YEAR END TECHNICAL REPORT
May 18, 2012 to August 17, 2013

Waste and D&D Engineering and Technology Development

Date submitted:

August 17, 2013

Principal Investigators:

Leonel E. Lagos, Ph.D., PMP®
David Roelant, Ph.D.

Florida International University Collaborators:

Leonel E. Lagos, Ph.D., PMP® (Project Manager)
Peggy Shoffner, M.S., CHMM, PMP®
Himanshu Upadhyay, M.B.A., PMP®
Walter Quintero, M.S.
Clint Miller, MCSE+Security
Justin Phillips
Amer Awwad, P.E.
Jose Varona, M.S.
DOE Fellows

Submitted to:

U.S. Department of Energy
Office of Environmental Management
Under Grant No. DE-EM0000598

Applied Research Center
FLORIDA INTERNATIONAL UNIVERSITY

Addendum:

This document represents one (1) of five (5) reports that comprise the Year End Reports for the period of May 18, 2012 to July 17, 2013 prepared by the Applied Research Center at Florida International University for the U.S. Department of Energy Office of Environmental Management (DOE-EM) under Cooperative Agreement No. DE-EM0000598.

The planned period of performance for FIU Year 3 under the Cooperative Agreement was May 18, 2012 to May 17, 2013. However, two no-cost extensions have been executed by DOE-EM. The first no-cost extension was received from DOE on 05/17/13 to extend the end of the period of performance for a period of two months (until 07/17/13). Another two months no-cost extension was received from DOE on 07/10/13 to extend the end of the period of performance to 9/16/13. The activities described in this report are for the FIU Year 3 period of performance from May 18, 2012 to August 17, 2013.

The complete set of FIU's Year End Reports for this reporting period includes the following documents:

1. Chemical Process Alternatives for Radioactive Waste
   Document number: FIU-ARC-2013-800000393-04b-213
2. Rapid Deployment of Engineered Solutions for Environmental Problems at Hanford
   Document number: FIU-ARC-2013-800000438-04b-217
3. Remediation and Treatment Technology Development and Support
   Document number: FIU-ARC-2013-800000439-04b-219
4. Waste and D&D Engineering and Technology Development
   Document number: FIU-ARC-2013-800000440-04b-216
5. DOE-FIU Science & Technology Workforce Development Initiative
   Document number: FIU-ARC-2013-800000394-04b-072

Each document will be submitted to OSTI separately under the respective project title and document number as shown above.

TABLE OF CONTENTS

LIST OF FIGURES

PROJECT 4 OVERVIEW

This project focuses on delivering solutions under the decontamination and decommissioning (D&D) and waste areas in support of DOE HQ EM. This work is also relevant to D&D activities being carried out at other DOE sites such as Oak Ridge, Savannah River, Hanford, Idaho and Portsmouth and international efforts being conducted by EM-2.1 with the Nuclear Decommissioning Authority (NDA) in England and the International Atomic Energy Agency (IAEA). For FIU Year 3, this project included the following 3 tasks:

Task 1: Waste Information Management System (WIMS)

This task provides direct support to DOE EM for the management, development, and maintenance of a Waste Information Management System (WIMS). 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. WIMS is successfully deployed and can be accessed from the web address http://www.emwims.org. The waste forecast information is updated annually. WIMS has been designed to be extremely flexible for future additions and is being enhanced on a regular basis.

Task 2: D&D Support for DOE EM for Technology Innovation, Development, Evaluation and Deployment

This task provides direct support to DOE EM for D&D technology innovation, development, evaluation and deployment. For FIU Year 3**,** FIU focused on assisting DOE EM-13 in meeting the D&D needs and technical challenges around the DOE complex. FIU engaged with D&D organizations in the U.S. and abroad to keep current and active in the identification of D&D technologies for the D&D complex. FIU also supported technology development, demonstrations and deployments such as completing a feasibility study for a technology to remotely remove strippable coatings and decontamination gels; supported Savannah River Site's *in situ* decommissioning efforts by evaluating several sensor network power and data transmission backbones that can be applied to a large-scale grouted structure and reviewing the software-based communication protocols required to gather and analyze data autonomously; collaborated with EFCOG in the development of Lessons Learned and Best Practices; and supported the EM-2.1 International Program and the EM-13 D&D program by participating in D&D workshops, conferences, and serving as subject matter experts.

Task 3: D&D Knowledge Management Information Tool (KM-IT)

The D&D Knowledge Management Information Tool (KM-IT) is a web-based system developed to maintain and preserve the D&D knowledge base. The system was developed by Florida International University's Applied Research Center (FIU-ARC) with the support of the D&D community, including DOE-EM (EM-13 & EM-72), the former ALARA centers at Hanford and Savannah River, and with the active collaboration and support of the DOE's Energy Facility Contractors Group (EFCOG). The D&D KM-IT is a D&D community driven system tailored to serve the technical issues faced by the D&D workforce across the DOE Complex. D&D KM-IT can be accessed from web address http://www.dndkm.org.

TASK 1.
DOE'S WASTE INFORMATION MANAGEMENT SYSTEM

TASK 1: EXECUTIVE SUMMARY

For Task 1, FIU has developed a Waste Information Management System (WIMS) to receive and organize the DOE waste forecast data from across the DOE complex and to automatically generate waste forecast data tables, disposition maps, and other displayed reports. The data can be displayed to show the regular waste forecast, the American Recovery and Reinvestment Act (ARRA) funded waste forecast, or the combined regular and ARRA funded waste forecast.

TASK 1: INTRODUCTION

Under Task 1, the Applied Research Center (ARC) at Florida International University (FIU) in Miami, Florida, has completed the deployment of a fully operational, web-based forecast system: the Waste Information Management System (WIMS). WIMS is designed to receive and organize the DOE waste forecast data from across the DOE complex and to automatically generate waste forecast data tables, disposition maps, and other displayed reports. This system offers a single information source to allow interested parties to easily visualize, understand, and manage the vast volumes of the various categories of forecasted waste streams in the DOE complex. The successful web deployment of WIMS with waste information from 24 DOE sites occurred in May 2006. Annual waste forecast data updates are added to ensure the long-term viability and value of this system. Individuals may visit the web site at http://www.emwims.org/.

TASK 1: EXPERIMENTAL

The initial requirement from DOE Headquarters was to consolidate waste forecast information from separate DOE sites and build forecast data tables, disposition maps and GIS maps on the web. An integrated system was needed to receive and consolidate waste forecast information from all DOE sites and facilities and to make this information available to all stakeholders and to the public. As there was no off-the-shelf computer application or solution available for creating disposition maps and forecast data, FIU built a DOE complex-wide, high performance, n-tier web-based system for generating waste forecast information, disposition maps, GIS Maps, successor stream relationships, summary information and custom reports based on DOE requirements. This system was built on Microsoft.net framework1.1 and SQL server 2000. Visual Studio 2003, SQL server reporting services, Dream Weaver and Photoshop were also used as development tools to construct the system. Since the initial requirements were met, additional features have been developed and deployed on WIMS.

TASK 1: RESULTS AND DISCUSSION

FIU regularly performed database management, application maintenance, and performance tuning to the online Waste Information Management System (WIMS) in order to ensure a consistent high level of database and website performance. New waste forecast and transportation forecast data is imported into WIMS on an annual basis.

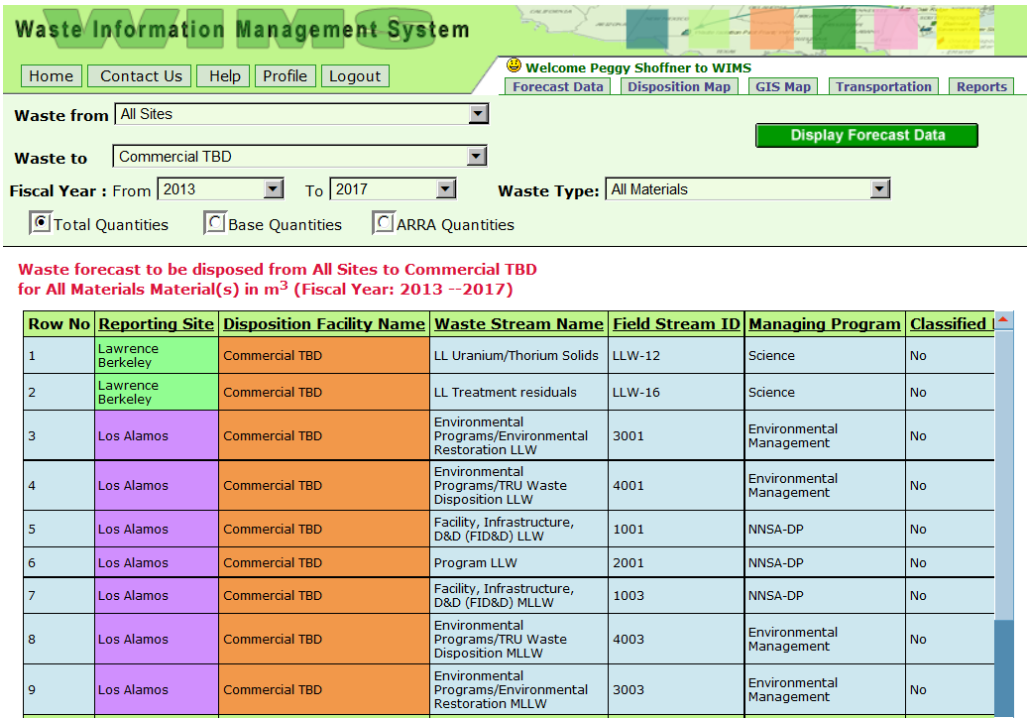
The 2012 waste forecast and transportation forecast data was collected, reviewed and transmitted from DOE to FIU on May 2, 2012. FIU completed the data import into the master database and modified the WIMS modules (Forecast, Disposition Map, GIS, and Transportation) to incorporate the new data set. FIU added 3 new commercial sites and facilities to the system as well as 2 new onsite locations. New data set was deployed on May 25, 2012 onto the test server for DOE testing and review. FIU incorporated the feedback from the data review and deployed the 2012 data on the public WIMS server on June 21, 2012.

The 2013 waste forecast and transportation data was received by FIU from DOE on April 16, 2012, incorporated into WIMS, and deployed onto the test server for DOE review and approval on May 20, 2013. Subsequent to the quality testing, FIU deployed the 2013 dataset onto the public WIMS server on June 21, 2013. The 2013 data set included low-level and mixed low-level radioactive waste data supplied by all DOE programs and included waste volumes forecasted for the ARRA funding in addition to the baseline waste forecast volumes and transportation information.

The data in WIMS can be viewed by site managers, stakeholders, and interested members of the public. Anyone with internet access may register and use WIMS (http://www.emwims.org). The current WIMS home page is shown in Figure 1.

Figure 1. WIMS website home page.

Figures 2 and 3 provide screenshots of the WIMS waste forecast and transportation forecast showing the 2013 data update. Figure 4 provides a screenshot of the GIS map displaying the 2013 data update.



Row No	Reporting Site	Disposition Facility Name	Waste Stream Name	Field Stream ID	Managing Program	Classified
1	Lawrence Berkeley	Commercial TBD	LL Uranium/Thorium Solids	LLW-12	Science	No
2	Lawrence Berkeley	Commercial TBD	LL Treatment residuals	LLW-16	Science	No
3	Los Alamos	Commercial TBD	Environmental Programs/Environmental Restoration LLW	3001	Environmental Management	No
4	Los Alamos	Commercial TBD	Environmental Programs/TRU Waste Disposition LLW	4001	Environmental Management	No
5	Los Alamos	Commercial TBD	Facility, Infrastructure, D&D (FID&D) LLW	1001	NNSA-DP	No
6	Los Alamos	Commercial TBD	Program LLW	2001	NNSA-DP	No
7	Los Alamos	Commercial TBD	Facility, Infrastructure, D&D (FID&D) MLLW	1003	NNSA-DP	No
8	Los Alamos	Commercial TBD	Environmental Programs/TRU Waste Disposition MLLW	4003	Environmental Management	No
9	Los Alamos	Commercial TBD	Environmental Programs/Environmental Restoration MLLW	3003	Environmental Management	No

Figure 2. WIMS waste forecast, 2013 data update, including baseline and ARRA activities.

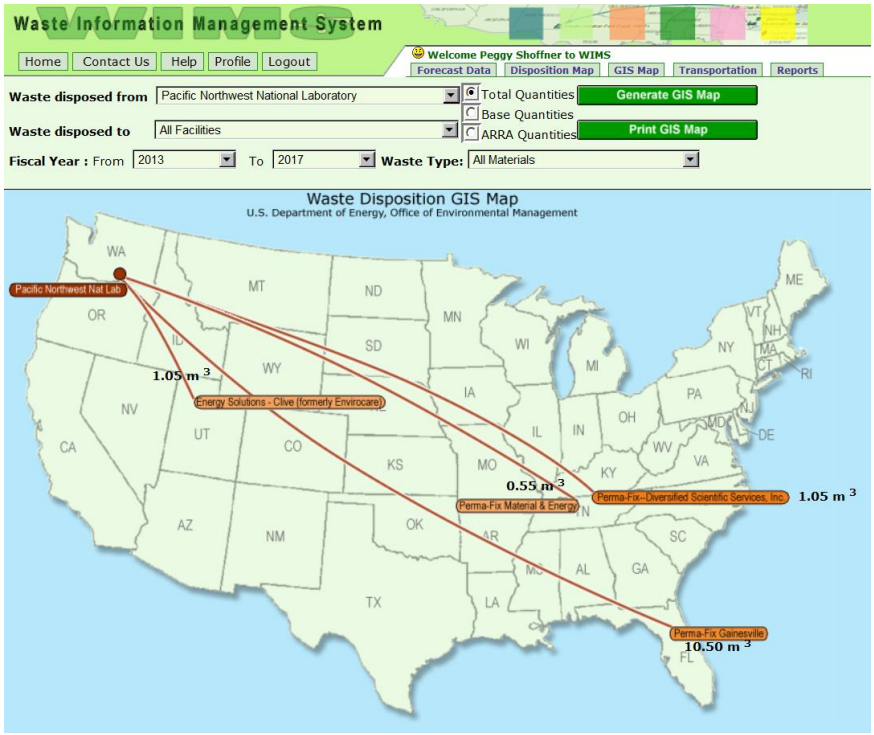


Figure 3. WIMS GIS Map showing 2013 data update.

WIMS Picklists for Querying Forecast Data

Upon entrance into WIMS, the information for display as a forecast data table, a disposition map, or a GIS map can be filtered in many ways through the provided drop-down menus. The updated filtration choices for each field of data are shown in the following lists. The fiscal year ranges are adjusted forward one year with each annual data update.

Waste type:

- All Materials
- Unknown
- Low Level Waste
- Mixed Low Level Waste
- 11e.(2) Byproduct Material
- Other Material

Fiscal Year:

- 2013
- 2014
- 2015
- 2016
- 2017
- 2018-2022
- 2023-2027
- 2033-2037
- 2038-2042
- 2043-2050

Waste from:

- All Sites
- Ames Laboratory
- Argonne National Laboratory
- Bettis Atomic Power Laboratory
- Brookhaven National Laboratory
- Energy Technology Engineering Center
- Fermi National Accelerator Laboratory
- Hanford Site – RL
- Hanford Site – RP
- Idaho National Laboratory
- Kansas City Plant
- Knolls Atomic Power Laboratory – Kesselring
- Knolls Atomic Power Laboratory – Schenectady
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- Naval Reactor Facility
- Nevada Test Site
- NG Newport News
- Norfolk Naval Shipyard
- Nuclear Fuel Services, Inc.
- Oak Ridge Reservation
- Pacific Northwest National Laboratory
- Paducah Gaseous Diffusion Plant
- Pantex Plant
- Pearl Harbor Naval Shipyard
- Portsmouth Gaseous Diffusion Plant
- Portsmouth Naval Shipyard
- Princeton Plasma Physics Laboratory
- Puget Sound Naval Shipyard
- Sandia National Laboratories – NM
- Savannah River Site
- Separations Process Research Unit
- Stanford Linear Accelerator Center
- Thomas Jefferson National Accelerator Facility
- Waste Isolation Pilot Plant
- West Valley Demonstration Project

Waste to:

- All Facilities
- 200 Area Burial Ground (HANF)
- 746-U Landfill (Paducah)
- Area 5 LLW Disposal Unit (NTS)
- Area 5 MLLW Disposal Cell (NTS)
- Clean Harbors
- Commercial TBD
- E-Area Disposal (SRS)
- EMWMF Disposal Cell (ORR)
- Energy Solutions-Clive (formerly Envirocare)
- Energy Solutions-TN (formerly GTS Duratek)
- ERDF (HANF)
- Impact Services - TN
- INL CERCLA Cell (INL)
- Integrated Disposal Facility (HANF)
- New RH LLW Vaults (INL)
- ORNL Liquid LLW System
- Paducah CERCLA
- Paducah WW Trt
- Perma-Fix Gainesville
- Perma-Fix-Diversified Scientific Services, Inc.
- Perma-Fix-Northwest (formerly PEcoS)
- Perma-Fix-Materials & Energy Corp
- Philotechnics (ORR)
- River Metals
- RMW Trenches (MLLW/LLW)(HANF)
- RMW Trenches/IDF (HANF)
- RWMC (LLW disposal) (INL)
- Siemens
- Studsvik/RACE, LLC
- TA 54/Area G (LLW disposal) (LANL)
- To Be Determined
- TOXCO

Waste Management Conference

FIU also participated in relevant meetings and conferences in support of this project. A professional poster entitled, *Waste Information Management System with 2012-13 Waste Streams*, was presented at the Waste Management Symposium 2013 on February 26, 2013 (Figure 4). This poster presented WIMS with the 2012 dataset of wastestream and transportation forecast information from the various DOE sites and facilities. The objectives of WIMS was addressed as well as the results to date for the DOE complex-wide, high performance, n-tier web-based system for generating waste forecast information, disposition maps, GIS maps, successor stream relationships, and custom reports. FIU also demonstrated WIMS to interested conference attendees at the FIU exhibitor booth during the conference.

Waste Information Management System – 2012-13

Authors: Himanshu Upadhyay, Walter Quintero, Leonel Lagos, Peggy Shoffner, David Roelant (FIU)

Presenters: Walter Quintero, Himanshu Upadhyay, Peggy Shoffner

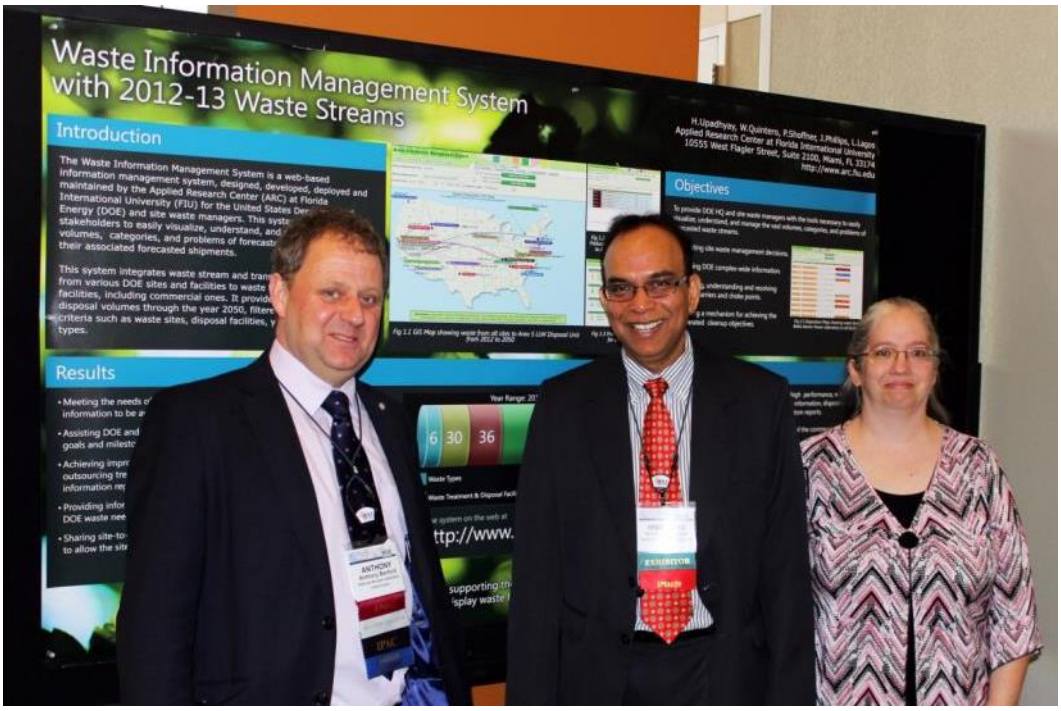


Figure 4. Poster presentation at WM13 for the Waste Information Management System.

TASK 1: CONCLUSIONS

WIMS continues to successfully accomplish the goals and objectives set forth by DOE for this project. WIMS has replaced the historic process of each DOE site gathering, organizing, and reporting their waste forecast information utilizing different database and display technologies. In addition, WIMS meets DOE's objective to have the complex-wide waste forecast information available to all stakeholders and the public in one easy-to-navigate system. The data includes low-level and mixed low-level radioactive waste data supplied by all DOE programs and includes waste volumes forecasted for the American Recovery and Reinvestment Act (ARRA) funding in addition to the updated baseline waste forecast volumes and transportation information

TASK 1: REFERENCES

Office of Science & Technology (OST), http://www.em.doe.gov/ost, Office of Environmental Management at US Department of Energy.

Office of Environmental Management (DOE-EM), http://www.em.doe.gov, US Department of Energy.

Waste Information Management System (WIMS), http://www.emwims.org, Applied Research Center, Florida International University.

Upadhyay, H., W. Quintero, P. Shoffner, L. Lagos, and D. Roelant. *Waste Information Management System 2012-13,* Waste Management 2013 Conference, Phoenix, AZ, February 2013.

TASK 2. D&D SUPPORT FOR DOE EM FOR TECHNOLOGY INNOVATION, DEVELOPMENT, EVALUATION AND DEPLOYMENT

TASK 2: EXECUTIVE SUMMARY

This task provides direct support to DOE EM for D&D technology innovation, development, evaluation and deployment. For FIU Year 3**,** FIU focused on assisting DOE EM-13 in meeting the D&D needs and technical challenges around the DOE complex. FIU engaged with D&D organizations in the U.S. and abroad to keep current and active in the identification of D&D technologies for the D&D complex. FIU also supported technology development, demonstrations and deployments such as completing a feasibility study for a technology to remotely remove strippable coatings and decontamination gels; supported Savannah River Site's *in situ* decommissioning efforts by evaluating several sensor network power and data transmission backbones that can be applied to a large-scale grouted structure and reviewing the software-based communication protocols required to gather and analyze data autonomously; collaborated with EFCOG in the development of Lessons Learned and Best Practices; and supported the EM-2.1 International Program and the EM-13 D&D program by participating in D&D workshops, conferences, and serving as subject matter experts.

TASK 2: INTRODUCTION

FIU directly supports DOE-EM's Office of D&D and Facility Engineering and affiliated DOE sites, national laboratories, and institutions contributing to the development of innovation in D&D. This task also collaborates with DOE-EM's international partnerships and agreements, when appropriate, by providing D&D expertise, knowledge and support. The technical approach for this task is to identify and demonstrate new technologies, methodologies, and approaches to support the D&D of facilities across the globe. In this report, FIU will present the accomplishments achieved during FIU Year 3 in support of technology innovation, development, evaluation and deployment.

TASK 2: EXPERIMENTAL

For FIU Year 3, FIU completed a feasibility study of a remote platform for the remote removal of strippable coatings and decontamination gels, supported SRS in research and experimental testing for *in situ* decommissioning, provided D&D support to DOE-EM international programs and EFCOG, and participated in workshops and conferences, and served as subject matter experts.

TASK 2: RESULTS AND DISCUSSION

Initial Feasibility Study for the Development of a Remote Platform for Remote Removal of Strippable Coatings

FIU provides support to the DOE EM Office of D&D and Facility Engineering by identifying innovative technologies suitable to meet specific facility D&D requirements, assessing the readiness of those technologies for field deployment, conducting technology demonstrations of selected technologies at FIU facilities, and working with technology vendors to optimize the design of their current technologies to accomplished dangerous and demanding D&D tasks during D&D operations. To meet the technology gap challenge for a technology to remotely apply strippable coatings, fixatives and decontamination gels, FIU previously identified and performed a demonstration of an innovative remote sprayer platform from International Climbing Machines (ICM), first using fixatives and subsequently using strippable coatings and decontamination gels under cold (non-radioactive) conditions. Based on the results from the FIU demonstrations and on feedback on needs from DOE sites, preliminary work has been conducted to integrate remote strippable coating removal capability into the existing remote platform.

During FIU Year 2, FIU worked with ICM to conduct initial feasibility and trade studies (Phase 1) to identify the requirements for the remote removal of strippable coatings using the existing remote controlled platform. The initial feasibility study entailed analyzing the technical challenges of developing such a device as well as trade studies/bench-scale testing to study and test various potential tools and mechanisms that could be integrated with the remote platform. The preliminary testing served as proof-of-concept that the tools are capable of removing a strippable coating. Since strippable coatings are typically removed by hand, this step was needed to help determine candidate tools that could work via remote control. The tools were further evaluated using factors such as size and weight, motor or electricity usage, and complexity of movement to determine a reasonable mechanism for integrating the tool with the ICM platform.

Since only the first phase of the feasibility study and bench scale testing was completed in FIU Year 2, carryover funds were utilized to complete the feasibility study in FIU Year 3. The deliverable for the initial feasibility study included a conceptual design and identification of potential tools that can be adapted to the ICM crawler for remote stripping of coatings.

During FIU Year 3, FIU worked with ICM on improvements to the methods that were identified during the Phase I feasibility study to develop tools that are capable of being attached and operated remotely from the ICM climbing machine platform to remove strippable coatings. The two tools used for this study were re-designed, enhanced and improved versions of the tools built and tested during Phase I. The two methods tested for remote removal included:

- Gripper/scraper (robotic arm with mechanical “hand” at end)
- Silicon carbide-bristled brush in a vacuum shroud

A series of tests were performed using the two methodologies. Two types of strippable coatings, InstaCote (InstaCote Inc.) and DeconGel (CBI Polymers), were applied to both concrete and metal surfaces and allowed to dry prior to the remote removal tests.

The remote removal with the gripper/scraper tool most resembles a human arm with a scraper removing the strippable coatings (Figure 5). Overall, this method proved to be straightforward and intuitive and once the operator had some experience with the tool. A qualitative assessment from the user perspective is shown in Figure 6. Productivity (square footage of coating removed over time) using this tool was good, even though the tool used was a prototype and proof-of-concept tool, not designed for maximum productivity. The primary drawback for this method was observed on vertical surfaces. When removing the strippable coating on a wall, the coating tended to drape onto the climber, impairing operations. A second remote controlled "hand" or even a vacuum tool to pull and manipulate away the draping strippable coating could remedy this issue. As expected, the rate of removal was faster on metal than it was on concrete (Table 1). Concrete's more porous nature and imperfections provide a much greater tooth for strippable coatings and they tend to grab better on concrete. Metal is smoother and shinier and the strippable coatings do not adhere as tenaciously, lending itself to easier removal using the gripper/scraper approach or any other mechanical approach.

Figure 5. ICM remote platform with a gripper/scraper tool to remove strippable coatings.

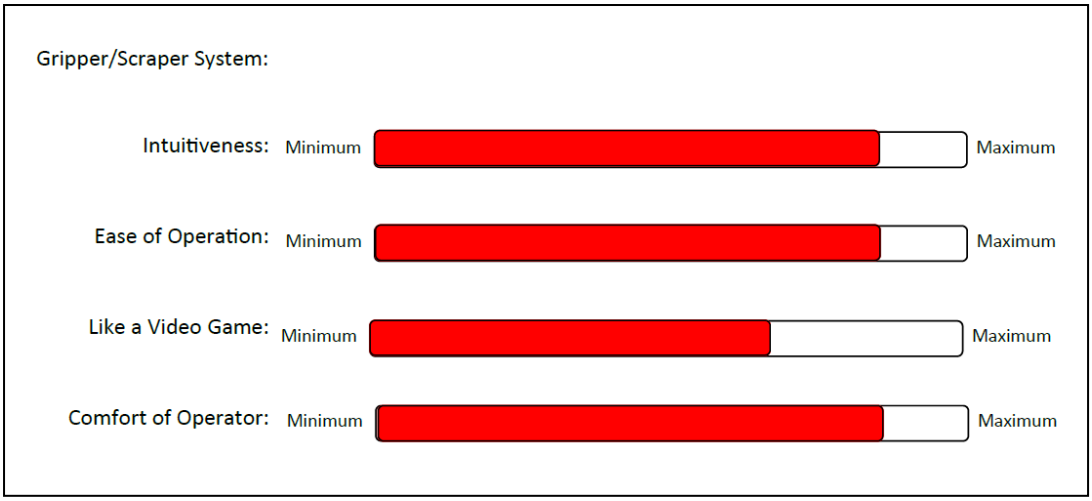


Figure 6. Qualitative assessment of the gripper/scraper system.

Table 1. Average Removal Rates for Brush and Gripper/Scraper Tools

Coating Product	Surface Type	Average Removal Rate (sq ft/min)	
		Brush Tool	Gripper/Scraper
Instacote	Concrete	0.48	1.08
Instacote	Metal	1.02	3.05
Decon Gel	Concrete	0.88	0.32
Decon Gel	Metal	0.65	0.55
Composite Average		**0.76**	**1.25**

The brush and vacuum shroud method relies upon a well proven mechanical abrader in a shroud with a vacuum attached to it to remove the coating from the surface and capture it in a collection vessel (Figure 7). ICM integrated a mechanical abrader and shroud onto one of the climbers to make it remote-controlled for the testing. This approach proved effective for the remote removal of strippable coatings on both concrete and metal (Table 1). A qualitative assessment from the user perspective is shown in Figure 8.

Figure 7. ICM remote platform using a brush with a vacuum shroud to remove strippable coating from vertical surface.

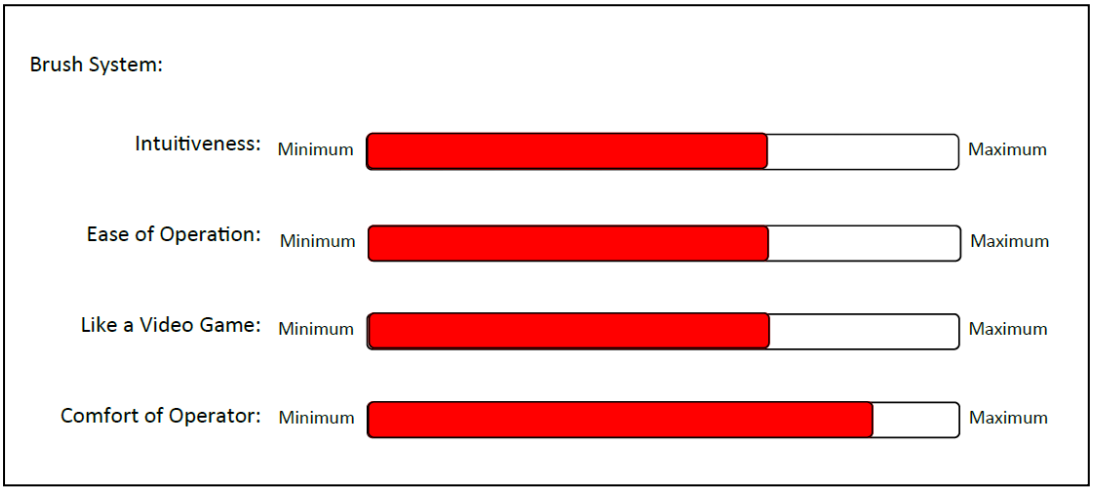


Figure 8. Qualitative assessment of the brush system.

Conclusions of the Phase II feasibility report include:

1) The brush with vacuum capture was effective at removing both manufacturers' materials tested and at removing them from both concrete and metal surfaces. This method is reliable and the average productivity of 45 square feet an hour for the small size brush tested was reasonable for field expectations. A larger, more powerful production brush would yield greater productivity.

2) The gripper/scraper method was also effective at removing both manufacturers' materials and at removing them from both concrete and metal. This method is particularly fast after an

edge has been lifted and, duplicating the actions of a human manually removing the strippable coating, it can be pulled up in sheets. Thus, the average productivity of this method of 75 feet per hour was quite impressive. A tool designed with two gripper / scrapers and possibly an air ejector to help manipulate the sheets of strippable coating being removed will be features built onto a production unit. These features will address certain shortcomings noted in the testing and increase productivity.

While the Phase II feasibility study for the remote removal of strippable coatings was completed and ICM prepared the Phase II feasibility report, the planned technology evaluation of the technology prototype to remotely remove strippable coatings and decontamination gels at the FIU cold-testing facility was suspended due to funding uncertainties.

In Situ Decommissioning

In an effort to aid in the evaluation of a sensor network for *in situ* decommissioning projects at the Savannah River Site (SRS), a meso-scale concrete experimental test bed has been designed and constructed at FIU-ARC in order to deploy and evaluate various sensors embedded in a specially formulated grout mixture (Figure 9). The construction of the FIU facility was completed by the end of December 2011. This experiment consists of using various sensors including Electrical Resistivity Tomography, Advanced Tensiometers, Piezoelectric Sensors, and Fiber Optic Sensors (ERT, AT, PES, FOS) to measure various parameters including strain, crack detention, corrosion, fluid mobility, moisture, pH and temperature. Principal Investigators (PIs) from Idaho National Laboratory (INL), Mississippi State University (MSU), University of Houston (UH), and University of South Carolina (USC) provided the sensors. The main purpose of the experiment is to recognize the limitations of these sensors for potential future use in monitoring decommissioned nuclear facilities.

Figure 9. Ariel view of the *in situ* decommissioning test site at FIU.

During FIU Year 3, FIU completed the design, procurement, fabrication, and installation of a renewable energy system to support the two of the sensor systems used on the meso-scale test bed (MSTB). The system is comprised of a 1kW PV array configured for a 120 VAC and 24 VDC output. The PV system provides power up to 200W continuous, using a 1040W PV array and a 540 AHr battery bank. The system is operational and being used to power the thermocouple and active tensionmeter (TC-AT) systems, as well as the weather station, and ancillary networking equipment in the container. The power system was implemented on a stand-alone structure that provides the appropriate wind-load capabilities for Miami, FL (Figure 10).

Figure 10. Photovoltaic system in support of ISD test site at FIU.

FIU also designed the support pads needed to secure the PV system to the ground. These pads are required to support wind loads up to 150 mph, in the event of a hurricane. After discussions with civil engineers, the footing design was modified to comply with the recommendation that a removable footing would prove beneficial based on the limited time that the system will be powering the sensor systems. With this in mind, a simple 2D Finite Element Analysis (FEA) of the A-frame supporting the PV panels was used to estimate the reaction forces and moments that would be generated by the array under a high wind load. These results were used to develop a system of ground stakes that could be used to support the reaction forces and mitigate the reaction moments.

Once installed and operational, FIU continued monitoring the usage and performance of the PV power system to maintain stable operation of the sensor systems continuously. The PV system encountered a generated two low-battery faults on the system during the course of operation; this was due to a 5-day period of cloudy weather (i.e. maximum PV array output less than 500 W). In order to allow for the batteries to fully charge, the ERT system was shut down for two days. This allowed the battery bank to charge up to a float mode.

In addition, FIU collected information on possible 500 – 1000 W wind turbines that could provide a supplemental energy source during times of low irradiance. The turbine could be

coupled into the balance system that is used by the photovoltaic modules. The turbine would likely require a small tilt-up tower or be attached to the building adjacent to the testbed.

In addition to the power system design, FIU worked on reducing the energy demand on one of the INL systems by employing a low-cost microcontroller board to pull data from the temperature system, and make it accessible via the network connection. FIU also researched the use of a shared variable engine to compile all system data into a central data location. This engine was then deployed on a main PC and the other systems communicate with this machine to transfer data between acquisition cycles.

FIU collected energy consumption data on the INL's ERT system during idle operation to determine the current minimum energy consumption required. The system utilizes a laptop that must be factored into the consumption numbers, although the system does not perform any operations while in idle. The laptop could be one component that can be configured for sleep in the event of idle operations. Also, the system uses an external power source to deliver the current that is injected into the media under test. This supply is also continuously running, and could be shed during idle operations. This would extend the system's operational life, and reduce energy demands on the overall system.

Energy monitoring equipment was procured, and setup, for long-term energy analysis. FIU completed collection of the ERT system energy consumption during idle mode. The data was imported into excel for analysis. Results indicated a mean energy consumption of approximately 4 kWhr per day. This number accounts for an expected current injection of 10A for a total of 45 minutes during an ERT scanning period. The value of current injected was validated during the ERT tests that were performed during the system demonstrations. This energy consumption, coupled with the ERT temperature system, is in good agreement with expected values used to estimate the total required from the backup renewable energy source.

Also, FIU worked on the design of a small-scale data network system for compiling information from the sensor systems during the demonstration, and showing it on a single host machine. Design work focused on how to collect the ERT temperature values from the existing logging station to the data repository (i.e. an FIU machine on the same data network). The logging station contains an application that was developed by INL for temperature data acquisition and logging. FIU developed a new VI that allowed data collection of this temperature data, and also configured the data to be available through Labview® shared variable engine. This allowed for data retrieval, analysis and visualization outside of the logging station. This VI contained the bare essentials to acquire the data from the temperature system, without altering the existing system configuration. FIU received approval from INL to integrate the developed Virtual Instruments (VI) with the temperature system. The VI was tested on a small scale local network, and was able to constantly log and display system-generated data.

Also, FIU successfully completed the testing of the TC-AT Virtual Instruments (VI) developed in order to capture data from the systems (Figure 11). This VI was used to acquire the values, and load them into an array of shared variables that could be accessed through a client application or loaded into an automation industry-standard Open Platform Communications (OPC) server. In addition, the VI was then modified to run on a low-power controller. This

controller was also programmed to capture data from the weather station and the power system. These datasets were also loaded into shared variables that could be accessed in a similar fashion to the TC-AT data. Finally, the integrated application was used to capture data from all systems in near real-time while all were in operation. The results could be seen on a client VI running on another computer located on another network. This completed the meso-scale testbed system demonstration on November 23, 2012.

The network virtual instruments (VI) were subsequently modified to improve communication, memory management and power management. In particular, the VIs were modified to control the acquisition state and sample rate depending on the battery state of charge. This allows better node autonomy depending on power system state.

A demonstration report was submitted to DOE on December 22, 2012, describing the details of the development and demonstration of the shared data network. This demonstration proved the capacity to develop a low-cost, integrated data network with the existing systems with minimal programming. This capability could be expanded to the other systems on the MSTB, and can be used to develop an integrated sustainable monitoring system with the capacity to monitor and notify.

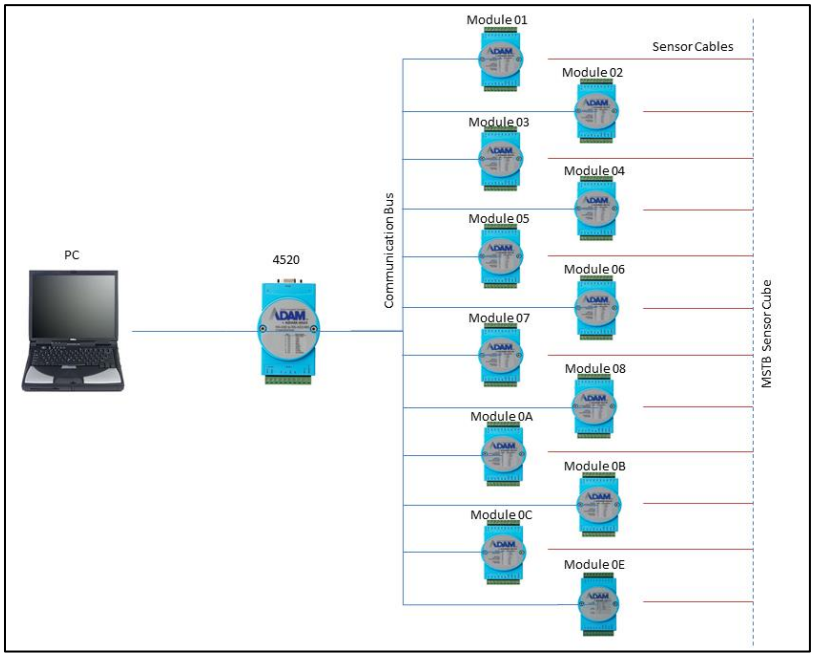


Figure 11. Diagram of INL's TC-AT System.

The sensor data network remained operational and continued to log system data. The network virtual instruments (VI) continued to be modified to improve communication, memory management and power management. The VI's were tested using an object-oriented programming (OOP) approach in Labview to improve runtime execution and memory management (Figure 12).

FIU completed several modifications to the network VI's developed for the shared data network. In particular, the data parsing VI's were improved for performance and variable acquisition rates. FIU also completed preparations for the planned fluid injection studies to occur on the meso-scale test bed through technical support of sensor systems. In preparation for these fluid injection studies, FIU completed the troubleshooting and testing of the INL systems. The TC-AT system was completely operational, with no acquisition issues or systemic errors in the collected data. The TC-AT and ERT wiring configuration was verified as a QA check for INL's final efforts in completion of a final test report.

FIU completed research of possible wireless charging technologies and methodologies that could be integrated as part of the current MSTB, to evaluate its potential for operation with a commercial acquisition and logging systems.

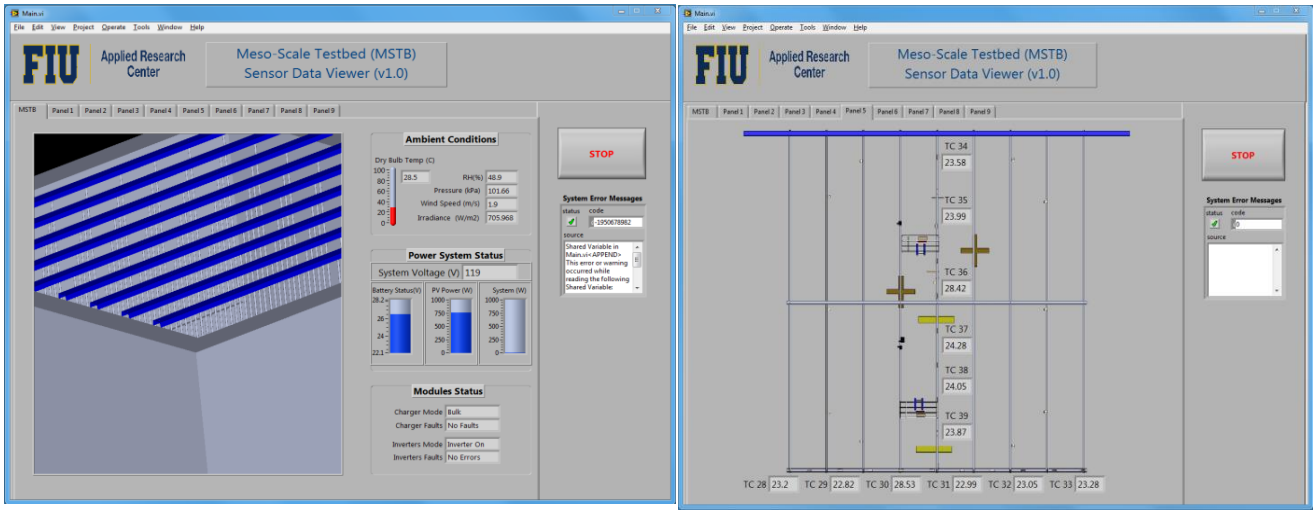


Figure 12. Screenshots from the MSTB Sensor Data Viewer

Technical D&D support to DOE-EM International Program & EFCOG

Under this subtask, FIU-ARC provided support to the DOE EM-2.1 international partnerships and supports the DOE Bi-Lateral Agreement by providing D&D expertise, knowledge and support. In addition, FIU continued active support to DOE's Energy Facility Contractor's Group (EFCOG) by collaborating in the development of Lessons Learned and Best Practices, and other activities as identified and agreed by EFCOG and FIU. In addition, FIU participates in monthly conference calls and Fall, Spring and Annual EFCOG meetings and presentations.

EFCOG Participation

FIU participated in the EFCOG D&D and Facility Engineering Working Group meetings and teleconferences during FIU Year 3, and reported on the progress of the Lessons Learned and Best Practices documents being developed by FIU.

EFCOG Lessons Learned and Best Practices

This subtask focused on capturing the manager experience through the EFCOG points-of-contact. In an effort to capture the lessons learned and best practices acquired at DOE sites, FIU

worked with EFCOG to identify various sites who were able to share their experiences and lessons learned with the EM D&D community. The development of each lessons learned and best practice was conducted with a standardized process, as shown in Figure 13.

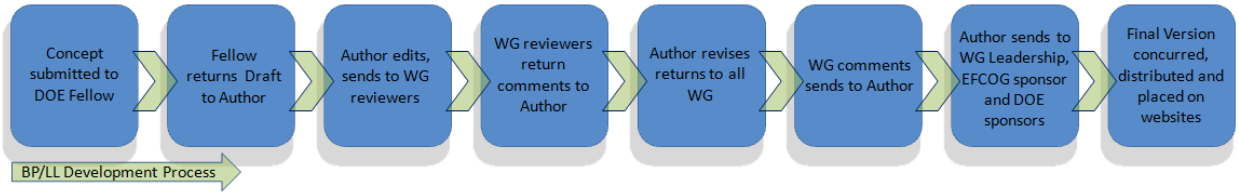


Figure 13. Process for developing Best Practice and Lessons Learned documents.

FIU has completed the development, review, and approval for 7 lessons learned and best practice documents and developed an additional 5 documents that are in the review and approval stages. The objective of these efforts was to capture previous work performed by the D&D community and facilitate the transfer of knowledge and lessons learned. The lessons learned and best practices developed by FIU to date include:

1. The Washington Closure Hanford Site Explosive Demolition of Buildings 337 and 337B
2. Lawrence Livermore National Laboratory Open Air Demolition of Asbestos Gunite by Using Track Mounted Wet Cutting Saw Best Practice
3. Savannah River Site 185-3K Cooling Tower Demolition Best Practice
4. Lawrence Livermore National Laboratory Historical Hazard Identification Process for D&D Best Practice
5. Closure of the Reactor Maintenance, Assembly, and Disassembly Facility and the Pluto Disassembly Facility at the Nevada National Security Site
6. Unanticipated High Dose During the Removal of Wire Flux Monitor Cabling from the Heavy Water Component Test Reactor (HWCTR) Vessel
7. Radiological Contamination Event During Demolition of the Separations Process Research Unit (SPRU) Building H2
8. Structural Code Guidance for D&D Activities at DOE Facilities
9. Electrical Code Guidance for D&D Activities at DOE Facilities
10. Savannah River Site R and P Reactor Disassembly Basin In Situ Decommissioning
11. Use of Earthen Benches and other Technologies to Support River Structures' Demolition Activities at the Hanford Site
12. Hanford Site 327 Facility Source Term Stabilization and/or Removal Prior to Demolition

The first four of these Best Practices and Lessons Learned were final and attached to last year's Year End Report. Documents 6, 8, and 9 were finalized during FIU Year 3 and are linked in this report in the Appendix. The remaining documents (5, 7, 10, 11, and 12) are in progress and being reviewed and/or revised. A summary of the lessons learned and best practices that were finalized or are in progress during FIU Year 3 are included below.

Unanticipated High Dose During the Removal of Wire Flux Monitor Cabling from the Heavy Water Component Test Reactor (HWCTR) Vessel

An unanticipated high dose was experienced during the removal of wire flux monitor cabling during the Heavy Water Component Test Reactor (HWCTR) deactivation at the Savannah River Site (SRS) (Figure 14). The potential radiation dose was not fully understood, because despite the review of over 1,400 drawings as part of the planning for the work, the presence of the ion chambers had not been identified. The lesson learned was developed to ensure that issues or concerns that are identified to individual members of a project team are shared with the entire team to ensure that they are adequately reviewed, the associated hazards are analyzed, and appropriate controls are identified and implemented during the work planning phase.

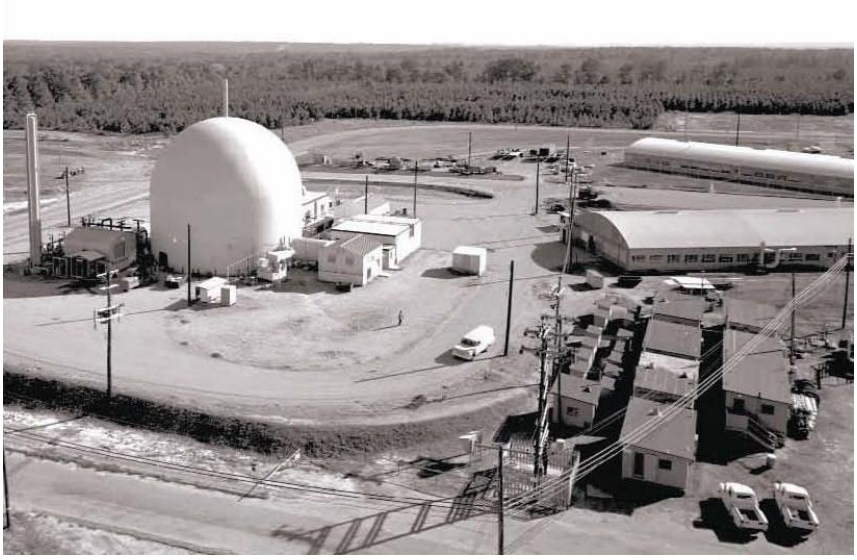


Figure 14. Heavy Water Component Test Reactor at SRS.

Radiological Contamination Event During Demolition of the Separations Process Research Unit (SPRU) Building H2

The Separations Process Research Unit (SPRU), located at the Knolls Atomic Power Laboratory (KAPL), near Schenectady, New York, was operated from 1950 to 1953 as a pilot plant to research the REDOX and PUREX chemical processes to extract uranium and plutonium from irradiated uranium. It supported operations at the Hanford Site (Washington State), and the Savannah River Site (South Carolina). The research was performed on a laboratory scale; SPRU was never a production plant. The research operations contaminated the SPRU facilities and land areas, resulting in the need to remediate the site.

On September 29, 2010, a radioactive contamination event occurred while performing open air demolition of the SPRU Building H2. Though initial indications demonstrated that low levels of contamination had been found on workers shoes and on KAPL property adjacent to the SPRU work activities, the magnitude and significance of the contamination event were not fully identified and understood by the SPRU project for several days. Based on the estimated cost to remediate the accident and event circumstances, a Type B investigation was ordered.

Structural Code Guidance for D&D Activities at DOE Facilities

D&D of facilities at DOE sites require engineering standards to safely accomplish D&D missions. Current engineering standards do not adequately address the unique situations arising during D&D activities. A new guidance document was developed to establish new code guidance governing structural design during D&D phases. SEI/ASCE 37-02 "Design Loads on Structures During Construction," is used to establish the basis of this document

Electrical Code Guidance for D&D Activities at DOE Facilities

A new DOE guidance document was developed to establish and interpret new code guidance governing electrical design during D&D phases. NFPA 70, "National Electrical Code," Article 590, "Temporary Power," is used to establish the basis of this document

Savannah River Site R and P Reactor Disassembly Basin In Situ Decommissioning

The 105-R Disassembly Basin was the first SRS reactor facility to undergo the in situ decommissioning (ISD) process followed by the 105-P Disassembly Basin (Figure 15). The best practice followed at SRS guided the identification and selection of appropriate ISD fill materials to successfully overcome the wide variety of challenges that the large size and structural complexity of these facilities presented. Considerations for grout formulations had to account for flowability, long term stability, set times, heat generation and interactions with materials within the structure. The large size and configuration of the facilities necessitated that grout be pumped from the exterior to the spaces to be filled, which required that the material retain a high degree of flowability to move through piping without clogging while achieving the required leveling properties at the pour site. Set times and curing properties were controlled to meet operational schedules, while not generating sufficient heat (known as heat of hydration) to compromise the properties of the fill material. In addition, the properties of residual materials in the facility necessitate additional requirements for the grout formulations. Where significant quantities of aluminum were present in the facility, common formulations of highly alkaline grouts were not appropriate because of the potential for hydrogen generation with the resultant risks. SRS developed specialized inorganic grout formulations to address this issue.

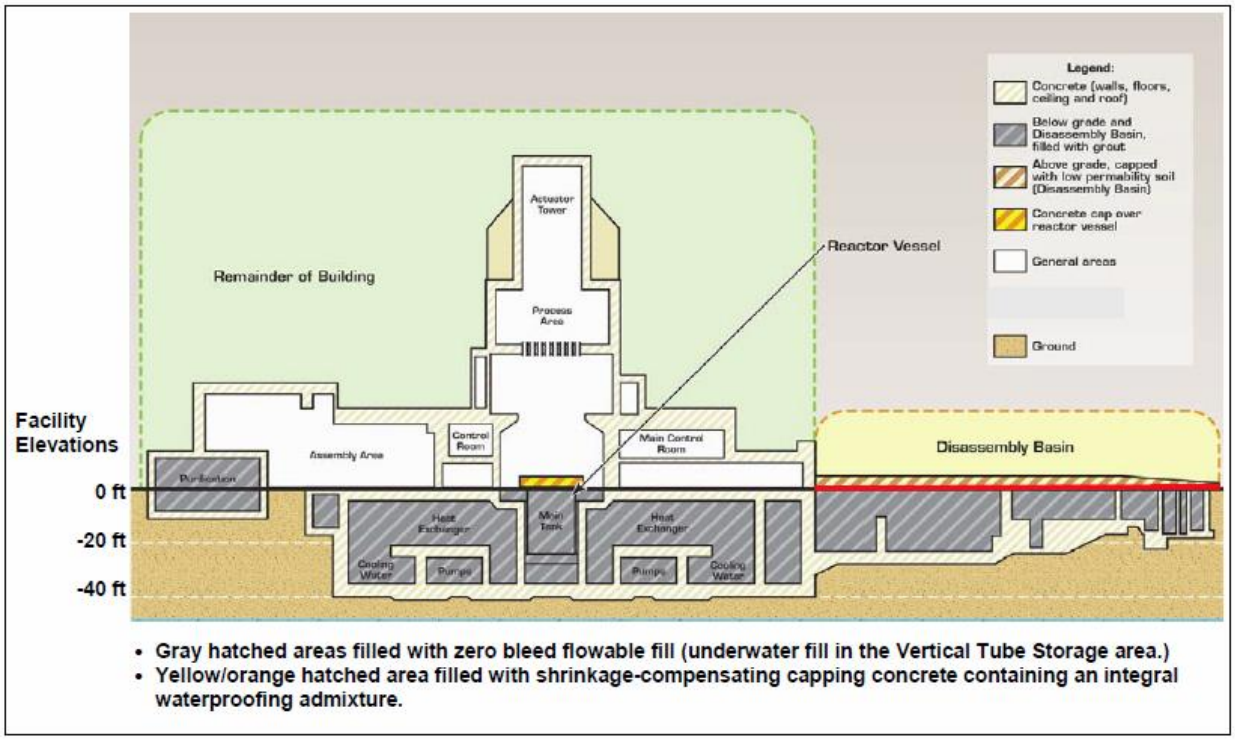


Figure 15. Cross section through SRS 105-P Reactor Building.

Use of Earthen Benches and other Technologies to Support River Structures' Demolition Activities at the Hanford Site

Washington Closure Hanford, as part of the River Corridor Cleanup Project, was contracted to demolish three structures which were located directly in the Columbia River (Figure 16). The project's original work scope included pre-demolition removal of contaminated equipment, followed by demolition of the structures. However, the final work scope included extensive agency, tribal, and regulator consultation, removal of contaminated equipment, manufacture and replacement of concrete panel sluice gates to isolate the intake structures, removal of contaminated sediment, use of acoustic deterrence to protect fish near the structures, monitoring fish activity and sediment turbidity, installation of earthen benches in front of the river structures to isolate them from the river, placement of clean sand in the structures to control pH during demolition, conventional demolition methods to remove the structures themselves, followed by the restructuring of the shoreline to restore a shallow-water habitat.

The design process for the river structure project went through extensive contractual, regulatory, tribal, and public evaluations. The proximity of the work to the Columbia River made environmental management an integral component in the planning and design process. Developing and maintaining a good working relationship with environmental and regulatory agencies is essential on any project, but especially those located on bodies of water or in culturally sensitive areas.

Figure 16. The Hanford Site River Structures.

Hanford Site 327 Facility Source Term Stabilization and/or Removal Prior to Demolition

The Hanford Site 327 hot cells were designed to provide shielded, ventilated protection for the examination of irradiated fuels and concentrated fission products and played a key role in reactor material and fuel research programs. Consequently, the amount of radioactive material inside the cells and throughout the attached ventilation ducts and waste piping made conventional demolition activities too risky to the employees, the environment, and the public. The final packaged cell shipment weights ranged from 75 to 230 tons. These massive structures required a safe method to lift and transport to the Environmental Restoration Disposal Facility (ERDF). WCH decided on a gantry system to remove 10 of the 11 cells from the building before demolition.

Several facility modifications had to be completed in order to install the temporary gantry system. These modifications included removal of several hundred feet of highly-contaminated ventilation ductwork and piping from the facility basement to allow for the installation of twenty shoring stands each with a 120-ton capacity. These stands were strategically located in the basement under the gantry joint locations to add additional support to the facility's main level concrete floor.

A large portion of the east wall was removed to permit movement of the hot cells out of the facility. A temporary plastic curtain and temporary HEPA filtered ventilation system were installed to help prevent any contamination spread from inside the building to the environment during final hot cell removal preparations. 300 ft. of gantry rail was installed inside the facility using the facility's overhead crane. An external mobile crane was used to install 400 ft. of gantry rail outside of the building. Four 400-ton capacity hydraulic gantry legs with two 25 ft. header beams were installed onto the rail system. Jacking haunches were fabricated and attached to the cells to lift and rotate the cells for movement out of the facility.

Once outside of the facility, metal boxes were built around each hot cell to prepare them for shipment. The internal voids of some cells and boxes were filled with grout prior to shipment to meet ERDF waste acceptance criteria. Finally, a 12-axle, 96-tire Goldhofer trailer was used to transport the cells to ERDF where a second gantry system was erected to offload the cells. Once offloaded, additional grouting was performed in preparation for final in-place disposal

(Figure 17).

Figure 17. The Hanford Site 327 Building during hot cell removal activities and in 2012.

Workshops, Conferences, and Outreach

Under this subtask, FIU-ARC provided support to the DOE EM-13 D&D program by participating in D&D workshops, conferences and serving as subject matter experts. During FIU Year 3, FIU participated in the American Nuclear Society (ANS) Decontamination, Decommissioning, and Reutilization (DD&R) conference held in Chicago, IL (June 24 – June 28, 2012) as well as the Waste Management 2013 Conference held in Phoenix, AZ (February 24-28, 2013).

FIU staff and DOE Fellows from the FIU-DOE Science and Technology Workforce Development Program participated in the ANS DD&R conference by participating as presenters during technical sessions as well as exhibiters at the FIU ARC booth. FIU presented a paper on the remote removal of strippable coating via a robotic platform (Figure 18). The paper and presentation detailed the accomplishments under the feasibility study for the development of a remote platform for the removal of strippable coatings. This research was conducted in collaboration with International Climbing Machines.

> ***Development of a Remote Platform for Remote Removal of Strippable Coatings – A Feasibility Study***
>
> Authors: Leonel Lagos, Peggy Shoffner (FIU), Sam Maggio, Blake Fall-Conroy (ICM)
> Presenter: Leonel Lagos

Figure 18. Dr. Leo Lagos presenting at the DD&R Conference.

Dr. Lagos also had the opportunity to co-chair a session on D&D Lessons Learned at the DD&R conference.

DOE Fellow Heidi Henderson presented a technical poster during the DD&R Poster Session Figure 19. Her presentations was based on the collaboration between DOE, FIU, and the Energy Facility Contractor's Group (EFCOG) to identify and develop lessons learned and best practices from across the DOE complex and disseminate the final documents to the DOE community by publishing them on the EFCOG website (www.efcog.org) and the D&D Knowledge Management Information Tool (www.dndkm.org).

Energy Facility Contractors Group Lessons Learned and Best Practices

Authors: Heidi Henderson, Lee Brady, Leonel Lagos, Peggy Shoffner (FIU)
Presenter: DOE Fellow Heidi Henderson

Figure 19. DOE Fellow Heidi Henderson presenting her poster at the DD&R Conference.

FIU staff and DOE Fellows also participated in the Waste Management 2013 Symposia. An oral presentation was given to present the results of FIU's work with the International Climbing Machine (ICM) technology vendor in demonstrating a remote platform technology for remotely applying fixatives, strippable coatings, and decontamination gels. The presentation further presented the results of the feasibility study with ICM on using the remote platform for remotely removing strippable coatings (Figure 20).

Application and Removal of Strippable Coatings via Remote Platform

Authors: Leonel Lagos, Peggy Shoffner (FIU), Sam Maggio, Blake Fall-Conroy (ICM)
Presenter: Peggy Shoffner

Figure 20. Peggy Shoffner presenting Application and Removal of Strippable Coatings via Remote Platform at WM13

FIU also made a presentation on the challenges and accomplishments of the sensor network demonstration for *in situ* decommissioning (Figure 21). Many of the conference attendees were interested in the results of the research efforts, as implementation strategies were defined for a heterogeneous sensor network that can assist many of the environmental remediation challenges faced within the Complex.

Sensor Network Demonstration for In Situ Decommissioning

Authors: Leonel Lagos, Amer Awwad, Jose Varona, Jose Rivera, Joel McGill (FIU)
Presenter: Jose Varona

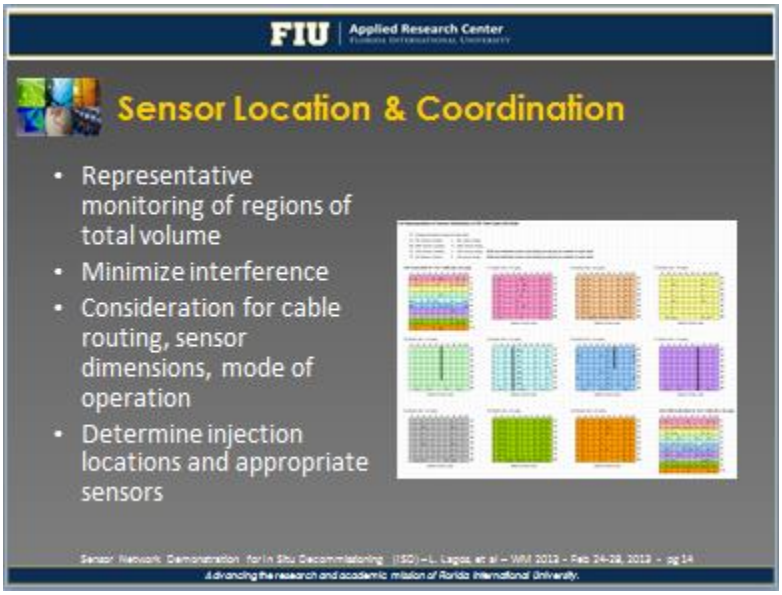


Figure 21. Screenshot of presentation at WM13 for the sensor network demonstration

Three DOE Fellows presented student posters on their research work related to this project. DOE Fellow Elicek Delgado-Cepero presented the design considerations for monitoring using batteryless RFID sensing platforms inside grout, used for decommissioning DOE's nuclear facilities.

Battery-less Wireless Sensors for Structural Health Monitoring for In Situ Decommissioning of DOE Facilities

Presenter: DOE Fellow Elicek Delgado-Cepero.

DOE Fellow Joshua Midence presented the Saltstone formulation (a cementitious mixture) for producing a grout waste form that meets both placement and performance properties.

Saltstone Processing of Low-Level Waste at Savannah River Site

Presenter: DOE Fellow Joshua Midence

Finally, DOE Fellow Raul Ordonez presented his research on alternative sources of energy and methods to diminish energy consumption for electrical resistance tomography systems used to monitor the performance of cementitious materials used for *in situ* decommissioning at the Savannah River Site (Figure 22).

Sensor Network Energy Demand for In Situ Decommissioning Applications at Savannah River Site

Presenter: DOE Fellow Raul Ordonez

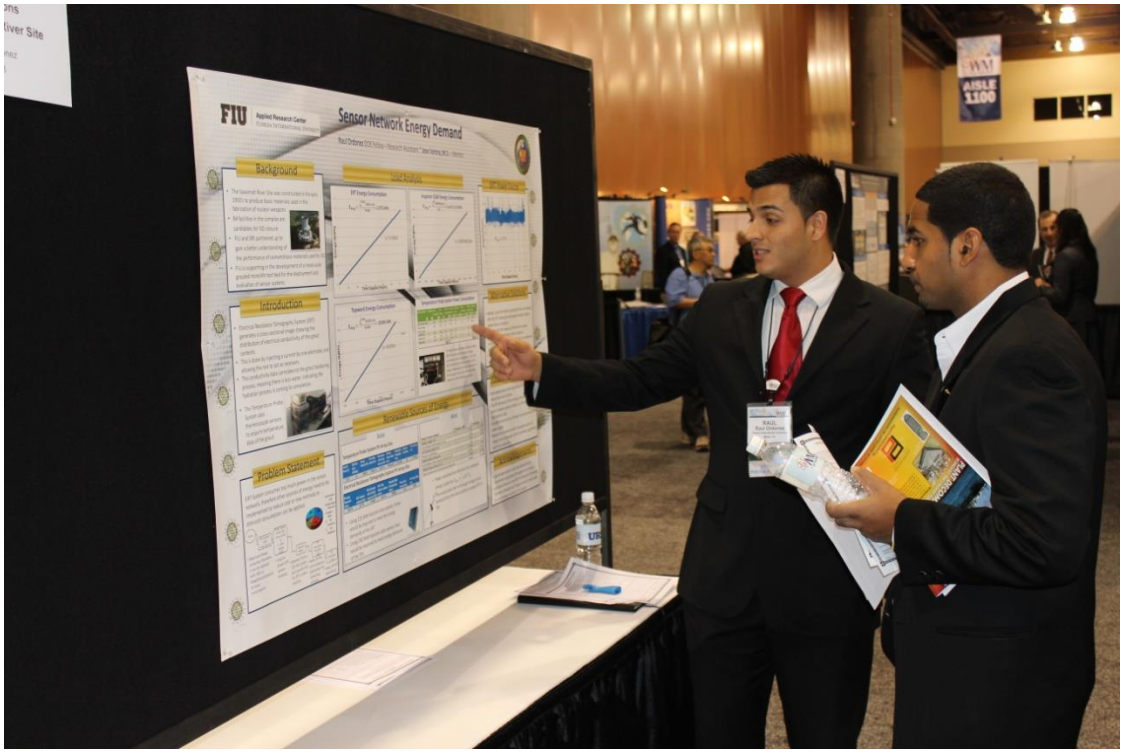


Figure 22. DOE Fellow Raul Ordonez presenting his student poster at WM13.

TASK 2: CONCLUSIONS

Planning for the D&D of facilities across the DOE complex is a tremendous undertaking, especially considering that a significant number of the facilities contain hazards to human health and the environment: seriously deteriorated structural integrity, very high dose rates, high levels of fixed and removable contamination on/in facility surfaces and equipment, and chemically hazardous materials. Providing support for technology innovation, development, evaluation, and deployment is critical to the safe and efficient completion of facility D&D.

TASK 2: REFERENCES

Florida International University, *In-Situ Decommissioning Sensor Network Meso-Scale Test Bed (ISDS-MSTB) Construction Report*, Final Report, March 2012.

Florida International University, *ISD Meso-Scale Test Bed Shared Data Network Demonstration Report*, December 2012.

International Climbing Machine, *ICM Climbing Machine Operations Manual*, ICM (2010).

Lagos, L., P. Shoffner, S. Maggio. *Application and Removal of Strippable Coatings via Remote Platform*, Waste Management 2013, Phoenix, AZ, February 2013.

Maggio, S., *Draft Feasibility Study for the Remote Controlled Removal of Strippable Coatings with the ICM Climbing Machine Technology* (Draft), ICM-FIU Report, April 2012.

Maggio, S., C. Gil, B. Fall-Conroy, *Phase II Remote Removal of Strippable Coatings using Robotic Platform*, ICM-FIU Report, December 2012.

Taboas, A.L., A.A. Moghissi, and T.S. LaGuardia, The Decommissioning Handbook, The American Society of Mechanical Engineers (ASME), 2004.

TASK 3.
D&D KNOWLEDGE MANAGEMENT INFORMATION TOOL

TASK 3: EXECUTIVE SUMMARY

For Task 3, FIU has developed a D&D Knowledge Management Information Tool (D&D KM-IT) to maintain and preserve the D&D knowledge base and to provide a focused web-based tool to assist the DOE D&D community in identifying potential solutions to their problem areas by using the vast resources and knowledge-base tools available through the web. During FIU Year 3, FIU performed several subtasks, including, community outreach and training, application development, system/database/network administration, data mining, and certification and accreditation (C&A) readiness.

TASK 3: INTRODUCTION

Planning for the D&D of facilities across the DOE complex is a tremendous undertaking. Capturing the knowledge, experience, and lessons learned from historic D&D activities at DOE sites is imperative to the successful and safe management of future D&D projects. The D&D Knowledge Management and Information Tool is a central initiative to accomplish these goals.

The D&D KM-IT is a web-based system developed to maintain and preserve the D&D knowledge base. The system was developed by FIU-ARC with the support of the D&D community, including DOE-EM (EM-13 & EM-72), the former ALARA centers at Hanford and Savannah River, and with the active collaboration and support of the DOE's Energy Facility Contractors Group (EFCOG). The D&D KM-IT is a D&D community driven system tailored to serve the technical issues faced by the D&D workforce across the DOE Complex. D&D KM-IT can be accessed from web address http://www.dndkm.org.

TASK 3: EXPERIMENTAL

The D&D KM-IT is a web-based knowledge management information tool custom built for the D&D user community by FIU. The objective of the D&D KM-IT is to provide a focused web-based tool to assist the DOE D&D community in identifying potential solutions to their problem areas by using the vast resources and knowledge-base tools available through the web. One such knowledge-base tool includes solutions provided by subject matter specialists who respond to specific questions. The D&D KM-IT archives, in a retrievable module within the system, information collected from the subject matter specialists, thereby building a knowledge repository for future reference. The primary subtasks for FIU Year 3 included community outreach and training, application development, system/database/network administration, data mining, and certification and accreditation (C&A) readiness.

TASK 3: RESULTS AND DISCUSSION

Outreach and Training

Significant effort was made towards community outreach in support of the D&D KM-IT system during FIU Year 3. FIU participated in meetings and conferences, hosted conference exhibitor

booths, finalized a project overview PowerPoint presentation, collaborated with international organizations, and disseminated newsletters on D&D KM-IT to registered users, subject matter specialists, and conference attendees.

Conferences

FIU participated in relevant meetings and conferences in support of this project. FIU presented D&D KM-IT during a technical session to the American Nuclear Society's Decontamination, Decommissioning, and Reutilization (DD&R) conference on June 27. 2012. Himanshu Upadhyay presented the Service Oriented Architecture Based Framework for D&D Knowledge Management to a live audience at the conference (Figure 23). D&D KM-IT web and mobile systems generated a lot of interest in the D&D community when presented to the conference participants which included U.S. and international attendees. The web system can be viewed at www.dndkm.org and the mobile version can be seen at http://m.dndkm.org.

Service Oriented Architecture Based Framework for D&D Knowledge Management

Authors: Himanshu Upadhyay, Leonel Lagos
Presenter: Himanshu Upadhyay

Figure 23. Himanshu Upadhyay presenting D&D KM-IT at DD&R 2012

In addition, FIU also hosted an exhibitor booth at the DD&R Conference. The booth was managed by Himanshu Upadhyay, Peggy Shoffner and DOE Fellows to showcase the D&D Knowledge Management Information Tool, the DOE Fellows Program, and DOE-EM applied research being conducted at the Applied Research Center in the areas of waste processing, soil and groundwater remediation, and deactivation and decommissioning. Fact sheets describing ARC research and projects were distributed to participants visiting the booth to increase awareness about FIU and ARC.

FIU also participated in the Waste Management Symposium 2013 from February 24 to February 28, 2013, in Phoenix, AZ. FIU gave an oral presentation entitled, *Knowledge Framework Implementation with Multiple Architectures* (Figure 24). This presentation discussed the various

development and deployment architectures like n- tier architecture, web/client server architecture and service oriented architecture. It explained the features and advantages/disadvantages of each of the various architectures and the development of knowledge framework. All the modules of the D&D KM-IT framework were discussed and demonstrated. Attendees were encouraged to sign up as a registered user and subject matter specialist in D&D KM-IT.

Knowledge Framework Implementation with Multiple Architectures

Authors: Himanshu Upadhyay, Leonel Lagos, Walter Quintero, Peggy Shoffner (FIU), John De Gregory (DOE)
Presenter: Himanshu Upadhyay

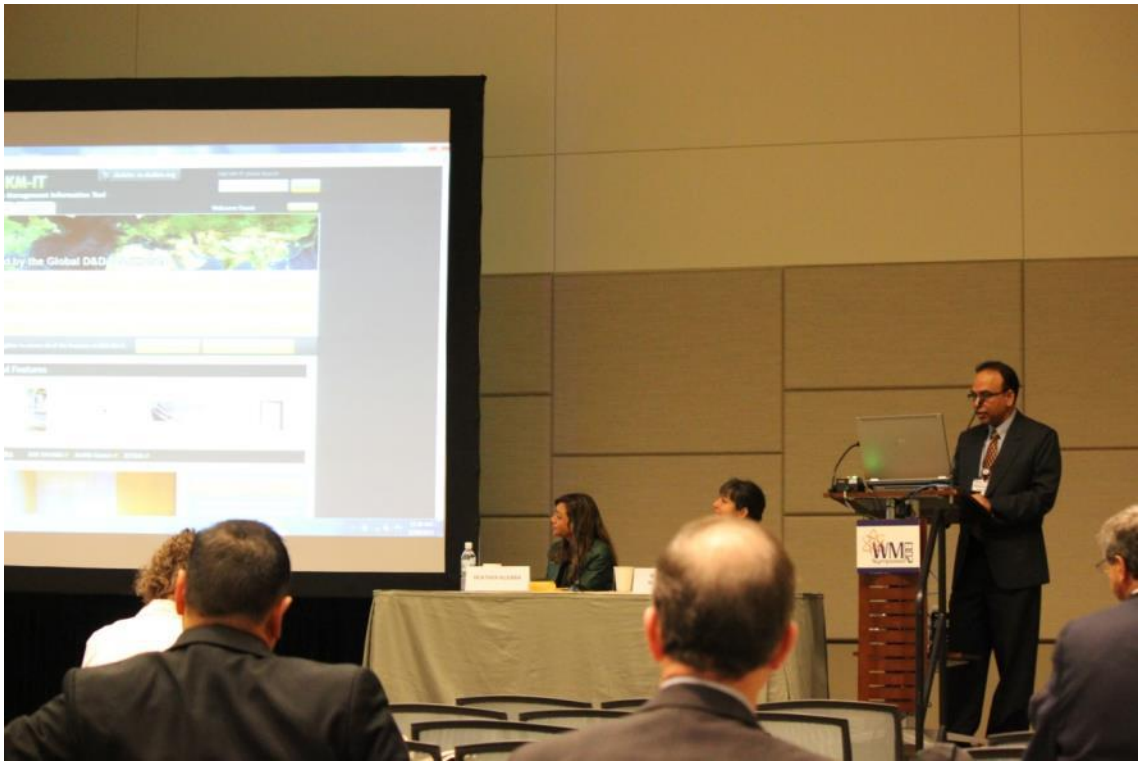


Figure 24. Himanshu Upadhyay presenting *Knowledge Framework Implementation with Multiple Architectures* at WM13.

During the WM13 Conference, FIU hosted a booth (#635) in the exhibiters' hall to provide conference attendees with additional information on the DOE-EM applied research being conducted at ARC. Projects fact sheets were made available, as well as DVD and CD containing description of the DOE-EM applied research as well as results of the research conducted. Also, a live demonstration of the D&D Knowledge Management Information Tool (Figure 25) was conducted at the ARC booth. Conference attendees were encouraged and assisted with registering as users on D&D KM-IT.

Figure 25. FIU Staff and DOE Fellows attending WM13.

The following three posters related to KM-IT were also presented at the WM13 conference (Figures 26 to 28).

A student poster entitled *D&D Technology Services Development using Windows Communication Foundation on Cloud* was presented by Revathy Venkataraman (DOE Fellow) at the 2013 Waste Management Symposium Student Poster Competition (Figure 26). This poster presented the technology services module provides comprehensive information on D&D related technologies, demonstrations and benefits including characterization, decontamination, dismantlement, worker health and safety and commercial vendors. The technology server module is being developed using Microsoft windows communication foundation services to study its performance, flexibility, implementation cost, scalability, interoperability and security of data when hosted in a cloud environment.

D&D Technology Services Development using Windows Communication Foundation on Cloud

Presenter: DOE Fellow Revathy Venkataraman

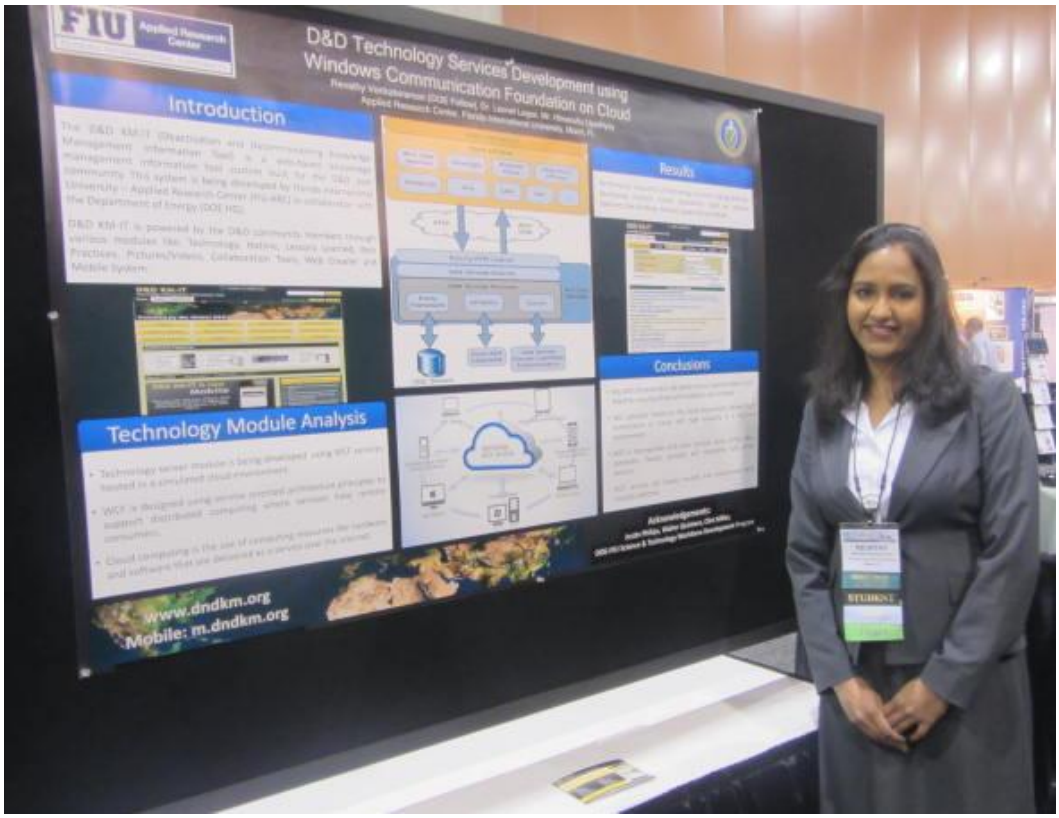


Figure 26. DOE Fellow, Revathy Venkataraman, presenting student poster titled *D&D Technology Services Development using Windows Communication Foundation on Cloud* at WM13.

A student poster entitled *Applications for Mobile Devices using Cloud Computing on Service Oriented Architecture* was presented by Justin Phillips (FIU Student) at the 2013 Waste Management Symposium Student Poster Competition (Figure 27). This poster presented three applications (based on jQuery, ASP.NET C#, and the Android Operating System environment) were created to test the performance and viability of service-oriented architecture in the mobile development task to ensure that it meets the standards and requirements for the D&D Knowledge Management Information Tool Mobile Application.

Applications for Mobile Devices using Cloud Computing on Service Oriented Architecture

Presenter: Justin Phillips

Figure 27. Justin Phillips presenting student poster titled *Application of Mobile Devices using Cloud Computing using Service Oriented Architecture* at WM13.

A student poster entitled *SharePoint Based Secured Collaboration System for DOE-EM Project Management* was presented by Mariela Silva (DOE Fellow) at the 2013 Waste Management Symposium Student Poster Competition (Figure 28). This poster presented a SharePoint-based secured collaboration system was implemented to enhance progress tracking, monitoring, and communication for five major projects that represent the continued support of Florida International University to DOE's Office of Environmental Management in its mission of accelerated risk reduction and cleanup of the environmental legacy of the nation's nuclear weapons program.

SharePoint Based Secured Collaboration System for DOE-EM Project Management

Presenter: DOE Fellow Mariela Silva

Figure 28. Mariela Silva presenting poster titled *SharePoint Based Secured Collaboration System for DOE-EM Project Management* at WM13.

Publications

An article on D&D KM-IT entitled, *Deactivation & Decommissioning (D&D) Knowledge Management– A Partnership between DOE, Contractors and Academia*, was published in the September-October 2012 edition of Radwaste Solutions.

Presentation

In addition, FIU finalized a PowerPoint presentation to present the D&D KM-IT project to upper level DOE management and other audiences (Figure 29). Portions of the presentation were used during the FIU Research Presentations to DOE from April 29 to May 1, 2013. The presentation was also used to present D&D KM-IT during a webinar with the Environmental Radiological Assistance Directory (ERAD) on June 27, 2012. The ERAD webinars originate at DOE HQ and are attended by personnel across the complex.

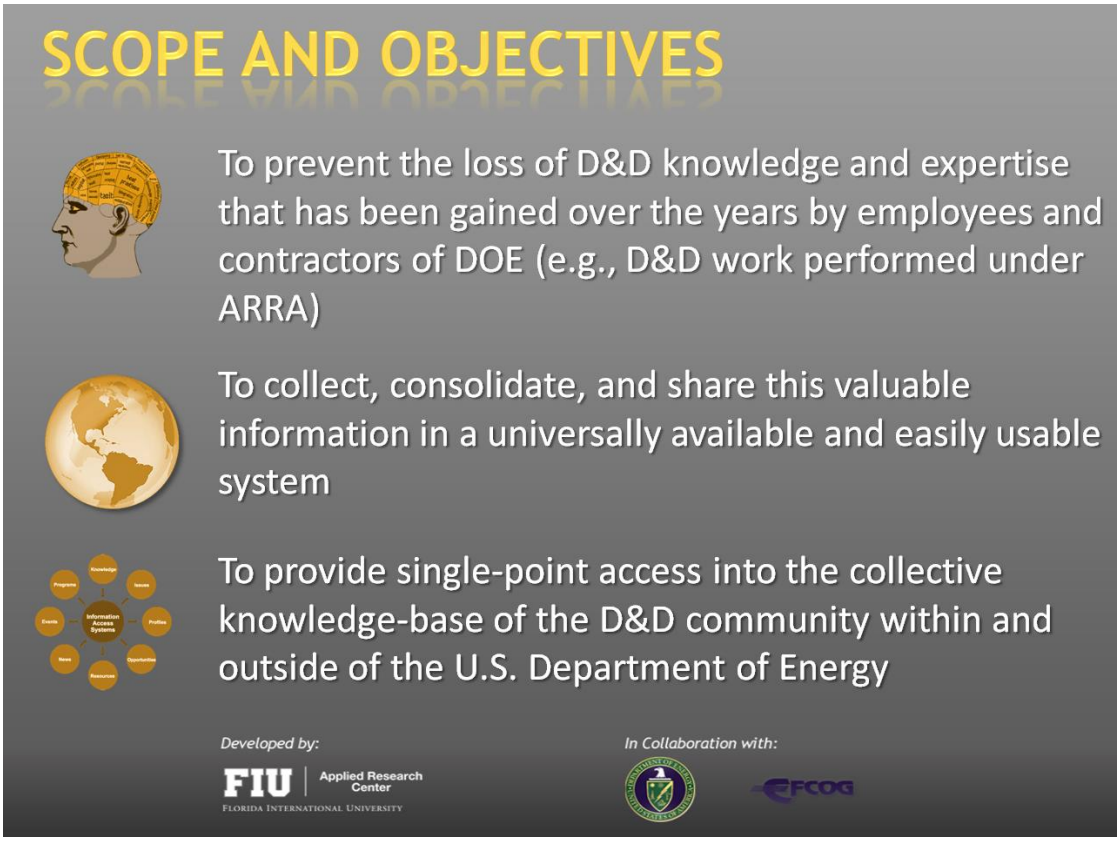


Figure 29. Sample slide for D&D KM-IT PowerPoint presentation.

User Outreach and Support

Also as part of the outreach effort, FIU created targeted newsletters to send electronically to D&D KM-IT registered uses, subject matter specialists, EFCOG D&D Working Group members, and Waste Management Conference attendees. These newsletters informed the recipients of current and newly added features of D&D KM-IT and provided quick links to the system website so that they could immediately try out the enhancements.

FIU provides training and support to the D&D KM-IT user community. A couple of examples are described here. One registered user from Lawrence Livermore National Laboratory contacted FIU for assistance in using the D&D KM-IT system to find an answer to his question related to the possible use of liquid nitrogen to remove radiologically contaminated asbestos floor tiles. FIU provided the user with a demonstration of the various modules of the system and assisted him in performing a search for his problem within the Hotline module. An identical question had been captured from an archived Hanford ALARA newsletter (February 18, 2010) and made available within the D&D KM-IT; the user was able to review both the original question and the solutions provided and was highly satisfied.

Another registered user contacted FIU for assistance in locating a report on various strippable coatings for radioactive materials. FIU was able to direct him to the several problems and solutions related to fixatives and strippable coatings in the KM-IT Hotline module as well as the Contamination Control Fixative List available within the Document Library. In addition, FIU

provided a list of other related reports and subsequently sent him a report titled, "Testing for Radiological Decontamination Strippable Coating for Cellular Bioengineering, Inc."

International Outreach

As an outreach effort for international collaboration, FIU worked with Sellafield Ltd to find areas of collaboration within the scope of D&D KM-IT:

- Comparisons of the D&D KM-IT subject matter specialist (SMS) areas of expertise and the listing of UK Technical Centres of Expertise (CoEs) were made. CoEs were invited/encouraged to register as subject matter specialists (SMS). The CoEs are Sellafield's community of recognized experts in a range of science and engineering subjects (similar to the subject matter specialists in D&D KM-IT). Four (4) SMS are currently registered from Sellafield Ltd.
- Links to the D&D KM-IT have been placed on the Sellafield intranet for the technical organizations, along with a descriptor paragraph on its benefits.
- A report by Sellafield Ltd for the UK Nuclear Decommissioning Authority titled "Technology Development and Delivery Summary 2011-2012" was integrated into the D&D KM-IT Document Library and is available for download (Figure 30).
- FIU extracted D&D related technology information from the report for integration with the D&D KM-IT Technology Module. Sellafield completed their review of the total of 23 D&D-relevant technologies that FIU extracted from the Sellafield report and integrated into KM-IT. These technologies were made live to the public and can be displayed within the D&D KM-IT system by entering "Sellafield" into the Technology Module search feature.

Figure 30. Screenshot of Technology Report from Sellafield in the Document Library Module of D&D KM-IT

Application Development

During FIU Year 3, FIU continued the development of the D&D KM-IT application and maintained the system for the D&D community at http://www.dndkm.org.

Application optimization

One type of application optimization that FIU performed in FIU Year 3 was a search engine optimization process for the D&D KM-IT web application. Search engine optimization (SEO) is the process of improving the visibility of a website or a web page in the search results provided by internet search engines (e.g., Google, Bing). In general, more users will visit sites that appear high or frequently on the search engine results page. SEO targets different kinds of searches, including image search, local search, video search, academic search, news search and industry-specific vertical search engines.

FIU has also been collecting and using web analytics to analyze the use of the D&D KM-IT website and implement website improvements. A summary of the 2012 web analytic data is shown in Figure 31. FIU finalized an annual report on the web analytics based on comments from DOE. The purpose of the report is to take a "bird's eye view" of the web traffic on D&D KM-IT for the past year. The period covered is from February 2011 to February 2012. In addition, D&D KM-IT Performance Analysis Reports were completed and submitted to DOE on October 15, 2012; January 24, 2013; and April 18, 2013.

The information gathered from the web analytics software is valuable since it provides insight on site visitor behavior and is helpful to anticipate users' interests and needs. Web analytics has allowed D&D KM-IT to respond to its users' needs by making the information they seek easier for them to access. The ultimate aim is to mature a system that will contain all the necessary information for the D&D KM-IT community and allow the users of the system to consume the information as efficiently as possible across all module and platforms.

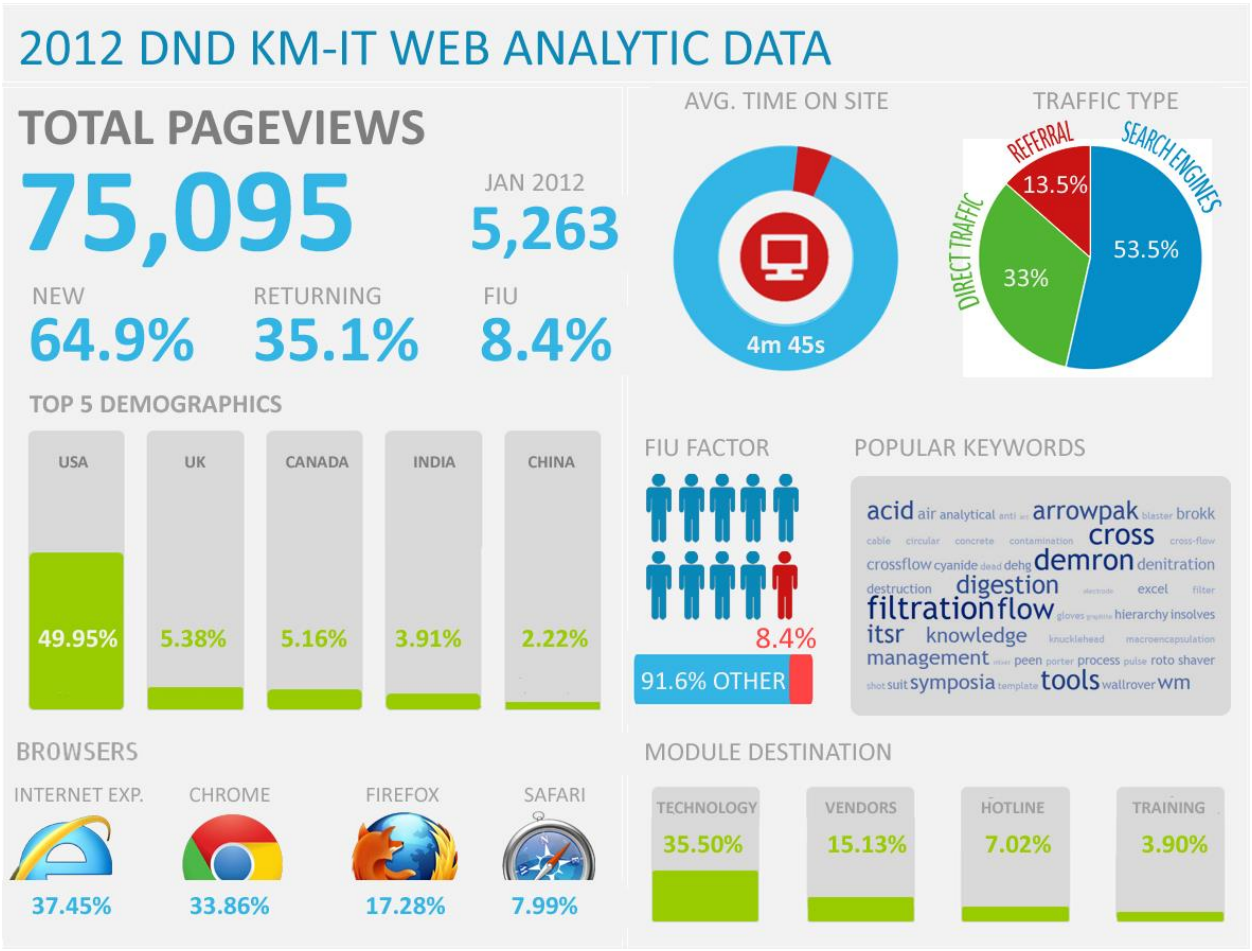


Figure 31. D&D KM-IT Web Analytic Data for 2012.

The primary application optimization that FIU implemented during FIU Year 3 is the user interface enhancement, also known as the new website look. FIU developed a new website template based on web semantics and the latest standards, including placement of page elements and the addition of machine readable content which can be used by search engines for better ranking of the system. Many descriptors were added to the template which can be picked up by popular search engines like Google and Bing as well as analytical tools like Alexa. It also provided the foundation for a uniform look across all modules and the ability to navigate to different modules from each screen.

The new template was first completed for the Technology Module and sent to DOE for review on September 5, 2012 (Figure 32). The new look is based on new HTML5 standards, machine semantic friendly HTML structure, dynamic meta data, and a more intuitive layout with element placement based on Google Analytic data. The data descriptors used are compatible with Google, Yahoo, and Bing search engines. The HTML5 standard used will help future proof the tool as well as provide a more dynamic user experience, such as animations, few page loading events, access to sharing tools, and so on.

Once DOE approved of the new website template on the Technology Module, FIU then used the template throughout the rest of KM-IT to create a unified look and feel, a more dynamic user experience, and better search engine indexing. The new template features more dynamic logins, faster access to other modules via a module list dropdown, greater page width, and larger fonts with type enhancements for more readability. The user interface enhancement for the D&D KM-IT website was completed on April 12, 2013 and deployed on the staging server for DOE review.

The new interface leverages HTML5 improvements for structured data, performance, and aesthetics. Certain elements of navigation and forms (login, radio buttons, photo gallery, etc.) have been updated with a dynamic feel. Bing and Alexa have been integrated into the website analytic tools, along with updated sitemaps. Finally, RSS has been integrated into Technology, Training Classrooms, Training Events, and News modules.

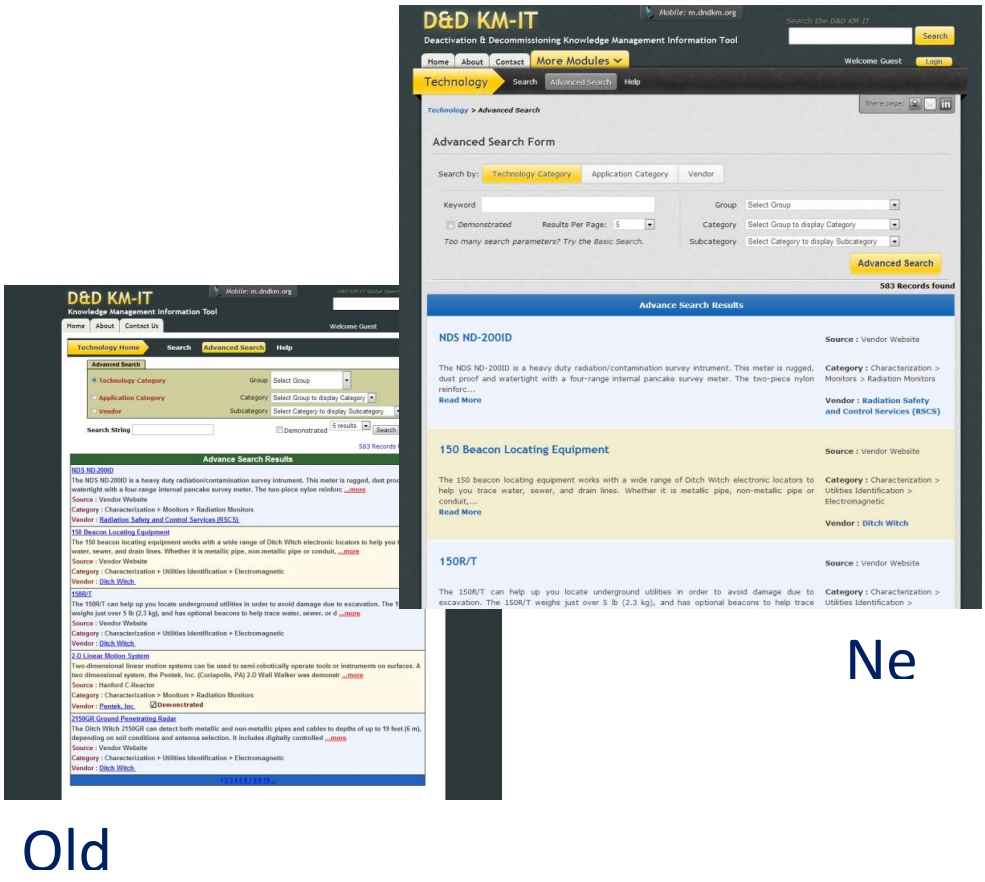


Figure 32. Comparison of old and new D&D KM-IT website interface.

SRS ISSC Report Integration

FIU successfully completed the integration of all reports from Savannah River Site's Integrated Safety Solutions Center into KM-IT on July 12, 2012 (Figure 33). This is accessible from the Document Library section of KM-IT. The document library provides a digital archive for storing and retrieving D&D related documents. Main features of this module are as follows:

- **SRS Integrated Safety Solutions Center (ISSC)** where the ISSC reports from 2003 to 2012 are published.
- **International Reports** where the Sellafield Technology report is published and where any future international reports received will be available.
- **Documents** section will contain a static links to all general documents that do not fit into other modules of KM-IT. It has one section dedicated to ARC EM D&D reports which will be expanded to include all reports related to D&D work performed by ARC for DOE HQ and field sites.
- **Hanford ALARA** contains all of the available bi-weekly reports from the former Hanford ALARA Center.
- **Report Search** is the implementation of the D&D web crawler for the SRS ISSC and ALARA reports. The ALARA reports are stored on the KM-IT server and are searched by the crawler using the search keywords. The SRS ISSC reports are stored on the SRS server and it is searched in real time by the D&D KM-IT web crawler. There is no duplication of reports as we search SRS reports on their server and bring the matched results links and display into KM-IT.
- **Innovative Technology Summary Reports** (ITSRs), also known as Green Books, are also available from the D&D KM-IT Document Library.

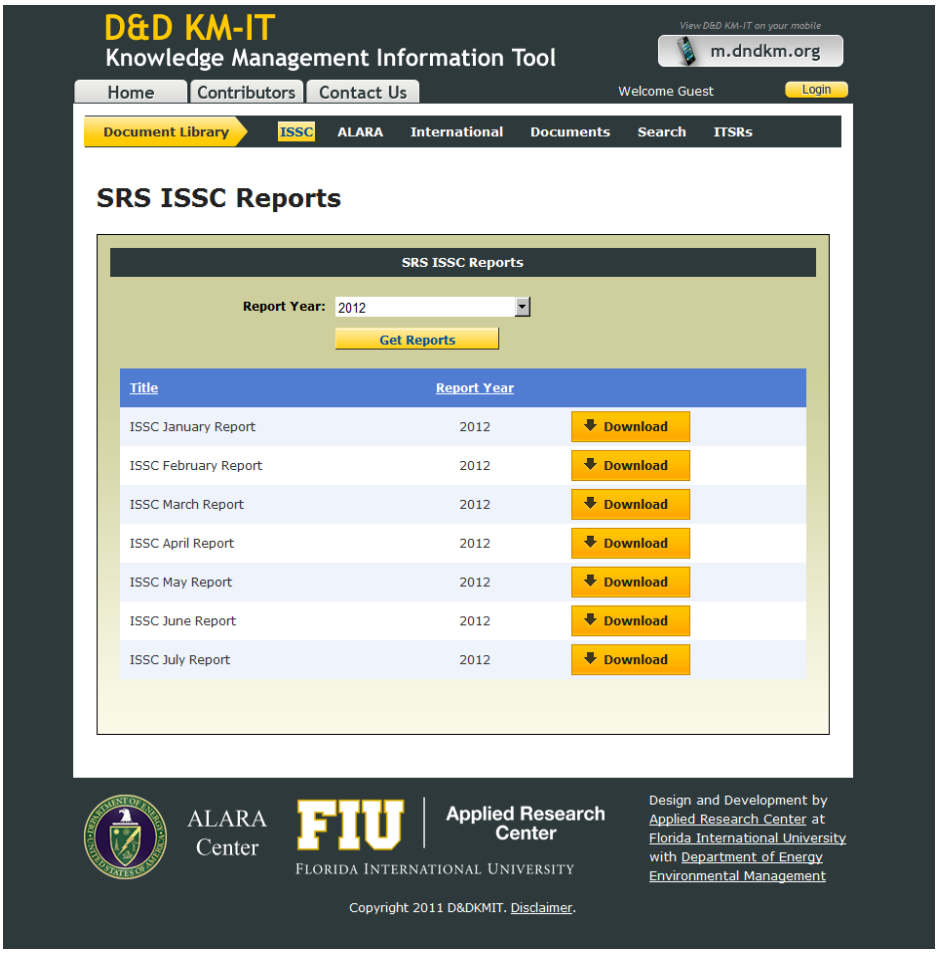


Figure 33. Screenshot of SRS ISSC Reports Feature on D&D KM-IT.

Global Search

FIU successfully completed the Global Search feature of D&D KM-IT and deployed it onto the D&D KM-IT public server on October 25, 2012. The global search box appears on the top right corner of the screen on all of the modules (Figure 34). A user can enter a search keyword and click the search button. The global search process searches through all the modules of KM-IT, including all the documents and KM-IT webpages.

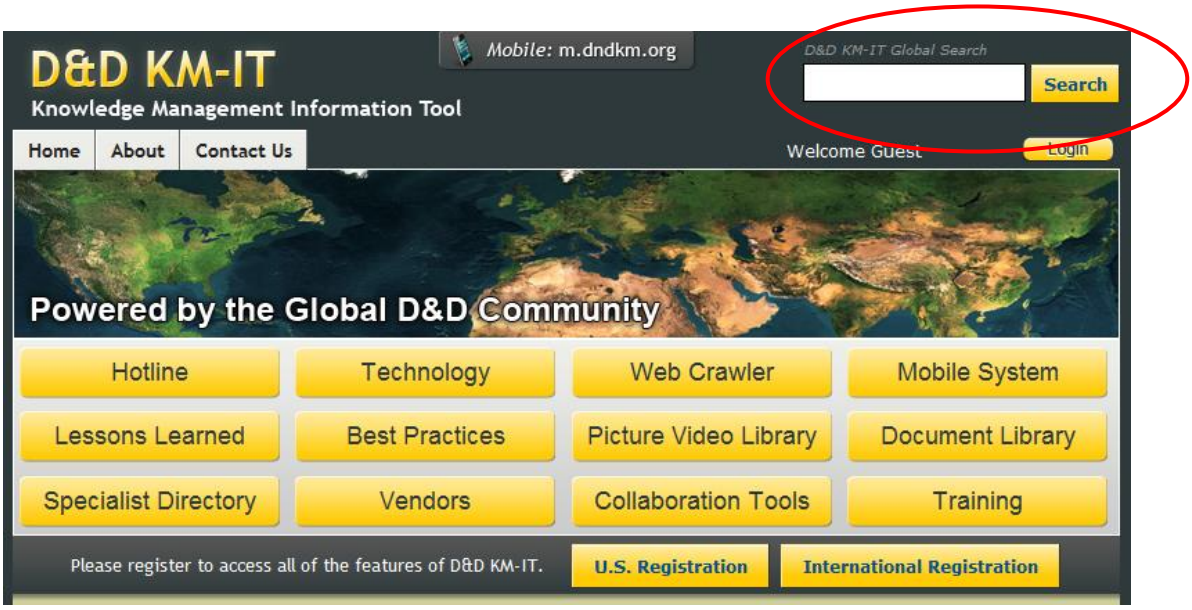


Figure 34. Global search feature has been added to D&D KM-IT.

D&D Dictionary

FIU successfully completed the development of the D&D Dictionary feature of D&D KM-IT (Figure 35). It was deployed on the staging server for DOE review on September 28, 2012 and deployed onto the public server on October 25, 2012. The D&D Dictionary is integrated into the training module and allows users the option to list keywords or to view all. The system then displays the summary results with a "continue reading" link to the details page. FIU researched and collected information on extensively searched D&D keywords, extracted from Google Analytics under the data management task, for inclusion in the D&D Dictionary.

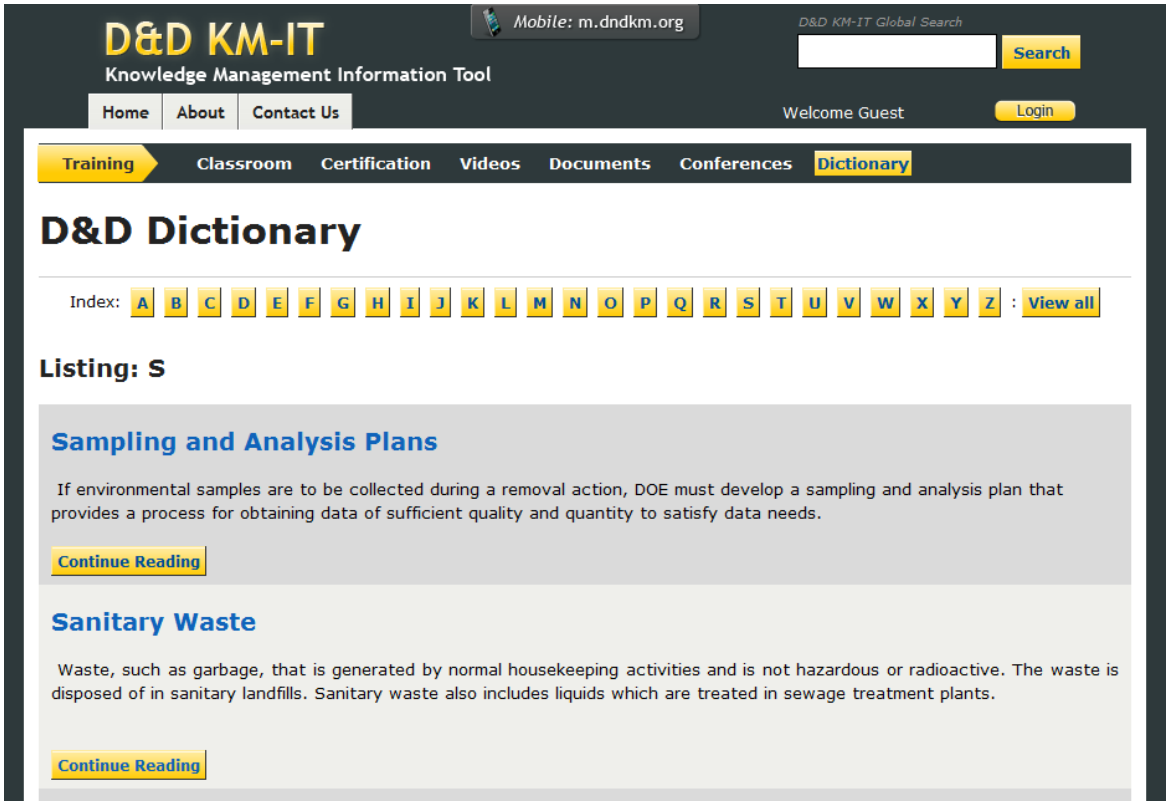


Figure 35. New D&D dictionary feature on D&D KM-IT.

Collaboration Tools

The Collaboration Tools module received DOE approval and was made live on September 20, 2012 (Figure 36). Collaboration Tools provide a platform for collaboration among the D&D community members and currently includes features such as news, event calendars, links, and FAQs. The various information tools will facilitate the exchange of information within the D&D community. Users will be able to post events and other news on the site, which will be published after administrative approval. It is envisioned that in future development of this module, registered users will be able to more actively participate with other members of the D&D community.

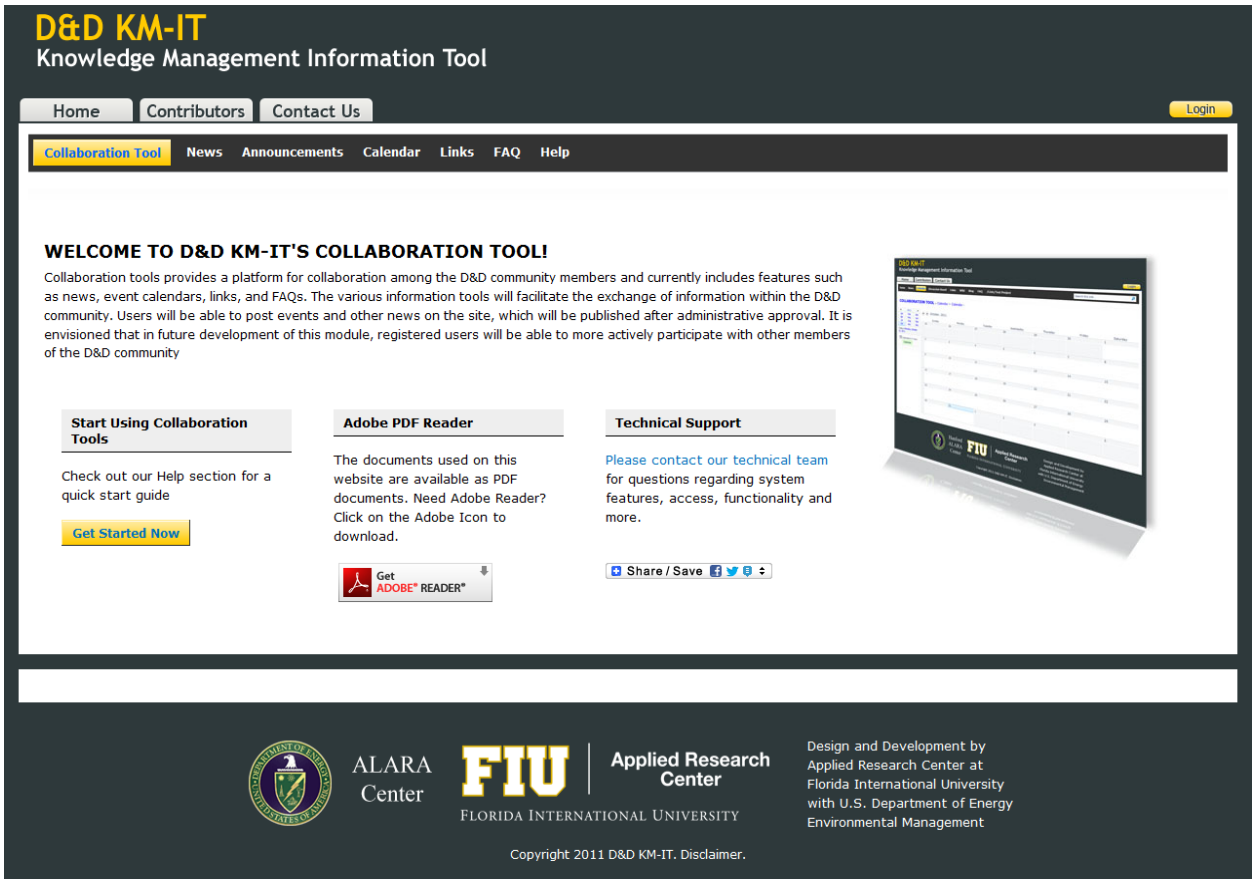


Figure 36. D&D KM-IT Collaboration Tools Module.

Training Module

The Training Module was revised based on comments received from DOE and the collaborators from ANL and ORAU. The module was launched live on the D&D KM-IT website on July 30, 2012. The Training module provides a central location for information on D&D related training. The main features of the Training module include:

- D&D Conferences & Workshops
- Classroom Training Opportunities
- Available D&D Certifications
- Training Videos
- Training Documents

Multiple SMS Support to D&D Hotline

FIU successfully completed, deployed and tested the multiple subject matter specialists (SMS) support for the D&D Hotline. With this process, when the user submits the problem, the system administrator receives automatic notification. After reviewing the posted problem, the administrator triggers the multiple SMS emailing process which sends an email to all the

registered SMS in the system. Once one or more solutions are received from the SMS, they are published in KM-IT and assigned to the expert who provided the solution.

Mobile development

Mobile development for the D&D KM-IT system is a challenging area because of the existence of multiple platforms, technologies, operating systems and hardware devices in the field. While the mobile application completed for D&D KM-IT during FIU Year 2 (for the Vendor and Specialist Directory modules) used the standard web-based development process, FIU realized that a significant amount of research in the technology, platform, development processes and framework, etc., was needed for future D&D KM-IT mobile development. During FIU Year 3, FIU completed the research work needed to establish the best development process for mobile systems which can be implemented in all the future modules of D&D KM-IT. This was done by developing the mobile vendor management module for two additional mobile platforms and evaluating its performance against the current standard web-based system. The best architecture will be used for the development of future D&D KM-IT mobile modules.

Service oriented architecture (SOA) is a development model for building distributed applications in a heterogeneous environment. This model depends on the transfer of messages between services and applications. The request and response messages used in the SOA model are either Extensible Markup Language (XML) or JavaScript Object Notation (JSON). This is a mature, widely distributed model that is now being utilized in mobile device development. To test the performance and viability for implementing the SOA model in the mobile development project for D&D KM-IT, three applications were created. The first, based on jQuery (a widely used JavaScript library), sends and receives messages via Asynchronous JavaScript and XML (AJAX); the second application is an ASP.NET C# application that interacts with the service via request made on the server hosting the application; the third application was built using the Android Operating System's (OS) environment, sending and receiving messages via a multithreaded send/receive class. The two former applications are accessible on mobile devices via the web browser, the latter is an application that runs locally on the device; all of the applications utilize the cloud to send and receive messages. The results of this test conclude that the native application running on the Android OS outperforms the other two applications by large margins. However, its viability is limited as there is a much higher development cost and upkeep compared to a browser based application. When comparing the two browser-based applications, the clear winner is the ASP.NET C# application; the ability for computation to be done on the server creates a very noticeable performance gap between it and the jQuery AJAX application. These results will ensure that the development process and environment used in the D&D KM-IT Mobile Application meet or exceed the standards and requirements of the D&D KM-IT. A draft summary report with the results for the mobile development research was completed and sent to DOE on December 14, 2012. Figure 37 shows the client-server interaction between the different development methods.

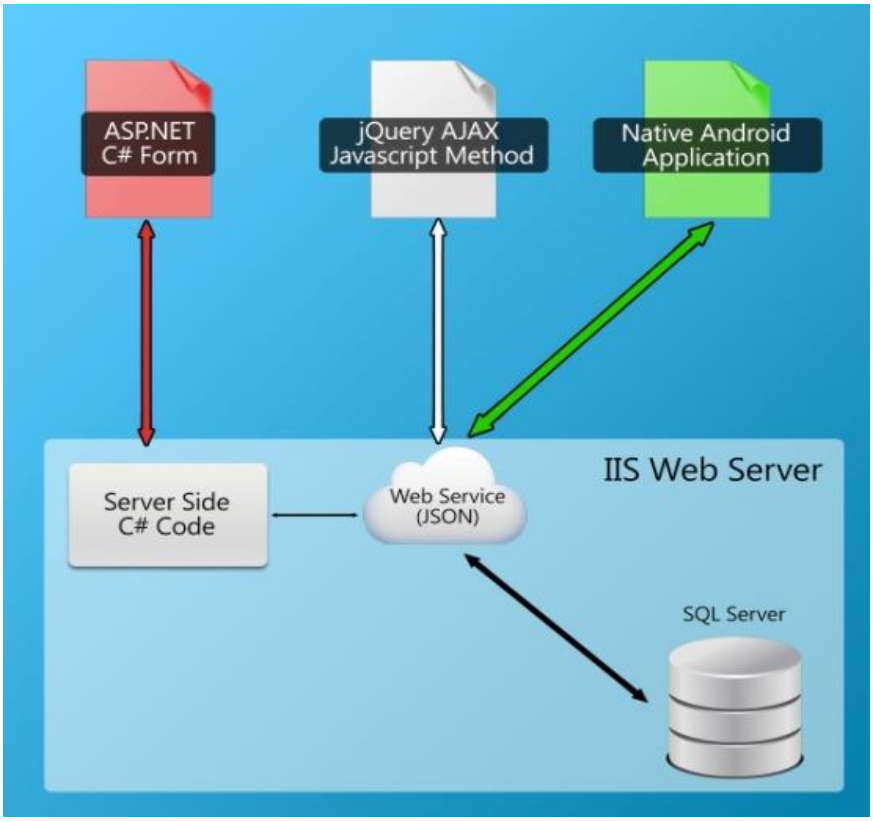


Figure 37. Client- Server interaction between different development methods.

Subsequent to the mobile development research, FIU completed the development and deployment of the picture lite mobile application (January 18, 2013) and the technology lite mobile application (February 15, 2013). These mobile applications allow users to access the information on the D&D KM-IT Picture Video Library and Technology Module on their mobile devices, such as iPhone, iPad, Blackberry, Android, and Windows smart devices.

Help Videos

FIU completed the development of 16 D&D KM-IT help videos to assist users in the overall use of D&D KM-IT and specific use of each module and deployed them on the staging server for DOE review on May 16, 2013. These videos are deployed in Help section of individual modules. The number of videos developed for each module is as follows:

- Hotline (3)
- Best Practice (1)
- Lessons Learned (2)
- Mobile (1)
- Picture Library (2)
- Subject Matter Specialists (2)
- Technology (1)

- Vendors (2)
- Training (2)

Administration

System, database, and network administration are ongoing activities that FIU undertakes to maintain servers and applications to ensure a consistent high level of performance. FIU continued these efforts during this reporting period. System administration included the day-to-day maintenance and administration of the D&D KM-IT servers. Major tasks involved load balancing, active directory accounts, security patches, operating system updates, system optimization, server monitoring, and emergency problem resolution. Database administration included database backup, optimization, performance tuning, system security, controlling and monitoring user access to the database, and maintaining the database cluster. Finally, the network administration involved monitoring the network and server traffic, installing and maintaining the network hardware/software, assigning addresses to computers and devices on the network, troubleshooting network activities and performance tuning.

Data Mining

EFCOG Lessons Learned and Best Practices

One data mining task for FIU Year 3 focused on capturing the manager experience through the EFCOG points-of-contact. FIU worked with EFCOG to identify lessons learned and best practices from across the DOE complex, engaged FIU staff and DOE Fellows by working with site managers to document their experiences, facilitated a review and approval process by DOE and EFCOG, and disseminated the final documents to the DOE community by publishing them on the EFCOG website (www.efcog.org) and the D&D Knowledge Management Information Tool (www.dndkm.org). This subtask is discussed in detail under Task 2.

Vendors and Technologies

FIU's DOE Fellows updated information for the vendor module by adding new vendor descriptions as well as areas of expertise for each vendor. DOE Fellows also worked on identifying and adding additional D&D vendors from various sources, including the Waste Management Symposia 2013 programs and industry journals. The DOE Fellows also continued adding technologies to the technology module from the archived Hanford ALARA and SRS ISSC newsletters as well as technologies identified from the newly added vendors. As of May 14, 2013, the Vendor module included a total of 588 vendors, an increase of 96 (20%) in the last year, and the Technology module included a total of 588 technologies, an increase of 143 (33%) in the last year.

Certification and Accreditation (C&A) Readiness

In preparation of meeting the guidelines and technical requirements of the DOE certification and accreditation (C&A) process, the FIU Applied Research Center used an internal auditor from FIU to perform the initial audit of the D&D KM-IT system and infrastructure. The audit was performed in early May 2012 and after testing the system and auditing the procedures and documentation based on NIST guidelines, the results were documented in a draft audit findings report. The audit report identified issues and categorized them as high, medium and low risks as

well as provided control categories of management, operational and technical. The findings were compiled into an initial report and sent it to DOE on June 19, 2012. The D&D KM-IT team implemented resolutions for the issues raised by the C&A internal audit and a summary report of the audit findings and the resolutions implemented was completed and sent to DOE on September 19, 2012.

A follow-up audit by the FIU security team was initiated in January 2013 and completed in February to test the resolutions against the identified vulnerabilities. A report was generated by FIU security team on the follow-up audit results and was used by the D&D KM-IT team to resolve all issues identified in the follow-up internal audit. A summary report was sent to DOE on April 18, 2013.

TASK 3: CONCLUSIONS

Planning for the D&D of facilities across the DOE complex is a tremendous undertaking, especially considering that a significant number of the facilities contain hazards to human health and the environment: seriously deteriorated structural integrity, very high dose rates, high levels of fixed and removable contamination on/in facility surfaces and equipment, and chemically hazardous materials. Capturing the knowledge, experience, and lessons learned from historic D&D activities at DOE sites is imperative to the successful and safe management of future D&D projects. The D&D Knowledge Management and Information Tool is a central initiative to accomplish these goals.

TASK 3: REFERENCES

D&D Knowledge Management Information Tool (D&D KM-IT), www.dndkm.org, Applied Research Center, Florida International University.

Phillips, J., *Leveraging Wikipedia and Wiki-Based Technologies – Significance to D&D Knowledge Management*, Rev. 1.2, White Paper, Applied Research Center, Florida International University, November 2011.

Phillips, J., *Performance Testing of Mobile Applications with Multiple Technologies,* White Paper, Applied Research Center, Florida International University, December 2012.

Quintero, W., *Annual Web Analytics Narrative Report for D&D KM-IT*, Applied Research Center, Florida International University, April 2012.

Upadhyay, H., L. Lagos, W. Quintero, P. Shoffner, J. De Gregory. *Knowledge Framework Implementation with Multiple Architectures*, Waste Management 2013 Conference, Phoenix, AZ, February 2013.

Upadhyay, H., L. Lagos, *Service Oriented Architecture Based Framework for D&D Knowledge Management,* American Nuclear Society, Decontamination, Decommissioning, and Reutilization (DD&R) Conference, June 2012.

OVERALL PROJECT CONCLUSIONS

WIMS continues to successfully accomplish the goals and objectives set forth by DOE for this project. WIMS has replaced the historic process of each DOE site gathering, organizing, and reporting their waste forecast information utilizing different database and display technologies. In addition, WIMS meets DOE's objective to have the complex-wide waste forecast information available to all stakeholders and the public in one easy-to-navigate system. The enhancements to WIMS made over the last year include annual updated data sets.

The D&D support work for this period of performance included the Phase II feasibility study of a remote platform for the remote removal of strippable coatings and decontamination gels, support to SRS in research and experimental testing for in-situ decommissioning, as well as D&D support to DOE-EM international programs and EFCOG. These activities provide DOE with the information necessary to complete D&D safely and effectively with technologies that include remotely operated technologies for facilities which contain hazards that prevent the use of safe manual techniques; enhance surveillance and monitoring capabilities for long-term applications applicable to monolithic structures; enhance safety while reducing risk to workers, the public, and the environment; reduce the future cost, schedule, and risk for similar work through a thorough understanding of existing technologies and technical approaches from past D&D projects, and provide the tools necessary to successfully complete difficult D&D tasks that can then be applied complex-wide to similar DOE facilities.

Planning for the D&D of facilities across the DOE complex is a tremendous undertaking. Capturing the knowledge, experience, and lessons learned from historic D&D activities at DOE sites is imperative to the successful and safe management of future D&D projects. The DOE D&D Support task and the D&D KM-IT are two central initiatives to accomplish these goals and FIU has made significant contributions towards developing these tools. The D&D KM-IT system was developed by FIU in collaboration with DOE (EM20), EFCOG, and the former ALARA Center at Hanford and former ISSC at Savannah River. The D&D KM-IT system is ultimately a tool for and by the D&D community. Its success will be dependent on the participation and cooperation of those for whom it was designed. FIU will continue to work closely with DOE, EFCOG, and the D&D community to ensure that the KM-IT system meets their needs for accurate and timely D&D information.

APPENDIX

The following reports are available at the DOE Research website for the Cooperative Agreement between the U.S. Department of Energy Office of Environmental Management and the Applied Research Center at Florida International University: http://doeresearch.fiu.edu

1. Florida International University, *In Situ Decommissioning (ISD) Meso-Scale Test Bed Shared Data Network Demonstration Report,* December 2012.
2. Maggio, S., C. Gil, B. Fall-Conroy, *Phase II Remote Removal of Strippable Coatings using Robotic Platform*, ICM-FIU Report, December 2012.
3. Phillips, J., *Performance Testing of Mobile Applications with Multiple Technologies,* White Paper, Applied Research Center, Florida International University, December 2012.
4. Quintero, W., *Annual Web Analytics Narrative Report for D&D KM-IT*, Applied Research Center, Florida International University, April 2012.

The following best practices and lessons learned were finalized during FIU Year 3 and are available for download from the D&D Knowledge Management Information Tool website: https://www.dndkm.org/BestPractices/SearchBestPractices.aspx?Query=All

1. Unanticipated High Dose During the Removal of Wire Flux Monitor Cabling from the Heavy Water Component Test Reactor (HWCTR) Vessel
2. Structural Code Guidance for D&D Activities at DOE Facilities
3. Electrical Code Guidance for D&D Activities at DOE Facilities