaged in a variety of containers, ranging from 55-gallon drums to fairly large cargo containers. Significant amounts of additional TRU and mixed low-level waste will also be generated within the next 70 years, primarily from environmental restoration and D&D activities, as well as site operations. The focus area is currently working on problems related to material handling and characterization and nonthermal and thermal treatment, while addressing technical concerns related to emissions of mercury, dioxins, furans, and particulate matter.

The building blocks of tomorrow's technical solutions often begin with basic research done through OST's **Environmental Management Science Program.** EMSP conducts leading-edge scientific research to improve the scientific basis for environmental management decision making. The program's research is also a foundation for the development of new technologies. EMSP engages in basic and applied research projects that will result in transformational or breakthrough approaches for solving DOE's most intractable environmental problems.

There are many other OST programs that support overall research, development, and deployment activities. OST is partnering with industry, universities, national laboratories, other federal agencies, and international organizations. Many are addressing similar environmental problems. Such collaboration is important as many of the problems confronting DOE are long-term, both because they involve materials that remain hazardous, in some cases, for hundreds of thousands of and years and because they are so complex and unique that R&D may have to continue for decades to generate their solutions.

Cleaning up and closing EM sites is technologically complex, closely regulated, and unlike any other program in the world. OST is responding to hundreds of environmental problems identified by cleanup project managers at affected DOE sites and achieving cost-effective, safe cleanup through targeted investments in science and technology.

OST's focus areas combine forces to develop the technologies needed for clean up across DOE–such as technologies that cut costs for the disposal of plutonium-contaminated glove boxes.

On the fast track for closure

In collaboration with the Office of Site Closure, EM is focusing on the needs of sites with the nearest-term closure timelines. In particular, the Science and Technology program is committed to no delay due to technology issues in meeting the goal to close the Fernald Environmental Management Project and the Rocky Flats Environmental Technology Site. Furthermore, EM is addressing a range of problems facing other sites slated for closure in the near term from legacy waste storage, treatment, and disposal to managing nuclear materials processing facilities; from the shutdown of nuclear reactors to remediating large tracts of land with soil or groundwater contamination.

Closing Fernald by 2006

DOE is pushing for a 2006 closing for the Fernald Environmental Management Project, located 18 miles northwest of Cincinnati, Ohio. Fluor Fernald, the management and integration contractor for the site, signed a contract that provides a target closure date of December 31, 2010 but will earn a maximum incentive fee for completing the site by December 31, 2006. Active community groups are also committed to the goal of an early closure for Fernald.

The EM Science and Technology program is providing technical solutions to help the site meet its 2006 closure goal. For example, Fernald's groundwater was contaminated with uranium as a result of the site's production of uranium metal products between 1953 and 1989 for the nation's defense programs. The baseline technology to address this contamination, pump and treat, was estimated to require 27 years and cost over $80 million. Groundwater reinjection through **Recirculating Wells** (Tech ID 65), a technology solution provided by the Subsurface Contaminants Focus Area, demonstrated that an optimized extraction strategy could reduce the treatment time to 10 years and reduce costs by more than $14 million. Groundwater reinjection is now fully deployed at Fernald.

An Accelerated Site Technology Deployment project has helped Fernald project managers accurately characterize the radiological constituents of soil, quickly identify areas needing remediation, and present the information so site contractors know where to excavate soil. The Integrated Technology Suite for Delineating Radioactive Contaminants in Soils project procured three pieces of real-time radiation equipment: the **Mobile Radiation Tracking System** (Tech ID 2361), the **Radiation Scanning System** (Tech ID 2362), and **High Purity Germanium Detectors** (Tech ID 2157). The equipment, combined with software for gathering, transmitting, and interpreting data, provides instantaneous data analysis, display, and mapping of the results, accelerating the excavation decision-making process and minimizing excavator down-time. As of July 2001, the suite has been used to characterize over 50% of Fernald's soil, generating cost savings in excess of $15 million.

The Nuclear Materials Focus Area is helping Fernald address its inventory of nuclear materials, including the nearly 200 metric tons of uranium compounds and more than 220 metric tons of enriched metallic uranium requiring inspection, sorting, size reduction, stabilization, and repackaging for shipment off site. The **Vacuum Transfer System** (Tech ID 3028), an automatic repackaging system that successfully started hot operations in June 2001, replaces Fernald's manual repackaging methods and will be used to repackage approximately

ASTD projects build a bridge to deployments

The Accelerated Site Technology Deployment (ASTD) initiative was begun in FY 1998 to bridge the gap between development and deployment of new technologies for environmental cleanup across the DOE weapons complex. One of the key features of the initiative is that, as part of the proposal process, sites or facilities must commit to using the proposed technology in an actual remediation project. Through this cooperation between problem holders and solution providers, ASTD has been eminently successful in encouraging sites to work together in effecting multiple deployments of successful technologies. An analysis of the ASTD initiative shows that 60 projects were initiated between FY 1998 and FY 2000 at 22 DOE sites, managed by 10 field offices. The average return on investment for the ASTD portfolio was estimated to be 16:1, with a total projected cost avoidance estimated to be more than $1 billion.

The Vacuum Transfer System successfully started hot operations at Fernald in June 2001. The closed system protects workers from radiation exposure.

96 metric tons of uranium trioxide, two metric tons of uranium hexafluorate, and possibly 71 metric tons of uranium oxide, depending on disposition paths chosen. Site workers will be protected from radiation exposure because the vacuum transfer is performed within a closed system. Use of the Vacuum Transfer System is expected to speed up site closure by about 18 months.

NMFA is also supporting Fernald's use of a Russian-developed technology—**Gubka** (Porous Crystalline Matrix, Tech ID 2343), or "sponge" in Russian—for stabilizing aqueous radioactive solutions. Under the auspices of EM's International Program, Idaho National Engineering and Environmental Laboratory and Russian scientists have been investigating Gubka material, a type of fly ash formed into a block, for its capability to adsorb solutions of plutonium, americium, curium, and high-level wastes. The stabilized solid waste form is suitable for storage, shipping, and disposal. Stabilization with Gubka, which requires fewer workers and offers reduced radiation exposure, could be used to process and stabilize liquid nuclear materials at many other EM sites.

Gubka material can stabilize plutonium, americium, curium, and high-level wastes for storage, shipping, and disposal.

As Fernald accelerates toward closure, the Deactivation and Decommissioning Focus Area is providing its share of innovative solutions. One of these is the **Remote Prismless Total Survey Station** (RPTS, Tech ID 2983) for robotic land surveys to support engineering, construction, and environmental remediation activities. This sophisticated system is the latest advancement in "total station" technology. Prismless measurements allow a single instrument operator to make highly accurate survey measurements of remote, inaccessible, or hazardous locations. Robotic operation of RPTS automatically tracks the surveyor's position, reducing the survey crew size from three to one. Robotic operation also eliminates the need for personnel to enter potentially hazardous work areas. This technology, deployed in February 2001 as an ASTD project, is helping Fernald achieve safer work practices, reduce worker exposure to hazardous environments, and significantly reduce personnel costs.

A D&D technology that is helping Fernald demolish numerous steel tanks and an estimated 239,000 cubic yards of concrete slabs, foundations, footers, I-beams, and other structures is the **Universal Demolition Processor** (UDP, Tech ID 2981). The UDP is actually three technologies in one; its exchanging jaw sets enable it to be used as a concrete pulverizer, concrete cracker, or shear capable of cutting thick steel. The UDP's pulverizer attachment has enabled the site to convert several concrete pads into aggregate for reuse in temporary support roads around Fernald's On-Site Disposal Facility.

EM's Science and Technology program delivers more than innovative technologies; it also provides technical assistance to enable sites to tap into a wide network of DOE experts on a range of environmental issues. In

2001, a Deployment Assistance Team sent experts on tanks-related issues to Fernald to strategize with users on waste retrieval from Silos 1 and 2, which contain more than 240,000 cubic feet of low-level waste from the days when Fernald processed high-grade uranium ores. The Accelerated Waste Retrieval Project, which seeks to remove the waste from Silos 1 and 2 and place it in transfer tanks, is an interim step in the site's remediation of the two silos.

To ensure Fernald's seamless transition from environmental cleanup to long-term stewardship, the Subsurface Contaminants Focus Area is collaborating with Fernald project management and stakeholders in developing a comprehensive post-closure care, inspection, and monitoring plan. The **Fernald Post Closure Stewardship Technology Project** is currently identifying, demonstrating, and deploying technologies to ensure that the Fernald On-Site Disposal Facility (OSDF) is adequately maintained and monitored for perpetuity. During FY 2001, an independent, broad-based, and objective stewardship team identified several crucial needs related to monitoring the OSDF final cover and evaluated candidate monitoring technologies. The team will also investigate needs and technologies for collecting, monitoring, and passively treating leachates from the OSDF. Another focus will be to provide a repository for long-term retention and retrieval of data and images.

Rocky Flats is closing down

The only mission of the Rocky Flats Environmental Technology Site is to accomplish closure by the end of 2006. The motto adopted by the Rocky Flats Closure Project says it all—"Make it safe. Clean it up. Close it down." For this DOE site, located about 16 miles northwest of Denver, a safe cleanup and shutdown is now the galvanizing force after nearly 40 years of nuclear weapons production.

Innovative technology will help Rocky Flats "Make it safe. Clean it up. Close it down."

EM is playing an important role in the Rocky Flats venture by supplying innovative D&D technologies, many of them through the Accelerated Site Technology Deployment initiative. These innovative technologies are helping the site plan for and execute safer, more effective, and more efficient methods for size-reducing and decontaminating large equipment, characterizing equipment and facilities, certifying wastes and structures, and improving worker safety and efficiencies.

There will be no delay due to technology issues in meeting the goal to close the Fernald Environmental Management Project and the Rocky Flats Environmental Technology Site.

Five ASTD projects, initiated between FY 1998 and FY 2000, have introduced technologies to help Rocky Flats reduce cost and increase safety while performing D&D of large equipment and facilities:

- Rocky Flats has more than 900 plutonium-contaminated gloveboxes, which must be removed, size-reduced, and disposed of as radioactively contaminated waste. To protect workers from airborne radioactive contamination during size reduction, the Deactivation and Decommissioning Focus Area helped the site obtain **Inner Tent Chambers** (ITC, Tech ID 3058)—hard-walled containment structures that not only separate workers from direct contact with size reduction, but also support multiple cutting options. In September 1999, the first-generation ITC was installed in Building 771 for workers' protection during the manual size reduction of gloveboxes. The most recent design enables workers to use hydraulically and mechanically actuated robotic arms for plasma arc cutting and loading cut pieces into boxes.
- Rocky Flats' adoption of the standard waste box (SWB), instead of 55-gallon drums, as the primary waste container for packaging large pieces of equipment is lowering its D&D costs: less size reduction is needed, and fewer containers require certification. To certify its SWBs, Rocky Flats is using the **Standard Waste Box Counter** (Tech ID 2917), a mobile technology for quantifying the concentration of transuranic waste in the SWBs without the necessity of opening the containers.

Inner Tent Chambers separate workers from direct contact as they remove and size-reduce plutonium-contaminated gloveboxes at Rocky Flats.

- An alternative to size reduction is decontamination. Instead of reducing the size of all equipment contaminated with transuranics and shipping it to WIPP, this ASTD project (**Decontamination of Gloveboxes, Tanks, and Equipment for Shipment and Disposal without Size Reduction**, Tech ID 2986) will investigate how decontamination technologies can be used to lower the costs of disposal. To be feasible, decontamination will have to lower contamination levels enough to enable reclassification from transuranic to surface-contaminated objects, thereby permitting shipment to low-level disposal sites.

Closing landfills at the Nevada Test Site

The Nevada Test Site (NTS) has seen more than four decades of nuclear weapons testing. Between 1951 and 1992, DOE and its predecessor agencies conducted more than 900 nuclear tests/detonations on this remote 1,375-square-mile property in southern Nevada, 65 miles northwest of Las Vegas. Since 1992, when a moratorium was called on nuclear weapons testing, NTS has diversified into hazardous chemical spill testing, emergency response training, conventional weapons testing, and waste management and environmental technology studies. The Nevada Test Site's environmental management mission is scheduled for completion in 2014; however, NTS is scheduled to remain open to receive low-level waste from other sites until 2070.

Three sites at NTS are preparing for closure, including approximately 90 acres of Resource Conservation and Recovery Act and low-level waste landfills. Innovative technologies supplied by EM are helping the site find safer, more effective, and less expensive ways to accomplish this mission.

EM-sponsored research on **alternative landfill covers** is yielding valuable information on better, less expensive ways to cap hazardous waste landfills, particularly those in the arid western United States. The Subsurface Contaminants Focus Area is funding the Alternative Landfill Cover Demonstration (ALCD, Tech ID 10), which is in its fourth year of collecting data for evaluating the performances of variously constructed covers. This side-by-side comparative testing conducted by Sandia National Laboratories has shown the superiority of a simple cover composed of a thick layer of native soil planted with a variety of shallow-rooted grasses indigenous to the region. This single-layer design is an evapotranspiration cover, which captures the moisture from precipitation and, through the processes of evaporation and plant transpiration, sends the moisture back into the environment before it can travel down through the landfill. It's easier and less expensive to construct and performs more effectively than the multiple layers of the baseline RCRA cover, especially in arid regions.

The Alternative Landfill Cover Demonstration at the Nevada Test Site is evaluating options for capping hazardous waste landfills in arid environments.

The early success of the evapotranspiration cover at the ALCD led to NTS's investigating its use at a disposal unit at the Area 3 Radioactive Waste Management Site. This ASTD project (Tech ID 2924) was initially funded, under the auspices of SCFA, in FY 1999 to characterize waste stored in the disposal unit and the existing operational cover, design an evaportranspiration cover, and obtain Nevada regulatory approval. In FY 2001, the evapotranspiration cover was constructed, and a string of sensors was installed in the cover to measure the amount of water in the soil column at four locations. The project also includes the construction of a facility adjacent to the disposal unit for monitoring and evaluating the performance of a variety of single-layer covers—both bare soil and a mix of indigenous vegetative species.

The evapotranspiration cover installed on the 2-acre landfill in Area 3 was easy to construct and saved the site approximately $450,000. It is also expected to require little maintenance. In the event of landfill settling, the cover will be self-sealing; the only maintenance required will be adding more soil to direct rainfall off the cover. Even more benefits are expected to accrue as DOE continues to collect performance data for evaluating the long-term reliability of various landfill cover designs.

Wrapping up cleanup at Los Alamos

Los Alamos National Laboratory (LANL) has a research mission that will outlive its environmental remediation and waste management projects. Plans call for Los Alamos to complete its environmental restoration project by 2008 and to have decommissioned and decontaminated two on-site TRU reduction and repackaging facilities by FY 2017. The site will maintain most of its 43-square-mile property but is considering transfer of up to 7,000 acres to the county for industrial use. Land and facilities that DOE retains will be remediated to allow for industrial use; land that is released will be remediated to allow for unrestricted use.

In FY 2001, Los Alamos deployed several EM-funded technologies that contribute to the site's completing tasks critical to closure. To meet increasingly stringent shipping and disposal regulations, Los Alamos needed an improved method of ascertaining the transuranic and low-level waste concentrations of containers without having to open them. **Combined Thermal/ Epithermal Neutron Interrogation** (CTEN, Tech ID 1568) provides this capability and was designed, built, and tested through funding from the Transuranic and Mixed Waste Focus Area. CTEN interrogates the waste drum with both thermal and epithermal neutrons, yielding a more accurate measurement of transuranic waste than the baseline technology. Los Alamos' two deployments of the CTEN prototype—in 1999 and 2001—at the Radio Assay and Nondestructive Testing facility has saved the site $80,000.

An innovative approach to cleaning LANL's firing range sites was deployed at the E-F Firing Site, where DOE had previously disposed of uranium shells by exploding them with high explosives. **Heap Leaching of Uranium from Soils** (Tech ID 589) was deployed in May 2001 to reduce an estimated 25,000 cubic yards of contaminated soil and avoid the expense of excavating soil whose transuranic levels were greater than 100 nanocuries per gram. A sodium bicarbonate solution was used to leach the uranium from the soil, and then the uranium was recovered from the solution filters.

Passing the baton...from environmental cleanup to long-term stewardship

What happens when closure is complete–after DOE sites have been cleaned to levels agreed to by regulators and local communities? Some sites will be used to pursue other DOE missions. Ownership of other sites will be transferred to landlords outside DOE, such as communities and industries. But at some sites, residual hazards will remain, which necessitates the continued involvement of EM to ensure that controls are instituted to maintain public health and safety. This long-term stewardship responsibility encompasses the needs to monitor and maintain remediation systems and ensure their continued effectiveness, institute controls to limit public access, and retain data related to residual hazards. The EM Science and Technology program is currently working on providing sustainable technologies for monitoring remediation systems and disposal sites.

Large-scale demonstration and deployment projects accelerate the application of private-sector technologies in the DOE complex.

Through its large-scale demonstration and deployment projects (LSDDPs), the Decommissioning and Decontamination Focus Area is demonstrating to sites how certain private sector–developed technologies can be used to solve D&D problems. LANL has hosted two LSDDPs—one completed and another ongoing. The completed TRU Waste Characterization, Decontamination, and Disposition LSDDP at LANL brought the following successful technologies to the attention of the DOE complex:

- **AeroGo Air Lift Pallet System** (Tech ID 2396) floats loads on a virtually frictionless film of air.
- **Vehicle and Cargo Inspection System** (Tech ID 2912) is a highly penetrating gamma ray imaging system that noninvasively images crate contents.
- **Mobile Characterization System for Large Crates** (Tech ID 2959) is a mobile nondestructive examination system for large crates.
- **Mega-Tech Hydraulic Shear** (Tech ID 2953) demonstrated its superiority to the baseline technology during testing to compare cutting rates. The Mega-Tech Hydraulic Shear cut eight legs from plutonium gloveboxes in 15 minutes, while the reciprocating saw took 45–60 minutes to cut through eight legs, including a rest break to alleviate worker fatigue.

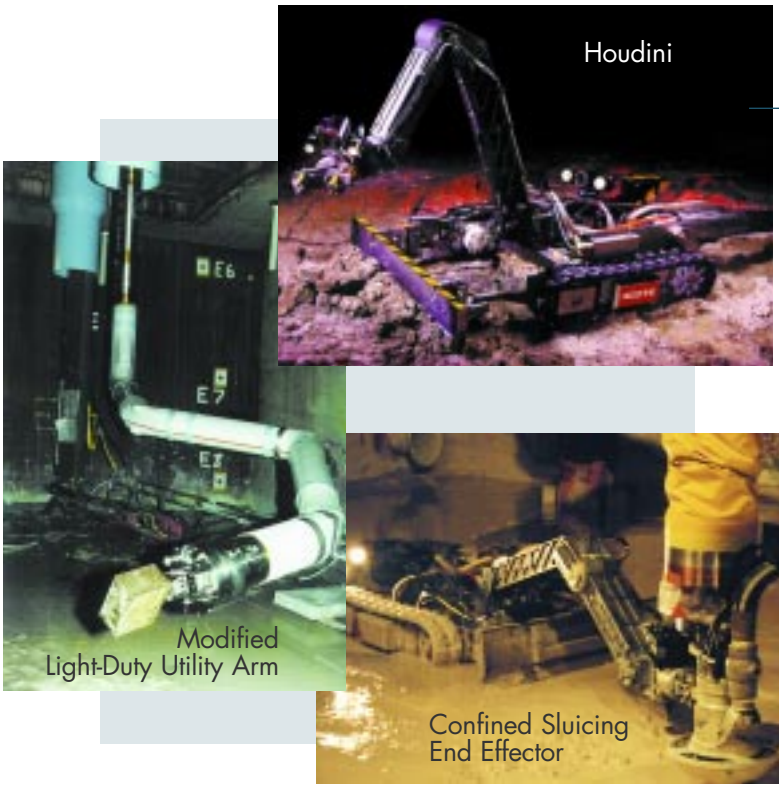
One of three new LSDDPs undertaken by DDFA is the Los Alamos Tritium Technology Deployment LSDDP, which will deploy proven, cost-effective innovative technologies for removing an estimated tritium inventory of 125–140 grams. The tritium must be removed before LANL's Tritium Systems Test Assembly facility can be transferred for D&D.

Oak Ridge Reservation uses robotics to close tanks

The Oak Ridge Reservation (ORR), consisting of Oak Ridge National Laboratory, the East Tennessee Technology Park, and the Y-12 Plant, has adopted an aggressive strategy for the accelerated completion of its EM mission by 2014. Remediation tasks run the gamut from D&D of facilities to soil and groundwater cleanup and treatment and disposal of wastes, including tank wastes.

A major accomplishment on the ORR closure timeline has been the completion of the Gunite and Associated Tanks (GAAT) Remediation Project. With key technology development provided by the Tanks Focus Area, ORR successfully concluded a three-year project that saw the retrieval and cleanup of eight underground gunite tanks, removing more than 423,000 gallons of

Robotic retrieval equipment reduced the baseline schedule for closing Oak Ridge tanks by 12 years, avoiding approximately $135 million in costs.



The Radioactive Tank Cleaning System applies an integrated suite of EM-developed technologies.

radioactive sludge and liquid containing approximately 88,000 curies of radiation. By using robotic retrieval equipment, ORR reduced the overall GAAT remediation baseline schedule by about 12 years and avoided approximately $135 million in costs. As part of an Accelerated Site Technology Deployment project, TFA delivered the Radioactive Tank Cleaning System, an integrated suite of technologies, combining both arm-based and vehicle-based retrieval approaches for mixing, mobilizing, retrieving, and transferring gunite tank waste. The system included the following technologies:

- **Modified Light-Duty Utility Arm** (Tech ID 40)—a mobile, multi-axis, robotic arm, equipped with a computer-based system, for controlling and monitoring in-tank activities and a gripper for holding tools.
- **Houdini** (Tech ID 98 and 2085)—a remotely operated vehicle that folds up for entry through tank risers and provides a working platform for manipulating tools and a plowblade for pushing dislodged materials to a jet pump.
- **Confined Sluicing End Effector** (Tech ID 812)—a tool employing rotating, high-pressure water jets for cutting apart and slurrying sludge waste.

To close out the last tank in the GAAT project, which is much smaller than the others and contains unique waste characteristics, TFA and ORR contracted with the Russian Integrated Mining Chemical Company to develop a pulsating mixer pump. After almost three years of collaboration, development, and testing, the **Russian Pulsating Mixer Pump** (Tech ID 2370) was deployed in Tank TH-4 in January 2001, where it successfully removed approximately 25,000 gallons of radioactive waste. On inspection, DOE and state regulators determined that sludge removal was sufficient to permit tank closure, thanks to this first successful deployment of a Russian retrieval technology in the U.S. radioactive tanks program.

As one of the first steps in closing out its Melton Valley Storage Tanks (MVSTs), EM has been working with ORR to develop a video inspection system capable of accessing and inspecting the interior of tanks and mapping the sludge. In April 2001, the development team demonstrated the **Remote Video Inspection and Mapping System** (Tech ID 2940), composed of three fiber optic light pipes for illumination and three remote cameras—all in a 2-inch-diameter cylindrical housing attached to a deployment arm. Deployed in July

The Russian Pulsating Mixer Pump was deployed at Oak Ridge in January 2001. It successfully removed 25,000 gallons of radioactive waste.

and August 2001, the video inspection system successfully captured video of the interior walls, other internal structures, and waste surface in all MVSTs, an excellent first step in delineating the scope of cleanup.

In other tanks-related research and development, TFA has been working with ORR problem holders to monitor corrosion processes and improve understanding of chemical processes for inhibiting corrosion in ORR's stainless steel Bethel Valley Evaporator Service Tanks. **Electrochemical Noise (EN) Corrosion Monitoring Probes** (Tech ID 3076) are being designed to measure corrosion rates and detect changes in waste chemistry that trigger the onset of pitting and cracking. These on-line probes will determine whether additional corrosion inhibitor is required and, if so, optimize the addition of chemicals. ORR will benefit from lessons learned while TFA also works with the Hanford Site to develop an **Electrochemical Noise Corrosion Monitor System** (Tech ID 1985) for its carbon-steel, double-shell tanks.

Sites with ongoing science and technology needs

The Office of Project Completion directs Environmental Management activities for the Office of River Protection and at the Hanford, Idaho, and Savannah River Sites. In addition to their sheer size, these sites have the longest timelines for closure for a variety of reasons: the length and variety of operations contributing to the nation's nuclear capacities and the volume and complexity of stored waste and residual contamination in soil and facilities. The office's mission encompasses reducing risk; safely managing hazardous and nuclear materials; protecting workers, the public, and the environment from radiological and nonradiological hazards; treating and disposing of wastes; deactivating and disposing of facilities; and remediating contaminated land.

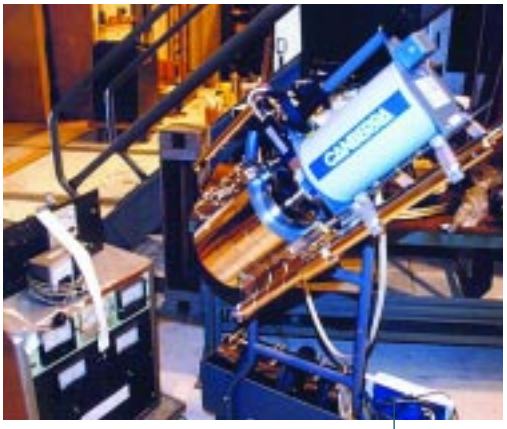
Making Richland D&D more safe and affordable

Eight production reactors were constructed along the Columbia River at the Hanford Site between 1942 and 1955 and closed down between 1964 and 1971. The Reactors Interim Safe Storage Project is decontaminating and decommissioning the reactor facilities and placing the reactor cores into interim safe storage. EM demonstrated nearly 20 innovative technologies in the cocooning of the first of these reactors, completed in 1998. A majority of these technologies were subsequently deployed and will contribute to the D&D of the next four reactors, now under way.

Many innovative technologies

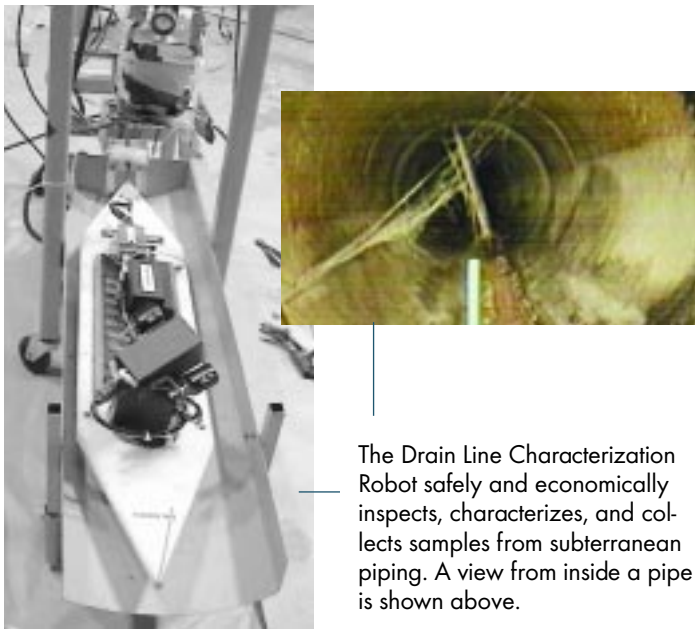
focus on making cleanup operations safer for workers.

New EM-sponsored technical solutions and systems continue to emerge to keep this immense undertaking safe and cost-effective. The **Nonintrusive Liquid Level Detection System** (Tech ID 2403) was deployed in FY 2001 to determine liquid levels inside pipes noninvasively. Eliminating the need to physically open and inspect these pipes cuts the risk of worker exposure to radioactive or contaminated contents. To determine where spent fuel fragments may be, the **Laser Assisted Ranging and Data System** (Tech ID 1946) was deployed to map the bottom of a reactor fuel storage basin. An advanced characterization system was also deployed there to keep risks as low as reasonably achievable. This system combines the **GammaCam™** (Tech ID 1840) to remotely locate buried gamma radiation sources with the **In Situ Object Counting System** (ISOCS™, Tech ID 2098) to identify irradiated fuel pieces prior to excavation and support planning for eventual packing, transporting, and processing.



ISOCS™, combined with a GammaCam™, identifies irradiation fuel pieces before excavation.

ISOCS was also deployed at the pilot facility for the Canyon Disposition Initiative. This collaborative project, which includes participation across EM programs, will establish an end state for the five Hanford processing canyons and potentially for similar facilities across the DOE complex. Using ISOCS for in situ analysis eliminates the need to collect samples of high-dose radioactive species and send them to a laboratory. EM also provided the **Drain Line Characterization Robot** (Tech ID 2328) to safely and economically inspect, characterize, and collect samples from subterranean piping in the facility. The unique remote capabilities of this technology greatly reduce radiological dose to operations personnel.



The Drain Line Characterization Robot safely and economically inspects, characterizes, and collects samples from subterranean piping. A view from inside a pipe is shown above.

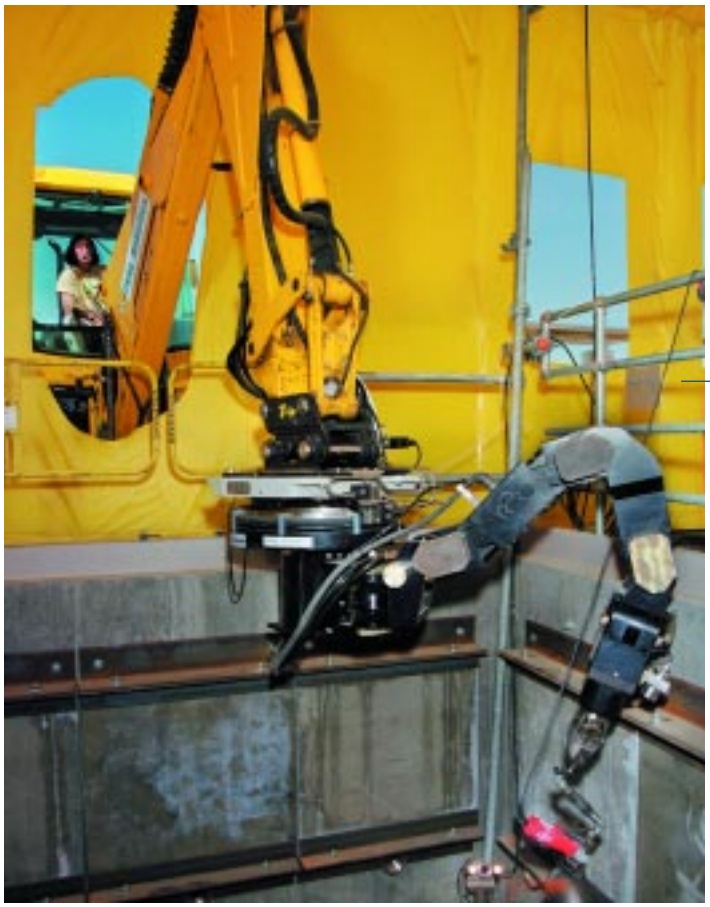
The Plutonium Finishing Plant, the final link in Hanford's historic plutonium production activities, is currently stabilizing legacy bulk plutonium-bearing materials. A new analytical technique using **Supercritical Fluid Extraction Moisture Measurement** (Tech ID 3002) was deployed this year to ensure the stability of impure plutonium compounds before placement in canisters for long-term storage. The method eliminates the need to transport samples to a laboratory and replaces a technique whose inaccuracy increased the unnecessary recycle of materials. The **Bagless Transfer System** (Tech ID 1932), recently deployed to remotely weld containers meeting specifications for long-term plutonium storage, is simpler and cheaper than the baseline system that was under development.

Taming the tanks for the Office of River Protection

About 60% of the liquid radioactive waste resulting from the nation's nuclear weapons development is stored in Hanford's 177 underground storage tanks. Congress established the Office of River Protection in 1998 to manage the site's tank waste remediation system, DOE's largest, most complex environmental cleanup problem. EM is sponsoring both basic and applied scientific research as well as innovative technology development to provide the knowledge and tools to make this daunting task possible, safe, and affordable. **Enhanced Sludge Washing** (Tech ID 233) is expected to reduce by 60% the volume of Hanford tank sludges requiring expensive treatment and off-site disposal. Its inclusion in the site baseline represents an estimated cost avoidance of almost $5 billion, far more than the cost of all EM Science and Technology program activities since its creation a dozen years ago.

EM continues to foster innovative technical solutions for treating these wastes and keeping them safely contained until they are treated. One challenge is the transfer of waste from aging single-shell tanks to safer double-shell tanks. **Temporary Transfer Lines** (Tech ID 3092) provide the required secondary containment for waste transfer with minimal risk of plugging and residual contamination. Because leak-prone permanent pipelines can be left undisturbed, these quickly deployable, temporary lines eliminate schedule delays and offer cost avoidance over the baseline estimated at $90 million.

Valves, pumps, and connections used to transfer waste from the single-shell tanks contain contaminated pipes and tools. Baseline procedures for valve pit operations are time-consuming, but radiation levels limit the time allowed for performing them. With funding from EM and the Office of River Protection, robotics experts at Pacific Northwest and Oak Ridge National Laboratories have developed the **Tank Riser Pit Decontamination System** ("Pit Viper," Tech ID 2195), incorporating a manipulator arm of French manufacture. Deployment in FY 2002 is expected to decrease decontamination costs and exposure risk and make riser pits more available for deployment of tank waste retrieval equipment.



"Pit Viper" is a promising robotic technology that is expected to facilitate access to tank waste.

None of Hanford's 28 double-shell tanks have leaked to the environment so far, but prudence requires continuous measurement of corrosion conditions that can lead to pits, cracks, or tank wall thinning. Traditional processes are expensive and don't detect localized corrosion or yield real-time data, but EM technologies and services are enabling tank integrity studies that reduce environmental risk. An **enhanced multifunction corrosion probe** incorporating the **Electrochemical Noise Corrosion Monitor System** (Tech ID 1985) detects localized corrosion and provides immediate information enabling operators to minimize the addition of corrosion inhibitor. The potential $110 million cost savings from this technology represent a 13-fold return on investment.

Tank waste behavior, the chemistry of potential treatment processes, and the viability of final waste forms present many still-unanswered questions, so EM sponsors and guides a broad range of basic research to build the knowledge we need to see DOE cleanup through to completion. For example, research at Pacific Northwest National Laboratory on the mechanics of bubbles in tank waste slurries and sludges aided understanding of hazardous gas retention, enabling more realistic safety and risk assessments, and Illinois Institute of Technology studies will help minimize foaming that complicates separation and treatment processes.

Remediating facilities, soils, and tanks in Idaho

Established in 1949 on an 890-square-mile reservation in the southeastern Idaho desert, INEEL contained for many years the world's largest concentration of nuclear reactors. The majority of the site's 52 reactors have been decommissioned and safely dismantled (only three remain in operation), and the laboratory's mission has broadened into such areas as biotechnology, energy and materials research, conservation, and renewable energy. But an environmental management program guided by a number of public agreements is treating, storing, and disposing of a variety of waste streams, cleaning up the environment, removing unneeded facilities, and preparing for the removal of DOE's inventory of spent nuclear fuel.

INEEL is the site of several ASTD projects and two LSDDPs, one completed this year and another just under way. One ASTD project alone deployed 15 technologies in actual D&D of 25 different facilities. Savings in the

Basic Research Focuses on the Most Challenging Problems

In its first decade, DOE's Office of Environmental Management wisely attacked "low-hanging fruit." In accord with the *Paths to Closure* plan, a large number of facilities and formerly contaminated areas will be removed or remediated in the not-too-distant future, but a smaller number of significant sites will still require decades of additional work and subsequent long-term stewardship, and not just because of the size of the job. We don't currently have ready solutions to some of the remaining problems because we don't have sufficient understanding of the contaminated media, the contaminants, or processes whereby they can be contained, cleaned, destroyed, or made safe for transportation and disposal. In large part, answering these questions will take too long and holds too little prospect for profit to attract the private sector. That's why, for the foreseeable future, EM will be funding, targeting, and managing basic scientific research in universities and the national laboratories, marshalling the country's best minds to deliver the knowledge needed to finish the job.

project approached $800,000, and additional deployments over the next 10 years are estimated in excess of $25 million. The first LSDDP demonstrated technologies for inspection, characterization, and dismantlement underwater and in confined spaces and for recycle of materials from D&D activities. INEEL's second LSDDP aims to significantly reduce overall life-cycle schedules and costs by deploying successfully demonstrated technologies at a wide range of facilities, including reactor fuel pool facilities and hot cell facilities in various stages of D&D at five sites in addition to INEEL.

EM technologies are also contributing to remediation of subsurface contamination at INEEL. A suite of six probes designed for insertion in the ground using the **ResonantSonic Drill Rig** (Tech ID 55) was developed to facilitate in situ analysis of wastes and environmental conditions in and around a transuranic waste disposal area. The **Advanced Tensiometer for Vadose Zone Monitoring** (Tech ID 2122), which measures how tightly soil holds water, enables collection of data required to calibrate subsurface contaminant migration models, demonstrates the effectiveness of landfill covers, and performs cost-effective long-term monitoring. EM-sponsored basic research at INEEL is building the knowledge needed to take fuller advantage of natural biological processes to remediate subsurface contamination in place. Researchers from INEEL and Lawrence Berkeley National Laboratory used multilevel sampling and seismic instruments at Test Area North to "map" underground geologic structures and study microbiological conditions in porous areas.

INEEL needs to measure the buildup of gases in contact-handled transuranic waste drums to increase the number qualifying for shipment to WIPP. By directly measuring gas generation rates and delivering analytical data in minutes rather than months, **Flammable Gas Headspace Measurement** (Tech ID 2026) accelerates schedule and enables compliance with enforceable milestones. EM is also providing **technical assistance** to INEEL in solving problems with liquids in containers of radioactive waste sludge and in selecting a treatment method for calcine waste, a highly radioactive mixture of dry solids stored in stainless steel bins at INEEL.

The spray ball washing system uses two rotating stainless steel nozzles to remove viscous waste from interior tank surfaces.

Approximately 1.4 million gallons of radioactive liquid waste is stored in 11 underground stainless steel tanks at INEEL. In three of these tanks, sampling activities have uncovered a viscous solids layer at the bottom and adhering to the walls. To help DOE meet terms of a closure agreement with the state of Idaho, EM and INEEL have been testing the **Tank Heel Retrieval System** (Tech ID 3138), a commercial technology combining a sluicing spray ball to stir up tanks contents and a pump to transfer the material. The remote control operation of this system

protects workers. EM is also assisting INEEL staff in developing a new technology to sample vault sumps to enable closure. Following successful demonstration of a full-scale prototype, deployment is expected in FY 2002.

Subsurface solutions are center stage at Savannah River

Situated on 310 square miles in South Carolina, the Savannah River Site (SRS) is home to five reactors; two chemical separations plants; a heavy water extraction plant; and facilities for tritium extraction, nuclear fuel and target fabrication, and waste management. The site continues to process and store nuclear materials in support of national defense and U.S. nuclear nonproliferation efforts and to treat nuclear and hazardous wastes left from the Cold War, and also develops and deploys technologies to improve the environment. EM helped SRS achieve the first closure of a radioactive waste storage tank in the DOE complex, and technologies demonstrated by the EM Science and Technology program were integrated into a fuel fabrication facility deactivation project to improve safety and cost-effectiveness and then added to the site's toolbox for application at other D&D projects.

The Ribbon NAPL Sampler is used in the field to screen for the presence of nonaqueous-phase liquids in the subsurface.

The greatest impact of the EM Science and Technology program on SRS to date has been with addressing subsurface contamination, with technologies fostered by multiple programs adopted as new baselines. The **Wireline Cone Penetrometer System for Multiple Tool Usage** (Tech ID 2222) enables rapid, safe, and cost-efficient characterization in soil, deploying tools like the **Ribbon NAPL Sampler** (Tech ID 2238) to delineate contamination by dense, nonaqueous-phase liquids, and **ResonantSonic Drilling** (Tech ID 55) accesses difficult soils such as cobbles and gravels to facilitate sampling and remediation. Other baselines are being outperformed by EM-developed technologies. **Dynamic Underground Stripping** (Tech ID 7), coupled with **Hydrous Pyrolysis/Oxidation** (Tech ID 1519), is withdrawing perchloroethylene from the soil at a solvent storage site five to ten times faster than the baseline and is economically monitored by **Electrical Resistance Tomography** (Tech ID 17).

With more than 2000 wells in its groundwater monitoring network and new restrictions on disposing of water purged from them prior to sampling, SRS is benefiting from the **Purge Water Management System** (Tech ID 2920), which reduces the amount of purge water generated and returns it to the originating aquifer, saving both the risks and costs of handling it as waste. Another innovative system requires no active sampling to perform post-closure monitoring—automatically and without supervision, the **Vadose Zone Monitoring System** (Tech ID 647) provides real-time information on the movement of contaminants through soil above the water table.

New passive treatment methods may hold the key to making treatment of subsurface contamination affordable. **Barometric Pumping** (Tech ID 56) takes advantage of natural fluctuations in barometric pressure to draw volatile organic compounds from the subsurface. A recently deployed enhancement, the **Baroball Flowmeter** (Tech ID 2331), acts as a valve to increase efficiency and provides data on contaminant removal. Paced by the Savannah River Technology Center (SRTC), EM-sponsored basic research is continuing to unlock the chemical and physical mysteries of subsurface contamination and transport.

SRTC is also teaming with experts from INEEL and Pacific Northwest National Laboratory, industry, and academia to develop the **Handling and Segregating System for 55-Gallon Drums** (HANDSS-55, Tech

ID 2336 and 2337), a remotely operated system to repackage 10,000 drums of transuranic and TRU mixed waste and prepare it for transport to WIPP. Safety is the greatest benefit of HANDSS-55, which is aimed toward deployment in FY 2003.

State and federal regulatory agreements require SRS's 49 underground waste storage tanks to be empty by 2028. Of the 34 million gallons of liquid high-level radioactive waste they contain, approximately 31 million gallons is salt waste. To make treatment of this vast volume manageable and affordable, cesium and other radioactive elements must first be removed. At DOE's request, the EM Science and Technology program managed the R&D efforts that supported the ultimate selection of a preferred **cesium removal process for the planned Salt Processing Plant**.

Natural fluctuations in barometric pressure can draw volatile organic compounds from the subsurface. The flow of a well can be examined with the help of a Baroball.

Laboratory management

The Assistant Secretary for Environmental Management is the Cognizant Secretarial Officer (CSO) for four DOE laboratories: Idaho National Engineering and Environmental Laboratory; Savannah River Technology Center; Environmental Measurements Laboratory; and the Radiological Environmental Sciences Laboratory. One CSO responsibility is to provide management oversight of these laboratories.

A Laboratory Management Team provides this oversight for EM and serves as landlord of the four laboratories by overseeing their long-term health through institutional planning and annual on-site laboratory reviews. In addition, team members provide management oversight of laboratory-directed research and development (LDRD), work for others (WFO), technology transfer, technical program reviews, contractor performance, and R&D laboratory facilities.

In FY 2001, the Laboratory Management Team accomplished the following:

- Provided programmatic leadership for laboratory management institutional programs and issues and served as an interface for studies by the General Accounting Office (GAO) on laboratory overhead structures and laboratory technology transfer activities.
- Held institutional planning on-site laboratory reviews at INEEL and SRTC, where EM headed the delegation of departmental research program offices.
- Provided comments on proposed environmental remediation research to the Offices of Science and Defense Programs on draft institutional plans for Oak Ridge, Pacific Northwest, Sandia, Los Alamos, and Lawrence Livermore National Laboratories.
- Developed and provided a report to Congress on how the EM program office does management oversight of its LDRD program at INEEL. Provided on-going management oversight of INEEL's LDRD program.
- Held a program review of the Environmental Measurements Laboratory with emphases on identifying opportunities for closer alignment with the needs of EM.
- Held an INEEL program review with emphases on LDRD program, validation and verification funding, subsurface science initiative, and long-term stewardship program.
- For technology partnerships, organized and chaired a panel of Program Secretarial Officers on "Mission-Focused Technology Partnerships" for the Department's 2001 Technology Partnerships Conference, June 2001.
- For WFO and technology transfer at INEEL, held a program review of program accomplishments and associated issues. Worked with GAO on its study of offset credits as part of INEEL WFO activities.
- Developed baseline information on intellectual property as a benchmark for environmental remediation research in the Departments of Defense and Energy, Environmental Protection Agency, and the National Institutes of Health.
- Developed and documented an assessment of environmental management industry trends with emphases on the environmental remediation sector.

Tackling the tough technical issues

EM provides technical solutions for difficult cleanup problems. Often the solutions are in the form of innovative technologies, but that's not always the case. The EM Science and Technology program is also working on finding answers to complex technical questions. By tackling these tough technical issues, EM is improving the ways it responds to cleanup needs.

Finding alternatives to incineration

Public concerns about off-gases and more stringent Environmental Protection Agency (EPA) requirements make it necessary for DOE to find alternatives to incineration, a waste treatment process that can involve high temperatures and open flames. For more than five years, EM has sponsored R&D projects to meet site needs for destruction of mixed waste containing transuranics, mercury, or explosives—classes of mixed waste that are not amenable to incineration. In particular, the Transuranic and Mixed Waste Focus Area is evaluating the promising technologies selected by the Secretary of Energy Advisory Board's Panel on Emerging Technological Alternatives to Incineration. The focus area sponsored the demonstration of several alternative technologies in FY 2001. The Blue Ribbon Panel also suggested increased opportunities for public involvement throughout technology-development process, so the **Alternative Technologies to Incineration Committee** was created as a citizens' working group to monitor progress and provide direct input into the DOE's technology-development efforts. Recognizing that public acceptance is an important aspect to finding alternatives to incineration, EM is actively participating in the committee.

Taking aim at unique wastes

A new, complex-wide **Waste Elimination Team** is taking aim at cleaning up "unique" low-level and mixed low-level wastes. Unique wastes represent only about 10 percent of DOE's mixed waste inventory, but they generally require highly specialized treatment solutions that are not affordable or, often, simply unavailable. Led by the Transuranic and Mixed Waste Focus Area, the team is finding affordable solutions for these wastes through an array of approaches including site-specific deployments, multiple site collaborations, and national initiatives.

One of the Waste Elimination Team's complex-wide treatment campaigns currently in progress is eliminating elemental mercury waste inventories. For many years, mercury was used at DOE sites as shielding for radioactive materials, in instrumentation, and in processes for concentrating certain isotopes in weapons production. Much of this mercury was lost to the environment or to process sludge and debris. Today, DOE is responsible for thousands of cubic meters of mercury waste that will require treatment to meet EPA regulations before it can be accepted into landfills. Mercury mixed waste cannot be commercially recycled and current treatment and stabilization technologies cannot meet land disposal restrictions.

Melting high-level waste

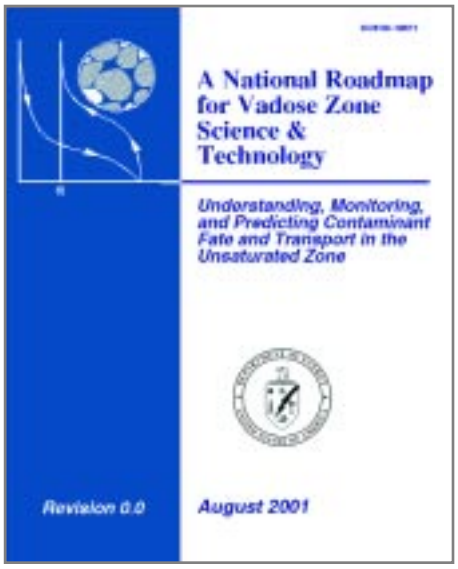
Sites must immobilize their high-level waste (HLW), such as tank sludge, into solid and stable forms that prevent releasing radioactivity or hazardous chemicals to the environment. The typical treatment solution is to melt the highly radioactive waste into a durable, vitrified (glasslike) form, which is stable, non-leaching and suitable for long-term storage. In FY 2001, the Tanks Focus Area evaluated HLW melter technologies. While vitrification is expensive and complicated, the High-Level Waste Melter Study determined that no waste forms are better than the current borosilicate glass form, and no melters are better than the current Joule-heated ceramic technology. Although the review findings reinforced the baseline HLW treatment path, they also included recommendations for improvements in vitrification operations and melter technology. TFA is funding several technology development projects in these areas.

Exploring the vadose zone

The vadose zone is the region between the land surface and underlying groundwater. Until recently, it was believed that contaminants released at or near the surface were relatively immobile. Hazardous chemicals and other pollutants are unexpectedly migrating through the vadose zone and towards groundwater at several DOE sites, so scientists now are changing their view of the vadose

zone and improve DOE's management of contaminated sites, EM, through the Subsurface Contaminants Focus Area, has funded the National Vadose Zone Program. EM assembled a team of scientists from a spectrum of federal agencies, national laboratories, universities and the private sector. In FY 2001 the team identified key areas of research necessary to improve the ability to predict and monitor flow and transport through the vadose zone.

The National Roadmap for Vadose Zone Science and Technology, published August 2001, represents another step toward the development and coordination of long-term interdisciplinary research into vadose zone fluid flow and contaminant transport. It identifies the research and development needed over the next quarter century to adequately assess and predict the fate and transport of contaminants in the vadose zone. Decades of critical vadose zone research are outlined in the roadmap, that, when successfully implemented, will advance state-of-the-art science and technology across the nation.



Separating salt waste

Treating the wide spectrum of radioactive and hazardous wastes at EM sites can be simplified and more cost-effective with separation methods. Separations technologies purify waste streams by removing and concentrating the contaminants they contain. After separating the most harmful components from a waste stream for isolated treatment, the rest may be released to the environment or downgraded to form that is less difficult or less expensive to dispose of.

Caustic-Side Solvent Extraction was selected as the preferred technology for safely removing cesium from liquid salt waste stored at the Savannah River Site.

The Tanks Focus Area supported the **Salt Processing Project**, which recently culminated in the selection of Caustic-Side Solvent Extraction (CSSX) as the preferred technology for safely removing cesium and trace amounts of other radionuclides from liquid salt waste stored in Savannah River Site's underground storage tanks. In separating these elements from the salt solution, SRS will be creating an almost nonradioactive salt—a waste stream that is amenable to grouting, a far less expensive treatment than vitrification. In CSSX tests, all but one part cesium in 100,000 was extracted from the solution.

Characterization shifts to long-term monitoring

Characterization is a critical prerequisite to remediation and, once cleanup activities have been completed, to site closure and long-term stewardship. Over the years, the EM Science and Technology program has developed numerous technologies and processes to reduce characterization costs, accelerate schedules, improve modeling and prediction accuracy and reliability, and reduce personnel exposure risk. Many of these technologies have become or are on their way to becoming commercial successes.

Now the Subsurface Contaminants Focus Area is turning to the development of innovative sensors and measurement systems for long-term monitoring. Such systems should eventually supplant conventional analyses, primarily of groundwater, involving periodic collection of samples that are shipped to off-site laboratories for analysis. The new systems will ideally rely on in-ground sensors that report remotely, perform their own maintenance and testing, and are long-lived with minimal power requirements. Field testing of prototype systems has begun, and workshops are being conducted to

foster communication among the DOE, research, and regulatory communities.

Making waste safe for transport and storage

Moisture trapped with mixed waste in sealed containers can generate hydrogen gas, which increases the internal pressure and the risk of releasing radioactive contamination. Because of such hydrogen gas generation, severe transportation limitations have been applied to several DOE mixed transuranic wastes with high organic content. Transporting temporarily stored mixed waste to long-term holding facilities is an urgent need for DOE. The Nuclear Materials Focus Area is improving scientific understanding of moisture generation and developing technologies to ensure the stability of impure plutonium compounds before being transported and placed in long-term storage.

NMFA is funding, for example, research at Los Alamos National Laboratory, where scientists are gathering experimental data and developing computer models to reliably predict hydrogen gas generation concentrations and pressures in a variety of stored nuclear materials. The focus area also deployed the **Neutron Moderation Analysis System** (NMAS, Tech ID 3004, 3005, 3006) at the LANL Plutonium Facility. Traditionally, waste samples would need to be transported to a laboratory to analyze moisture content. NMAS samples the entire container without having to remove any contents.

Improving worker safety by using robots

Many old buildings across the DOE complex contain hot cells and gloveboxes that are contaminated with radioactivity, explosives, and toxic materials. Separating the workers from the hazards through remote robotic technologies is a desirable and, in some cases, a necessity. The Deactivation and Decommissioning Focus Area is finding and developing remote and/or robotic technologies for remote characterization, decontamination, and dismantlement of these surplus facilities and advancing current systems beyond the “joystick and tether ” technology into full automation. The future holds an increased emphasis on robotics research to lower worker risk and increase productivity in contaminated facilities and highly radioactive environments.

An example of an EM-sponsored success with robotics is the multiple deployments of the **GammaCam™ Radiation Imaging System** (Tech ID 1840), a two-dimensional gamma imaging system. It has been used at the Chicago Pile 5 Research Reactor, Wolf Creek Nuclear Operating Corporation, Hanford’s B Plant, Peach Bottom Atomic Power Station, Limerick Generating Station, and Arkansas Nuclear One Reactor. This technology provides high gamma-ray energy sensitivity and remote operation capabilities, which accurately map gamma radiation sources and help eliminate worker exposure risks.

The GammaCam™ enables workers to measure and map radiation fields from a safe distance.

Organizational partners help accomplish mission the science and technology

Searching for the best available expertise, EM works with other DOE offices, national laboratories, private industry, academia, other federal agencies, international agencies and organizations, and other sectors of the science and technology community. This extensive network of partners enables EM to leverage resources, mobilize participation, and minimize duplication of effort. The result is accelerated use of technically defensible solutions for cleanup and environmental stewardship.

Joining with federal agencies to tackle common problems

Although some environmental problems are unique to DOE, others are faced by multiple federal agencies. By tackling the common problems together, R&D dollars can be stretched to have the maximum impact.

An interagency consortium focuses on DNAPLs

A prime example of multiagency cooperation is the Interagency DNAPL Consortium (IDC), comprising representatives from EPA, NASA, DOD, and DOE. The agencies agree that dealing with DNAPLs—dense, nonaqueous phase-liquids—is one of the most difficult environmental challenges they face. DNAPLs typically include industrial chlorinated solvents—trichloroethylene, perchloroethylene, and carbon tetrachloride. DNAPLs are toxic, only marginally soluble in water, denser than water, and subject to becoming trapped in pore spaces between soil particles.

The Subsurface Contaminants Focus Area coordinates DOE's involvement in the consortium. IDC is cooperatively testing and documenting the cost and performance of three innovative technologies for treating DNAPLs—compounds that have traditionally proven difficult to characterize and remediate. Side-by-side technology demonstrations are being conducted at Launch Complex 34 at the Cape Canaveral Air Station in Florida. Comparative cost and performance data collected under the same field conditions expedites regulatory acceptance and the use of these remedial technologies. The third and final demonstration, Dynamic Underground Stripping (Tech ID 7), began in July 2001.

Leveraging funding with the EPA SITE program

SCFA also collaborates with EPA's Superfund Innovative Technology Evaluation (SITE) program. Joint technology development activities have focused on phytoremediation, bioremediation, DNAPL source removal, alternative landfill covers, and monitoring techniques. Collaboration with EPA not only results in greater research funding targeted toward common problems but also expedites the development process and facilitates the transfer of research results to the EPA regions. Through joint conferences and workshops, EM and the SITE program are providing a vehicle for the research community to discuss the results of the projects being funded as well as a forum to discuss other projects to avoid costly overlap.

DOE and the U.S. Geological Survey enter into an MOU

EM and the U.S. Geological Survey (USGS) have signed a memorandum of understanding (MOU) agreeing to work together on areas of research specific to DOE site needs. In particular, USGS is conducting research related to organic and inorganic contamination that is beneficial to DOE. For example, the USGS has been developing vadose zone monitoring technology that can be applied at the Idaho National Engineering and Environmental Laboratory. USGS is also conducting research on DNAPL monitoring that can be included in the work of the Interagency DNAPL Consortium.

Cooperation with EPA on mixed waste challenges

In February 2000, EM and EPA's Office of Solid Waste signed a memorandum of understanding to improve cooperation in the research and development of technical solutions for mixed waste treatment. Mercury waste treatment and disposal is one area where dramatic changes are under consideration. EPA is evaluating new technology options that may be used in developing new treatment standards for mercury, in conjunction with the Transuranic and Mixed Waste Focus Area's regulatory support group, which works to ensure that DOE's mixed waste R&D activities comply with current and future environmental regulations.

A number of EPA treatment standards are based upon the desire to recycle waste materials, but the radioactive nature of mixed waste sometimes prevents recycling, leaving DOE no legally acceptable way to treat and dispose of these wastes. Through the MOU, TMFA has been working with DOE sites and EPA to modify these regulations to allow safe and effective treatment of these wastes. For example, work is complete on lead acid batteries—and under way on nickel cadmium and mercury batteries—to enable these wastes to be macroencapsulated.

TMFA has also been multiplying the benefits of DOE's research on mixed waste treatment technologies by including EPA's Waste Treatment Branch in research planning. This coordination and collaboration benefit both organizations. DOE mixed waste research goals address regulatory concerns, and EPA influences research in groundbreaking areas of hazardous waste treatment. EPA better understands the special issues involved in mixed waste treatment, and DOE gains better understanding of and access to the regulatory development process.

TMFA provided two unique opportunities for DOE and its contractors in FY 2001. At a meeting of DOE program managers and the EPA's regulatory development staff, EPA representatives presented key EPA initiatives, and participants developed areas of potential implication to DOE treatment facilities. TMFA also participated in the development of a forum where new technologies were presented and both EPA and state regulators discussed the challenges of permitting these innovative treatment technologies.

Working toward regulatory acceptance

Realizing the importance of regulatory acceptance of innovative technologies, EM helps to fund the Interstate Technology and Regulatory Council (ITRC), a state-led, national coalition of environmental experts and stakeholders from both the public and private sectors working to break down regulatory barriers to the use of new technologies. Before ITRC existed, it was difficult to convince environmental contractors and regulators to use new remediation technologies. Through ITRC-developed guidance documents and training courses, however, regulators and environmental consultants have become more open to using innovative remediation technologies. Having an environmental community that is open to innovative technologies is essential for DOE to realize the benefits of OST's investments in finding improved solutions.

International collaborations

Through international partnerships, the EM Science and Technology program is spanning the globe in its search for environmental technologies to clean up DOE sites. EM works with world-class scientists, sharing experiences and jointly developing innovative technologies in areas of mutual interest. A recent project between EM and the Institute for Ecology of Industrial Areas in Katowice, Poland has resulted in a first-ever deployment the Radiological/Petroleum Contaminated Soils Bioreactor at the Savannah River Site. Developed and deployed in Poland, the bioreactor is a mobile, ex situ technology that can be used for on-site batch remediation of organically contaminated soil. The SRS deployment will be the first test of the bioreactor on small amounts of mixed low-level contaminated soil, currently in storage. Without such technology, disposal would be impossible, and the contaminated soils would have to be stored indefinitely.

Representatives from EM met with project investigators from Poland in FY 2001. The chlorinated solvents bioreactor is in the foreground. The petroleum-contaminated soils bioreactor is in the background.

Universities and industry partnerships

Some of the most innovative science and engineering work being done can be found within U.S. universities and businesses. EM is tapping into these reservoirs of knowledge and creativity through university and industry partnerships, drawing upon the best knowledge and experience throughout the country and providing complementary scientific and engineering skills directly to its focus areas. The benefits of these partnerships are mutual.

For example, a researcher at Illinois Institute of Technology leveraged funding from the Environmental Management Science Program to develop a new antifoaming agent that is deployed at the Defense Waste Processing Facility. This material is also expected to have broad application in waste tank remediation throughout the DOE complex. The basic research performed during this project was vital to understanding the complex interaction of the antifoaming agent.

Similarly, EM also assists private-sector companies, especially small businesses, in penetrating the DOE market with their technology solutions and services. EM support helps many companies conduct applied research, development, demonstration, testing, and evaluation, enabling them to achieve earlier market entry than would be possible under exclusively company-funded development. In turn, as these technologies become available, many are now being deployed at multiple DOE sites. To date, EM has supported the development of more than 250 technologies that are now commercialized.