

The DOE-FIU Cooperative Agreement – Addressing DOE-EM’s Technical Challenges - 14607

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ABSTRACT

Since 1995, the Applied Research Center (ARC) at Florida International University (FIU) has provided critical support to the U.S. Department of Energy (DOE) Office of Environmental Management (EM) in their mission of accelerated risk reduction and cleanup of the environmental legacy of the nation’s nuclear weapons program. The applied research, technology development, demonstration and testing, information technology, and workforce development covers four major areas of environmental cleanup operations at DOE facilities across the U.S. Applied research is currently being executed in the following technical areas: radioactive waste processing, facility deactivation and decommissioning (D&D), soil and groundwater remediation, and information technology (IT) applications for environmental management. In addition, support is being provided in the area of student workforce development and training. The overall objective of the Cooperative Agreement is to develop technical solutions for the environmental challenges faced across the DOE complex at sites such as Hanford, Oak Ridge, Savannah River, Idaho, and Moab. ARC staff, DOE Fellows, and students work closely with DOE headquarters, DOE sites, DOE contractors and technical support groups such as the Energy Facility Contractors Group (EFCOG).

INTRODUCTION

ARC’s applied research is performed under the DOE-FIU Cooperative Agreement (under Contract # DE-EM0000598) and provides technical support to DOE EM in the area of environmental remediation and student workforce development and training. The applied research, technology development, demonstration and testing, and STEM workforce development covers four major areas of environmental cleanup operations: radioactive waste processing, facility deactivation and decommissioning, soil & groundwater remediation, and information technology (IT) development for environmental management. More specifically, projects focus on the areas identified as highest priorities by DOE EM. All DOE EM research projects are coordinated by DOE site customers/stakeholders, DOE EM headquarters (HQ), and experts from the DOE national laboratories. All research tasks are organized into the major project areas. These projects develop technical solutions for the DOE sites at Hanford, Oak Ridge, Savannah River, Idaho, Moab and DOE-HQ.

FIU STEM (science, technology, engineering, and math) students are fully engaged during the development of the scope of work as part of the FIU-DOE Science & Technology Workforce Development Program. The students, given the title of DOE Fellows, are trained and mentored by ARC technical personnel in an effort to secure the next generation of scientists and engineers that will be responsible for solving the technical challenges of the DOE nuclear complex legacy due to seven decades of nuclear research & development and production of nuclear weapons in the U.S. Project fact sheets, quarterly reports, publications, and year end reports are sent to DOE-

HQ for review as well as posted on a dedicated website available at <http://doeresearch.fiu.edu>.

DESCRIPTION AND DISCUSSION OF APPLIED RESEARCH AREAS

High Level Waste

The high level waste project provides support to the DOE Office of Tank Waste Management (EM-21) in the areas of tank waste transport and characterization for DOE sites at Hanford, Savannah River, and Idaho. Several operational shortcomings in the current high-level waste processing strategy have been identified and research has been needed to develop promising alternative processes and technologies that can be applied to address the shortcomings. The implementation of advanced technologies to address challenges faced with baseline methods is of great interest to the DOE sites. Specifically, the use of field or *in situ* technologies, as well as advanced computational methods can improve several facets of the retrieval and transport processes of HLW. One primary task under this project focuses on developing novel pipeline unplugging tools within the constraints and limitations required by the sites. The objective is to develop cost effective tools that can be used by site engineers in the event that a plug forms in a waste line. Deployment of the new technologies will result in major cost savings and minimization of risk to scheduled milestones and the environment.

A number of commercially available pipeline unplugging technologies have been tested and evaluated. Based on the lessons learned from the evaluation of the technologies, two alternative approaches have been developed. These are an asynchronous pulsing system (APS) and a peristaltic crawler. The APS is non-invasive and utilizes pressure pulses on both sides of a plug to impose optimal unplugging forces. This technology is based on the principle of creating pressure waves in the pipeline filled with water from both ends of the blocked section in order to break the bonds of the blocking material with the pipe wall via forces created by the pressure waves. The waves are created asynchronously in order to shake the blockage as a result of the unsteady forces created by the waves.

In addition, a peristaltic crawler has been developed that can navigate through complex pipe geometry and utilize unplugging tools in close proximity to plugs (Figure 1). The peristaltic crawler is a pneumatically operated crawler that propels itself by a sequence of pressurization/depressurization of cavities (inner tubes). The changes in pressure result in the translation of the vessel by peristaltic movements.



Fig. 1. Peristaltic pipe crawler technology (top) and peristaltic crawler performing an unplugging operation (bottom).

A second task for high level waste focuses on providing the sites with mathematical modeling, validation, and testing of computer programs to support critical issues related to HLW retrieval and processing. A lattice Boltzmann model (LBM) for multiphase flow that utilizes a multi-relaxation-time approach has been developed that can be used to model air sparging and other multiphase mixing processes. The LBM will provide essential data and a computational tool for the engineering staff at the sites to use in order to predict various scenarios that can occur during operations at DOE sites that involve multiphase flows. Successful completion of the task will result in time and cost savings and risk minimization leading to increased environmental safety in the operations at the DOE sites. A 3D multi-relaxation time LBM code offers increased stability and accuracy when modeling multiphase flows.

A third high level waste task focuses on identifying possible technologies that could enhance current out-of-tank instrumentation through an in-situ, real-time monitoring of the mixing process. Additional objectives included the evaluation of possible candidate technologies through confirmatory testing and comparison of testing results to sampling and real-time monitoring collected by standardized techniques. This task evaluates technologies that will provide viable alternatives to costly sampling and laboratory analysis by allowing retrieval engineers to assess waste feed and adjust the mixing and preparation as necessary prior to transfer. An ultrasonic spectroscopy system manufactured by ITS has been evaluated and tested for its ability to measure bulk densities in slurries with various carrier fluids and containing particles with various sizes and densities. In addition, ultrasonic transducers have been evaluated

as a means to measure bulk densities of HLW slurries at Hanford. The transducers are intended to be used for the evaluation of the level of homogeneity in a slurry during mixing processes.

Soil and Groundwater Remediation

The soil and groundwater projects provide support to the Office of Soil and Groundwater Remediation (EM-12) and the DOE Hanford and Savannah River Sites in developing a strategy to improve the efficiency of uranium stabilization in the subsurface. Uranium is a key contaminant of concern at many the DOE sites due to its high persistence in the environment and toxicity to living organisms. In addition, uranium is an important risk-driving contaminant at the Hanford Site. Soil and groundwater also provides technical assistance to EM-12 in remediation and treatment technology development for the Oak Ridge and Moab sites, including modeling of soil and groundwater and simulation of fate and transport of contaminants and remedial activities. The modeling is being used by the sites to determine the impact of remediation alternatives on the complete hydrologic cycle, the transport overland and in surface water and rivers, sediment transport and reactions, and mercury exchange with sediments.

One of the major efforts under soil and groundwater is the investigation of uranium (U) contamination in the vadose zone of the 200 Area at Hanford that may affect potential discharges to the Columbia River via groundwater migration. Injection of reactive gases such as ammonia gas (NH_3) is an innovative remediation methodology that targets U contamination in the vadose zone to reduce the potential for radionuclides mobility in the subsurface. The resulting alkaline conditions can greatly enhance the solubility of most Al- and Si-containing minerals by many orders of magnitude. The following decrease in pH will cause uranium co-precipitation during the recrystallization of minerals. In addition, microbial activities in many environmental systems add layers of complexity that affect U(VI) mobility in the subsurface. The bacterial effect on U(VI) release from the autunite mineral is being investigated to provide a more comprehensive understanding of the important microbiological processes affecting autunite stability and uranium mobility within subsurface bicarbonate-bearing environments (Figure 2).



Fig 2. Soil and groundwater analytical laboratory at ARC and DOE Fellow research assistant.

Another major effort under soil and groundwater is the development of integrated flow and transport models of the East Fork Poplar Creek (EFPC) and White Oak Creek (WOC)

watersheds to analyze the mercury (Hg) transport patterns within the Oak Ridge Reservation (ORR) (Figure 3). The models have been applied to determine the effect of historical hydrological events on mercury transport within the relevant watersheds and to determine the efficiency of selected remedial alternatives.

The integrated surface/subsurface numerical model of EFPC includes sedimentation and reactive transport modules, and has been used to perform numerical simulations that are relevant for the National Pollutant Discharge Elimination System (NPDES) and total maximum daily load (TMDL) regulations. Laboratory experiments were also conducted to determine more information on significant parameters related to Hg transport, reaction, and speciation (e.g., methylation/demethylation kinetics) within the watershed. Critical mercury exchange parameters between pore water, colloidal and suspended particles, and streambed sediment, were then applied in the numerical model to study the effect of sediment transport on Hg mobilization. A geodatabase was developed as a strategy for centralization, management, processing, and analysis of spatial and temporal numerical modeling data. The hydrologic geodatabase model used possesses a structure that enables linkage with scalable hydrologic modeling tools and applications, and can be used to automate and simplify the process of calling stored GIS and timeseries data. This modeling work has created a better understanding of the flow and transport of Hg within the ORR watersheds on a regional scale and the risks associated with D&D operations and potential mobilization of mercury at ORR.

A groundwater numerical model has also been used to evaluate the tailings pore-water seepage in order to assist in effective dewatering of the tailings pile and to optimize the groundwater extraction well field as part of the DOE Uranium Mill Tailings Remedial Action (UMTRA) for the Moab site in Utah. This activity included the utilization of a density-dependent model of groundwater flow to assess the general effects of brine on subsurface water flow and transport of contaminants released from a legacy tailings pile at the Moab site. The overall goal is to accelerate the cleanup at Moab and reduce cleanup costs.

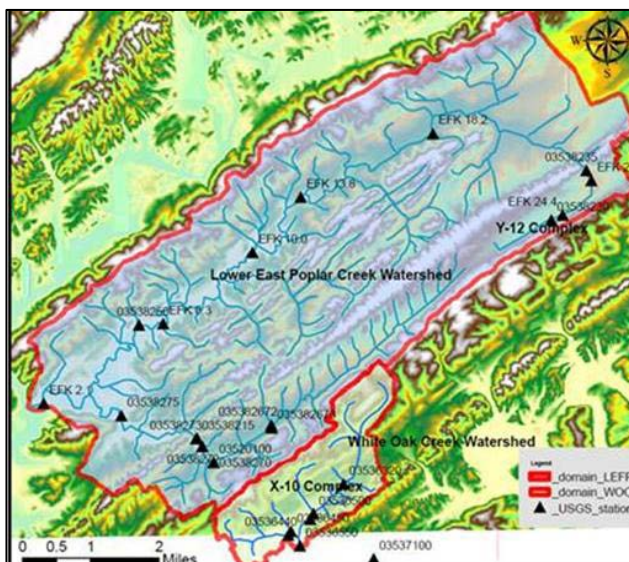


Fig 3. Oak Ridge Reservation watersheds.

Deactivation and Decommissioning

Deactivation and decommissioning (D&D) provides support to the DOE Office of D&D & Facility Engineering (EM-13) in the areas of D&D and nuclear waste management. This work is relevant to D&D activities being carried out at DOE sites such as Oak Ridge, Savannah River, Hanford, Idaho and Portsmouth or international efforts being conducted by EM-2.1 with the Nuclear Decommissioning Authority (NDA) in England and the International Atomic Energy Agency (IAEA). The D&D support focuses on meeting the D&D needs and technical challenges around the DOE complex. The objective is to identify and demonstrate new technologies & methodologies to support EM's collaborative domestic and international activities as well as support EFCOG in the development and dissemination of lessons learned and best practices. These activities reduce technical risks, improve safety, and limit uncertainty within D&D operations.

Areas of current and recent applied research in the area of D&D include:

- *In situ* decommissioning (ISD) research on cementitious materials.
- Structural health of nuclear facilities.
- Sensor network development and testing for *in situ* decommissioning.
- Development of remote stack characterization tool for nuclear stacks.
- Development and demonstration of a remote platform for application of fixatives and strippable coatings.
- Feasibility study of remote platform for removal of strippable coatings & decontamination gels.
- Design and installation of renewable energy system to support meso-scale test bed.

As a result of the evaluation of over 200 baseline and innovative technologies for D&D, directly comparable performance data related to operations and maintenance, primary and secondary waste generation, and health and safety have been compiled. The data from these assessments have assisted EM project managers in making decisions on the deployment of innovative technologies.

To expedite work at several DOE facilities, existing and new technologies have been integrated to accomplish such tasks as real-time characterization and decontamination of pipes, floor, and wall surfaces during facility decontamination, thus achieving time and cost savings during cleanup operations. Technology development projects include:

- Integrated spray applicator arm to a remote platform climber for remote application of fixatives, strippable coatings, and decontamination gels.
- Integrated vertical and overhead decontamination system.
- Mobile integrated decontamination and characterization system.
- *In situ* pipe decontamination system.
- Online integrated decontamination system.
- Alternative high-level waste canister decontamination methods.

- Remote operated wall shaver unit (ROWS) integration wheel operated electric lift and a Marcris diamond concrete shaver.
- Large-bore pipe decontamination and characterization system for characterizing and decontaminating large-bore (6-24") pipes.
- Remote stack characterization system developed in collaboration with the Robotics and Energetic Systems Group at the Oak Ridge National Laboratory.



Fig 4. Installation of remote sensors at the ISD test site (left) and remote platform technology applying decontamination gel to vertical surface (right).

Information Technology

Information technology (IT) provides support to the DOE Office of D&D & Facility Engineering (EM-13) in the area of information technology applications for environmental management. Two major IT applications developed for DOE EM include a Waste Information Management System (WIMS) and a Deactivation and Decommissioning Knowledge Management Information Tool (D&D KM-IT).

WIMS was developed to receive and organize the DOE waste forecast data from across the DOE complex and to automatically generate waste forecast data tables, disposition maps, GIS maps, transportation details, and other custom reports. The overall objective of WIMS is to provide DOE HQ and site waste managers with the tools necessary to easily visualize, understand, and manage the vast volumes, categories, and problems of forecasted waste streams. WIMS is fully developed and deployed at <http://www.emwims.org> with the latest set of DOE waste forecast data (Figure 5). WIMS is updated with new waste forecast data on an annual basis to ensure the long-term viability and value of the system.

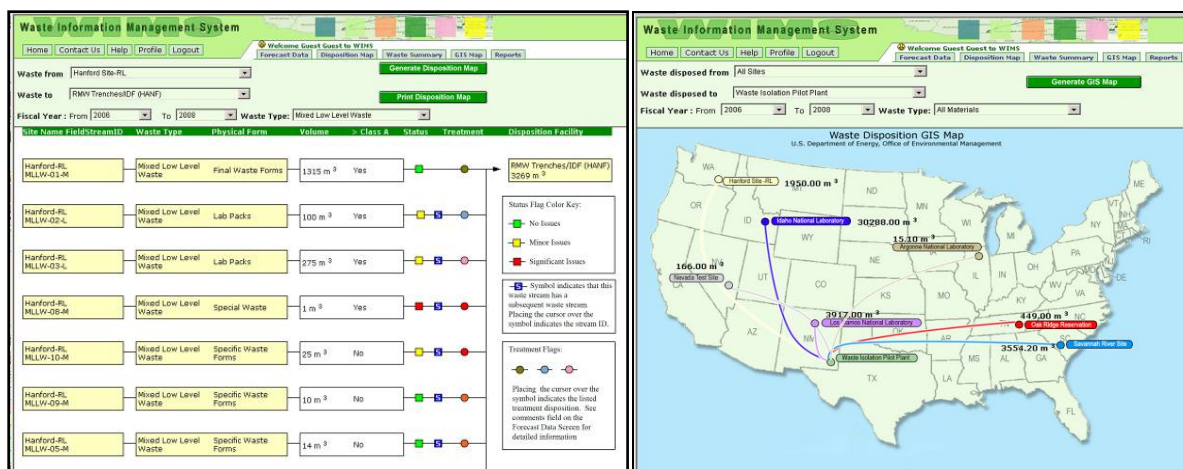


Fig 5. WIMS disposition map (left) and GIS map (right).

D&D work is a high priority across the DOE complex and subject matter specialists associated with the DOE sites and the D&D community have gained extensive knowledge and experience over the years. To prevent the D&D knowledge and expertise from being lost over time, an approach was needed to capture and maintain this valuable information in a universally available and easily usable system. DOE EM aims to gather, organize, and maintain D&D knowledge and experience from across the DOE complex with the development of a D&D Knowledge Management Information Tool. D&D KM-IT is a community-wide web-based system for capturing and sharing D&D knowledge in the U.S. and internationally. The D&D KM-IT main site can be accessed at <https://www.dndkm.org> and the mobile site at <http://m.dndkm.org/> (Figure 6).

The overall objectives of D&D KM-IT are to provide a focused web-based tool to assist the D&D community in identifying potential solutions to their problem areas by using the vast resources and knowledge-base tools available through the web; provide a mechanism to the global D&D community for searching relevant D&D information; collect information from subject matter specialists; build a knowledge repository for future reference; archive lessons learned, best practices, ALARA reports and other relevant documents; and provide a secured collaboration platform for the global D&D community to share knowledge.

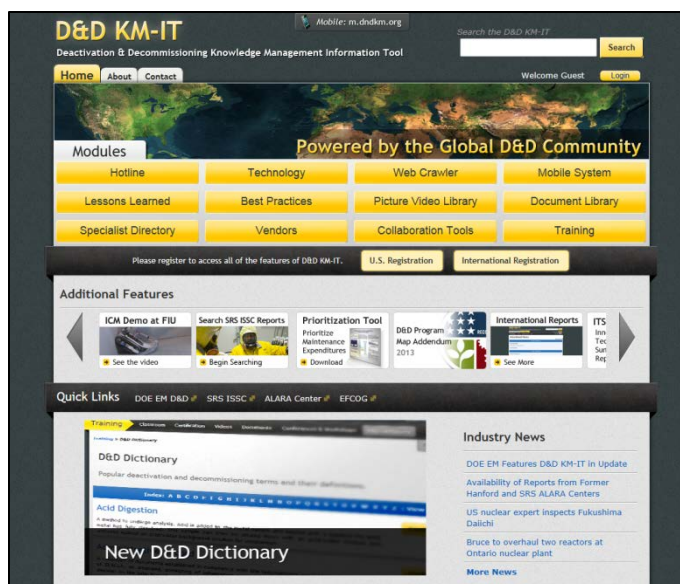


Fig 6. Screenshot of D&D KM-IT website.

Workforce Development

Workforce development engages DOE EM offices and DOE EM-Human Resources in the development of an innovative workforce development program designed to create a “pipeline” of minority FIU students in the areas of science and engineering specifically trained and mentored to enter the DOE workforce in technical areas of need. Current DOE-EM’s labor statistics show that 91% of EM employees are 40 years old or older and only 1% of its workforce is under 30 years old. In addition, it is estimated that within the next few years, DOE-EM will lose as much as 30-35% of its technical workforce due to retirement. The aging of the current workforce has the potential to significantly affect the environmental restoration program.

The DOE-FIU Science and Technology Workforce Development Program is designed to help address DOE’s future workforce needs by partnering with academic, government and DOE contractor organizations to mentor future minority scientists and engineers in the research, development, and deployment of new technologies addressing DOE’s environmental cleanup challenges. Students selected as DOE Fellows perform DOE-EM related “hands on” research by working alongside ARC’s scientists and engineers as well as with FIU faculty. The students also participate in summer internship assignments at DOE facilities such as national laboratories and DOE sites. Upon graduation and completion of this fellowship, the students are encouraged to submit an application to join Federal internship programs such as the Pathways Program or apply to DOE national laboratories and DOE contractors.

DOE Fellows who complete the workforce development program have the opportunity to seek employment with DOE, DOE national laboratories, and DOE contractors. A total of 7 DOE Fellows have been hired by DOE EM, DOE national laboratories and private contractors participating in the US DOE environmental restoration program, including 3 hired by DOE HQ, 1 hired by ORNL, and 3 hired by DOE contractors (AREVA, Waste Control Specialists, and Bechtel). Over 30 additional DOE Fellows have been hired by Boeing Company, Florida Department of Environmental Protection, NASA, General Electric, Bechtel Corporation, Florida

Power & Light, Mount Sinai Medical Center, Lockheed Martin, Motorola, Bouygues Civil Works Florida, Internal Revenue Service, U.S. Patent Office, Federal Department of Transportation, Florida Department of Environmental Protection, Crane Aerospace and Electronics, HP Foundation, and others.

DOE Fellows Induction Ceremony

Each year, FIU coordinates and conducts the DOE Fellows Induction Ceremony in November, during which the newly selected FIU minority students are inducted as DOE Fellows. A total of 93 FIU minority students in science, technology, engineering, and math (STEM) have been inducted as DOE Fellows since the program inception in 2007. DOE-HQ officials, DOE site mentors; FIU faculty and administrators, FIU-ARC scientists, and DOE Fellows are invited to participate in these events. DOE Induction Ceremonies have been attended by DOE EM officials including Mr. Mark Gilbertson (2007); former Assistant Secretary for Environmental Management, Mr. Jim Rispoli (2008); Ms. Yvette Collazo (2009); former Assistant Secretary for Environmental Management, Ms. Ines Triay (2010); Acting Principal Assistant Secretary for Environmental Management, Ms. Tracy Mustin (2011); Associate Principal Deputy Assistance Secretary for EM, Ms. Alice Williams (2012) and Senior Advisor to the U.S. Secretary of Energy for Environmental Management, Ms. Elizabeth “Betsy” Connell (2013).

Poster Exhibition

FIU also coordinates and hosts the DOE Fellows Poster Exhibition & Competition in October of each year. DOE Fellows prepare posters to be presented at this annual event to showcase their research accomplishments in the areas of high-level waste, soil and groundwater, deactivation & decommissioning (D&D), and information technology (IT) in support of the Department of Energy’s Office of Environmental Management. The winners of this competition are recognized at the DOE Fellows Induction Ceremony the following month.

Summer Internships

The program provides the students with opportunities to complete 10-week internships at DOE national laboratories such as Oak Ridge, Pacific Northwest, Lawrence Livermore, Savannah River, Los Alamos, and Idaho, as well as DOE-HQ, and DOE offices (Figure 7). Each summer, approximately 6 to 10 DOE Fellows are paired with scientists and engineers at DOE facilities and/or national laboratories and DOE contractors. During the ten weeks, the Fellows work on environmental research projects under the guidance of their site scientist mentors. At the end of the internship, each DOE Fellow prepares a technical report on the work they performed during their internship. As of the end of summer 2013, DOE Fellows have completed a total of 81 internships; the internship technical reports are available at <http://fellows.fiu.edu>.

Waste Management Conference

Attendance and participation by the DOE Fellows in national and international conferences such as the Waste Management Symposia, American Nuclear Society’s annual meetings and topical conferences is facilitated by this program. A total of 84 student posters and professional

presentations have been given at Waste Management Symposia (2008-2013). Recognition of the best student poster at this conference has been awarded to DOE Fellows in 2009, 2010, and 2011. In addition, the best overall professional poster recognition was awarded to a DOE Fellow in 2009.

Graduate Education

Student participation in this program provides opportunities for students to enhance their professional development and work experience by participating in hands on research working alongside ARC and FIU scientists. In addition, graduate students are encouraged to develop master theses and/or PhD dissertation topics with direct supervision of ARC scientists and FIU faculty based on their DOE EM research. To date, 31 master's theses and 3 PhD dissertations have been completed (or are being completed) by DOE Fellows at FIU as a result of DOE EM research. Others have continued their graduate education at Massachusetts Institute of Technology, Michigan, Purdue, Stanford, Virginia Tech, University of Tennessee, University of South Florida, and other institutions.

DOE Fellows Website and Facebook Page

The DOE Fellows program hosts its own website (<http://fellows.fiu.edu/>) and Facebook page (<http://www.facebook.com/pages/FIU-Science-and-Technology-Workforce-Development-Initiative/145462492139115>). The DOE Fellows webpage provides information on the various program components, biographies for each of the DOE Fellows, internship reports, and other program publications. The Facebook page provides information on all the most recent news and events related to the program and the DOE Fellows' activities.



Fig 7. DOE Fellows performing summer internships at DOE sites (top) and participating in the Waste Management Symposia (bottom).

CONCLUSION

The last 20 years has seen substantial progress towards DOE EM's mission to complete the safe cleanup of the environmental legacy brought about from five decades of nuclear weapons development and government-sponsored nuclear energy research. The need for environmental remediation at 107 sites across 31 states has been reduced to only 17 sites in 11 states. However, some of the most challenging work lies ahead, from remediating hazardous mercury in Oak Ridge to treating millions of gallons of radioactive and chemical waste at Hanford. Innovative technologies such as robotics and remote systems, detection instrumentation, and advanced modeling capabilities, will continue to play a key role in meeting these challenges.