YEAR END TECHNICAL REPORT
September 29, 2018 to September 28, 2019

Waste and D&D Engineering and Technology Development

Date submitted:

January 17, 2020

Principal Investigator:

Leonel E. Lagos, Ph.D., PMP®

Florida International University Collaborators:

Leonel E. Lagos, Ph.D., PMP® (Project Manager)
Himanshu Upadhyay, Ph.D., PMP®
Joseph Sinicrope, M.S., MBA
Peggy Shoffner, M.S., PMP®
Walter Quintero, M.S.
Clint Miller, MCSE+Security
Mellissa Komninakis, B.S.
Thomas Donoclift, Ph.D.
DOE Fellows

Submitted to:

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

FIU | Applied Research Center
Florida International University

Addendum:

This document represents one (1) of four (4) reports that comprise the Year End Reports for the period of September 29, 2018 to September 28, 2019 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. Incremental funding under this cooperative agreement resulted in FIU having to execute carryover scope, which was completed in November 2019. The technical information for the carryover scope from FIU Performance Year 9 has therefore also been included in these reports.

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

Project 1: Chemical Process Alternatives for Radioactive Waste
Document number: FIU-ARC-2018-800006470-04b-264

Project 2: Environmental Remediation Science and Technology
Document number: FIU-ARC-2018-800006471-04b-263

Project 3: Waste and D&D Engineering and Technology Development
Document number: FIU-ARC-2018-800006472-04b-253

Project 4: DOE-FIU Science & Technology Workforce Development Initiative
Document number: FIU-ARC-2018-800006473-04b-297

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

TABLE OF CONTENTS

TABLE OF CONTENTS i
LIST OF FIGURES iv
LIST OF TABLES vi
PROJECT 3 OVERVIEW 1
MAJOR TECHNICAL ACCOMPLISHMENTS 3
TASK 1: WASTE INFORMATION MANAGEMENT SYSTEM (WIMS) 4
Task 1: Executive Summary 4
Subtask 1.1: Incorporate New Data Files with Existing Sites into WIMS 5
Subtask 1.1: Introduction 5
Subtask 1.1: Objectives 5
Subtask 1.1: Methodology 5
Subtask 1.1: Results and Discussion 5
Subtask 1.1: Conclusions and Future Work 2
Subtask 1.1: References 3
Subtask 1.2: Upgrade WIMS Application Framework (NEW) 3
Subtask 1.2: Introduction 3
Subtask 1.2: Objectives 3
Subtask 1.2: Methodology 3
Subtask 1.2: Results and Discussion 4
Subtask 1.2: Conclusions and Future Work 8
Subtask 1.2: References 8
TASK 2: D&D SUPPORT FOR DOE EM FOR TECHNOLOGY INNOVATION, DEVELOPMENT, EVALUATION AND DEPLOYMENT 9
Task 2: Executive Summary 9
Subtask 2.1: Uniform Testing Protocols and Performance Metrics for D&D 10
Subtask 2.1: Introduction 10
Subtask 2.1: Discussion and Case Study 12
Subtask 2.1: Conclusion and Way Ahead 13
Subtask 2.1: References 13
Subtask 2.2: Applications of Intumescent Foams to D&D Problem Sets 14
Subtask 2.2: Introduction 14
Subtask 2.2: Objectives 14
Subtask 2.2: Methodology 14

Subtask 2.2: Results and Discussion ... 16
Subtask 2.2: Conclusions and Future Work ... 28
Subtask 2.2: References ... 29
Subtask 2.3: Support to SRNL and SRS 235-F for Onsite Hot Demonstration ... 30
Subtask 2.3: Introduction ... 30
Subtask 2.3: Objectives ... 30
Subtask 2.3: Methodology ... 30
Subtask 2.3: Results and Discussion ... 30
Subtask 2.3: Conclusions and Future Work ... 31
Subtask 2.3: References ... 31
Subtask 2.4: Support for Open Air Demolition Activities (NEW) ... 32
Subtask 2.4: Introduction ... 32
Subtask 2.4: Objectives ... 32
Subtask 2.4: Methodology ... 32
Subtask 2.4: Results and Discussion ... 34
Subtask 2.4: Conclusions and Future Work ... 35
Subtask 2.4: References ... 35
TASK 3: D&D KNOWLEDGE MANAGEMENT INFORMATION TOOL ... 36
Task 3: Executive Summary ... 36
Subtask 3.1: Outreach and Marketing (EM Community Support) ... 36
Subtask 3.1: Introduction ... 36
Subtask 3.1: Objectives ... 36
Subtask 3.1: Methodology ... 37
Subtask 3.1: Results and Discussion ... 39
Subtask 3.1: Conclusions and Future Work ... 39
Subtask 3.1: References ... 39
Subtask 3.2: KM-IT Development and Enhancement ... 39
Subtask 3.2: Introduction ... 39
Subtask 3.2: Objectives ... 40
Subtask 3.2: Methodology ... 40
Subtask 3.2: Results and Discussion ... 41
Subtask 3.2: Conclusions and Future Work ... 47
Subtask 3.2: References ... 48

Subtask 3.3: Content Management and Data Analytics.....48
Subtask 3.3: Introduction..... 48
Subtask 3.3: Objectives..... 48
Subtask 3.3: Methodology..... 49
Subtask 3.3: Results and Discussion..... 49
Subtask 3.3: Conclusions and Future Work..... 54
Subtask 3.3: References..... 54
Subtask 3.4: Cybersecurity Research for KM-IT.....54
Subtask 3.4: Introduction..... 54
Subtask 3.4: Objectives..... 55
Subtask 3.4: Methodology..... 55
Subtask 3.4: Results and Discussion..... 55
Subtask 3.4: Conclusions and Future Work..... 55
Subtask 3.4: References..... 55
TASK 6: ANALYSIS OF IMAGE DATA USING MACHINE LEARNING/DEEP LEARNING AND BIG DATA TECHNOLOGIES (NEW).....56
Task 6: Executive Summary..... 56
Task 6: Introduction..... 56
Task 6: Objectives..... 56
Task 6: Methodology..... 57
Task 6: Results and Discussion..... 59
Task 6: Conclusions and Future Work..... 61
CONFERENCE PARTICIPATION, PUBLICATIONS & AWARDS.....62
APPENDIX.....63

LIST OF FIGURES

Figure 1. Walter Quintero presenting WIMS at WM2019. 4
Figure 2. WIMS waste forecast module with 2019 data. 6
Figure 3. WIMS website showing GIS data for 2019. 7
Figure 4. WIMS website showing disposition map data for 2019. 8
Figure 5. WIMS transportation module with 2019 data. 9
Figure 6. Microsoft .NET versions and features. 4
Figure 7. WIMS homepage after framework upgrade. 5
Figure 8. WIMS GIS module. 6
Figure 9. WIMS report module. 7
Figure 10. Tensile foam sample dimensions. (ASTM International, 2017) 15
Figure 11. ASTM D1623 adhesion test sample (left) and FIU fabricated I-H foam adhesion sample (right). 16
Figure 12. I-H foam curing temperature profile using one foam cartridge (about 100 in^3) per container. 17
Figure 13. Experimental setup (top) and after foam application (bottom) to determine viability of NDE method. 18
Figure 14. I-H foam temperature profile in clear PVC pipe with areas of uniform application and anomalies that were purposely created. 19
Figure 15. Thermal images of the control and obstruction pipes at varying time intervals after foam application. 20
Figure 16. Graph of external temperature averages over time for the known obstruction pipe, with Section 2 containing the Styrofoam obstruction. 21
Figure 17. Graph of external temperature averages over time for the control pipe. 22
Figure 18. 3D printed Tensile Testing Mold (left) and I-H foam cured inside mold (right). 23
Figure 19. Foam sample before failure (left) and after failure (right). 23
Figure 20. Compression sample molds. 24
Figure 21. Compression process for I-H cylindrical sample. 25
Figure 22. Stress-Strain graph of all geometries of I-H foam compression samples. 25
Figure 23. 3D mold with stainless steel coupons inside (left) and cured foam samples (right). 26
Figure 24. Initial foam adhesion test result. 27
Figure 25. Adhesion results for each I-H foam sample. 28
Figure 26. Simple pneumatic system. Black arrows represent exhaust flow. 33

Figure 27. Load cell/piezoelectric setup to measure the impact force applied to samples. 33
Figure 28. Stainless steel coupon with surrogate contamination (bismuth trioxide). 35
Figure 29. FIU newsletter to attendees of the 2019 Waste Management Symposia 38
Figure 30. The D&D KM-IT web crawler landing page. 41
Figure 31. Search D&D KM-IT index crawler information 42
Figure 32. D&D KM-IT data flow interaction with OSTI Web API 43
Figure 33. OSTI Search summary using radiological as the search term. 44
Figure 34. OSTI search result details view showing details for the document and associated links. 45
Figure 35. D&D KM-IT DOE Research for DOE EM module. 47
Figure 36. Technology HX30 Vacuum Excavator 51
Figure 37. D&D KM-IT growth from March 2012 to January 2020 52
Figure 38. D&D KM-IT Google Analytic activity (2018 vs. 2019) 53
Figure 39. D&D KM-IT activity by state (2018 vs. 2019). 53
Figure 40. Map showing Chicago, IL web activity on D&D KM-IT. 54
Figure 41. Mock-wall in the outdoor test facility simulation D&D conditions. 57
Figure 42. Convolutional Neural Network architecture for image classification. 59
Figure 43. Accuracy plot for 10 layer deep convolutional neural network. 60
Figure 44. Confusion matrix showing Type I and Type II errors. 60

LIST OF TABLES

Table 1. List of Sites and Facilities Supported by WIMS 9
Table 2. Maximum curing temperatures for each foam cartridge. 16
Table 3. Maximum temperatures in areas of uniform application and anomalies. 18
Table 4. I-H Foam Tensile Test Results 23
Table 5. Average Dimensions and Testing Rate for Compression Samples 24
Table 6. Calculated Modulus of Elasticity and Final Thickness of Compression Samples 26
Table 7. Monthly Measurements of Control Coupon 1 (indoors) at FIU 31
Table 8. Monthly Measurements of Control Coupon 2 (outdoors) at FIU 31

PROJECT 3 OVERVIEW

The Waste and D&D Engineering and Technology Development Project (Project 3) focuses on delivering solutions under the waste, D&D and IT areas for the DOE Office of Environmental Management. This work directly supports D&D activities being conducted across the DOE EM complex to include Oak Ridge, Savannah River, Hanford, Idaho and Portsmouth. This project included the following tasks during the September 29, 2018 to September 28, 2019 period of performance:

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 https://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 Performance Year 9**,** FIU expanded its research in technology test and evaluation in the following key areas: 1) Support to SRNL in addressing high priority fire protection and safety basis requirements related to the material-at-risk (MAR) at the SRS 235-F PUFF risk reduction project; 2) Identification of broader applications for intumescent technologies to mitigate the impacts of postulated contingency scenarios outlined in Basis for Interim Operations documents across the DOE complex; 3) Execute a phased approach for the standards development, testing, evaluation, and deployment of D&D technologies to support Open Air Demolition activities; 4) Support for an onsite demonstration at SRS of the intumescent coating; and 5) Collaborate with ASTM to continue development of standards and testing protocols in support of D&D technologies. FIU further supported the EM D&D program by participating in D&D workshops, conferences, and serving as subject matter experts.

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

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

Task 6: Analysis of Image Data using Machine Learning/Deep Learning and Big Data Technologies (NEW)

This task is aimed at using Machine Learning/Deep Learning and Big Data Technologies to run analysis of image data. The research focuses on specific LiDAR technology mounted on a robotic platform to be deployed at FIU mock up facilities to develop a pilot-scale infrastructure using machine learning/deep learning and big data technologies for structural health monitoring of facilities. FIU will work closely with SRNL to identify applications at SRS or other DOE facilities.

MAJOR TECHNICAL ACCOMPLISHMENTS

Task 1: Waste Information Management System (WIMS)

- FIU received a new set of waste stream forecast and transportation forecast data from DOE and completed the data import and all the necessary code updates to the back-end and front-end of the application to accommodate the new waste streams. FIU also completed upgrading the WIMS framework from the previous .NET framework (Version 1.1) to the current .NET framework (Version 4.6.1).

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

- Participated in the development and formal approval of two new ASTM International standards:
    - E3191-18, Standard Specification for Permanent Foaming Fixatives Used to Mitigate Spread of Radioactive Contamination.
    - E3190-19, Standard Practice for Preparation of Fixed Radiological/Surrogate Contamination on Porous Test Coupon Surfaces for Evaluation of Decontamination Techniques.
- Developed and completed the Test Plan titled, "Testing and Evaluating Intumescent Foams in Operational Scenarios", which focused on testing parameters required to take the down-selected technology to a hot test and evaluation in 2021.
- Continued to support SRNL with follow up activities for the intumescent coating fixative hot test and evaluation at the SRS 235-F PuFF Facility.
- Developed an initial experimental design to quantitatively determine a fixative technology's ability to immobilize and fix contamination during open air demolition activities.

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

- FIU completed enhancing and optimizing the web crawler to search and retrieve information related to D&D from within KM-IT as well as from OSTI and identified internet sources/websites. D&D KM-IT Search module has been updated so that users have greater access to information from both inside the D&D KM-IT and outside sources like OSTI. A total of 274 technologies were added to the D&D KM-IT technology module.

Task 6: Analysis of Image Data using Machine Learning/Deep Learning and Big Data Technologies (NEW)

- The FIU team has used the D&D mock-up outdoor test facility that simulates D&D infrastructure to monitor structural health of nuclear infrastructure. The team collected 28,000 images representing "good" and "damaged" wall surfaces. They also designed a ten layer deep convolutional neural network model to classify good wall surfaces from the damaged one. The model achieved a very high accuracy for classification of the surfaces which it has not encountered previously.

TASK 1: WASTE INFORMATION MANAGEMENT SYSTEM (WIMS)

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, GIS map, transportation data 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. WIMS is successfully deployed and can be accessed from the web address https://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.

By March 30, 2019, FIU had successfully upgraded the WIMS application to the latest Microsoft.Net framework 4.6.1 from framework 1.1 (Windows 2003). This work was performed under Subtask 1.2. This is the first major task in this multi-year upgrade effort for WIMS.

FIU received a new set of waste stream forecast and transportation forecast data from DOE on April 5, 2019 and updates to specific site waste streams through April 10, 2019. The revised waste forecast data was received as formatted data files and, to incorporate these new files, FIU built a data interface to allow the files to be received by the WIMS application and import it into SQL Server. FIU performed all the technical task in Subtask 1.1 to get the information imported into WIMS. DOE was notified of the final deployment on May 20, 2019.

In addition to completing the following subtask, FIU published a paper at the 2019 Waste Management Symposia (WM2019) titled *Waste Information Management System with 2018-19 Waste Streams*. The paper was presented in the poster session under the characterization category on March 5, 2019.

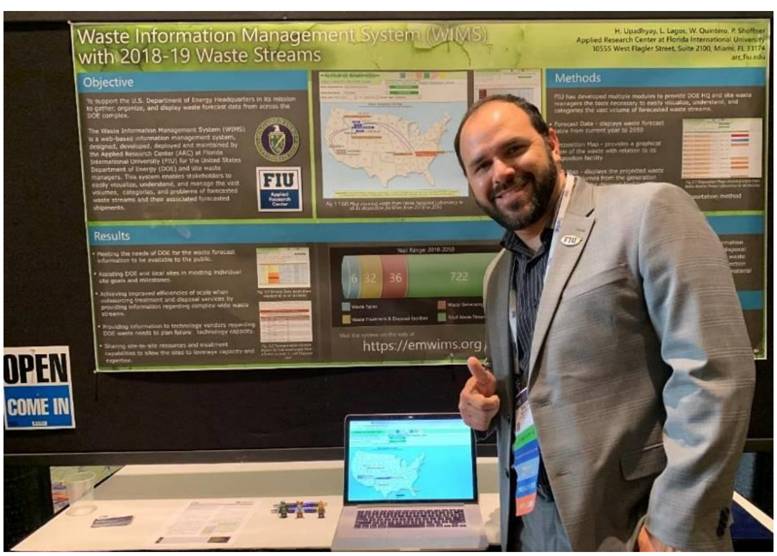


Figure 1. Walter Quintero presenting WIMS at WM2019.

Subtask 1.1: Incorporate New Data Files with Existing Sites into WIMS

Subtask 1.1: Introduction

Under this subtask, FIU receives revised waste forecast data and transportation data as formatted data files on an annual basis. To incorporate these new files, FIU built a data interface to allow the files to be received by the WIMS application and imported into SQL Server. SQL server is the database server where the actual WIMS data is maintained. This data is typically received from DOE in the April/May timeframe.

Subtask 1.1: Objectives

The objective of this task is 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 is 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.

Subtask 1.1: Methodology

This system was originally built on Microsoft.net framework 1.1 and SQL server 2005. 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. One of the tasks this year was to upgrade the infrastructure of the system to improve performance and security. The details of this effort are discussed in Subtask 1.2.

FIU receives revised waste forecast data and transportation data as formatted data files from DOE EM on an annual basis. To incorporate these new files, FIU built a data interface to allow the files to be received by the WIMS application and imported into SQL Server. SQL server is the database server where the actual WIMS data is maintained. Once integrated, reviewed and verified, the new waste data replaces the existing/previous waste data and becomes fully viewable and operational in WIMS.

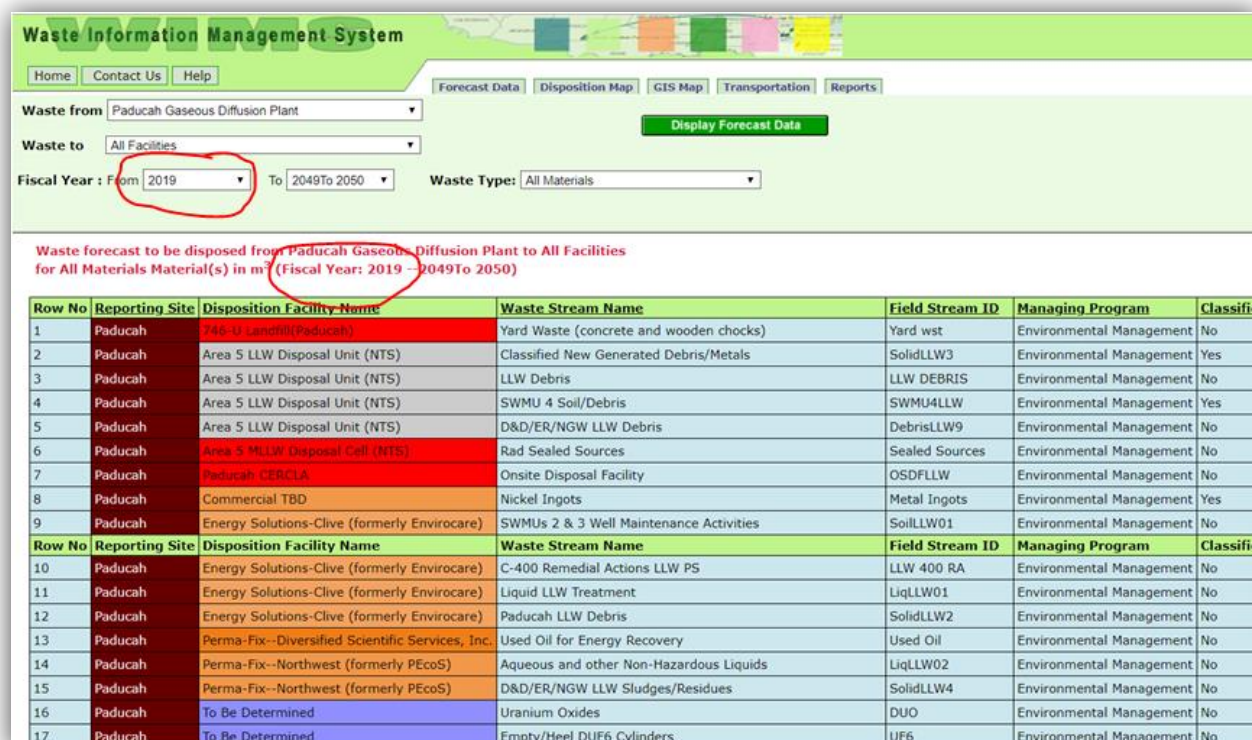
FIU received a new set of waste stream forecast and transportation forecast data from DOE on April 5, 2019 and updates to specific site waste streams through April 10, 2019. The revised waste forecast data was received as formatted data files and, to incorporate these new files, FIU built a data interface to allow the files to be received by the WIMS application and imported into SQL Server. SQL server is the database server where the actual WIMS data is maintained.

Subtask 1.1: Results and Discussion

Once the new annual waste forecast dataset was received from DOE EM, FIU completed the data import and all the necessary code updates to the back-end and front-end of the application to accommodate the new waste streams. The application was then moved from a development server to a staging server where FIU staff and DOE Fellows performed quality assurance reviews to ensure that all of the data displayed matched the raw data that was imported. FIU also performed unit and integration testing on the staging server prior to moving the application to the production server. After all the internal testing was completed, the staging testing URL was forwarded to DOE and they performed a final review of the application. FIU addressed any feedback and comments from DOE prior to deployment.

During May 2020, FIU completed the data import and all the necessary code updates to the back-end and front-end of the application to accommodate the new waste streams. As mentioned before, the application was moved from a development server to a staging server where FIU staff and DOE Fellows performed quality assurance reviews to ensure that all of the data displayed matched the raw data that was imported. After FIU performed unit and integrating testing to ensure that all of the modules functioned properly and displayed the new data, the staging testing URL was forwarded to DOE on May 10 and they performed a second review of the application. FIU addressed all the feedback provided by DOE and published the application to the production server, making it publicly available.

DOE was notified of the final deployment on May 20, 2019. The updated WIMS application with the 2019 data can be accessed at http://www.emwims.org. Although, at this point the task is considered completed, FIU will continue to monitor the application to assure that no data anomalies develop. Screenshots of the WIMS application reflecting the updated data are included below.



Row No	Reporting Site	Disposition Facility Name	Waste Stream Name	Field Stream ID	Managing Program	Classifie
1	Paducah	746-U Landfill(Paducah)	Yard Waste (concrete and wooden chocks)	Yard wst	Environmental Management	No
2	Paducah	Area 5 LLW Disposal Unit (NTS)	Classified New Generated Debris/Metals	SolidLLW3	Environmental Management	Yes
3	Paducah	Area 5 LLW Disposal Unit (NTS)	LLW Debris	LLW DEBRIS	Environmental Management	No
4	Paducah	Area 5 LLW Disposal Unit (NTS)	SWMU 4 Soil/Debris	SWMU4LLW	Environmental Management	Yes
5	Paducah	Area 5 LLW Disposal Unit (NTS)	D&D/ER/NGW LLW Debris	DebrisLLW9	Environmental Management	No
6	Paducah	Area 5 MLLW Disposal Cell (NTS)	Rad Sealed Sources	Sealed Sources	Environmental Management	No
7	Paducah	Paducah CERCLA	Onsite Disposal Facility	OSDFLLW	Environmental Management	No
8	Paducah	Commercial TBD	Nickel Ingots	Metal Ingots	Environmental Management	Yes
9	Paducah	Energy Solutions-Clive (formerly Envirocare)	SWMUs 2 & 3 Well Maintenance Activities	SoilLLW01	Environmental Management	No
Row No	Reporting Site	Disposition Facility Name	Waste Stream Name	Field Stream ID	Managing Program	Classifie
10	Paducah	Energy Solutions-Clive (formerly Envirocare)	C-400 Remedial Actions LLW PS	LLW 400 RA	Environmental Management	No
11	Paducah	Energy Solutions-Clive (formerly Envirocare)	Liquid LLW Treatment	LiqLLW01	Environmental Management	No
12	Paducah	Energy Solutions-Clive (formerly Envirocare)	Paducah LLW Debris	SolidLLW2	Environmental Management	No
13	Paducah	Perma-Fix--Diversified Scientific Services, Inc.	Used Oil for Energy Recovery	Used Oil	Environmental Management	No
14	Paducah	Perma-Fix--Northwest (formerly PEcoS)	Aqueous and other Non-Hazardous Liquids	LiqLLW02	Environmental Management	No
15	Paducah	Perma-Fix--Northwest (formerly PEcoS)	D&D/ER/NGW LLW Sludges/Residues	SolidLLW4	Environmental Management	No
16	Paducah	To Be Determined	Uranium Oxides	DUO	Environmental Management	No
17	Paducah	To Be Determined	Empty/Heel DUF6 Cylinders	UF6	Environmental Management	No

Figure 2. WIMS waste forecast module with 2019 data.

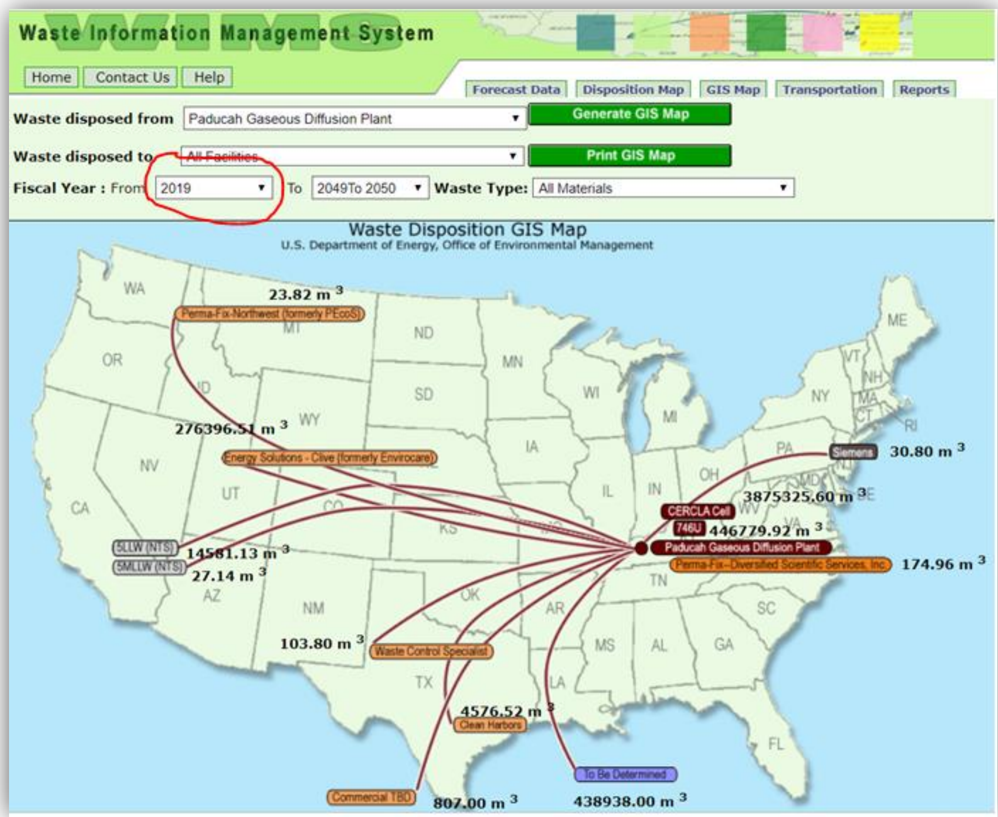


Figure 3. WIMS website showing GIS data for 2019.

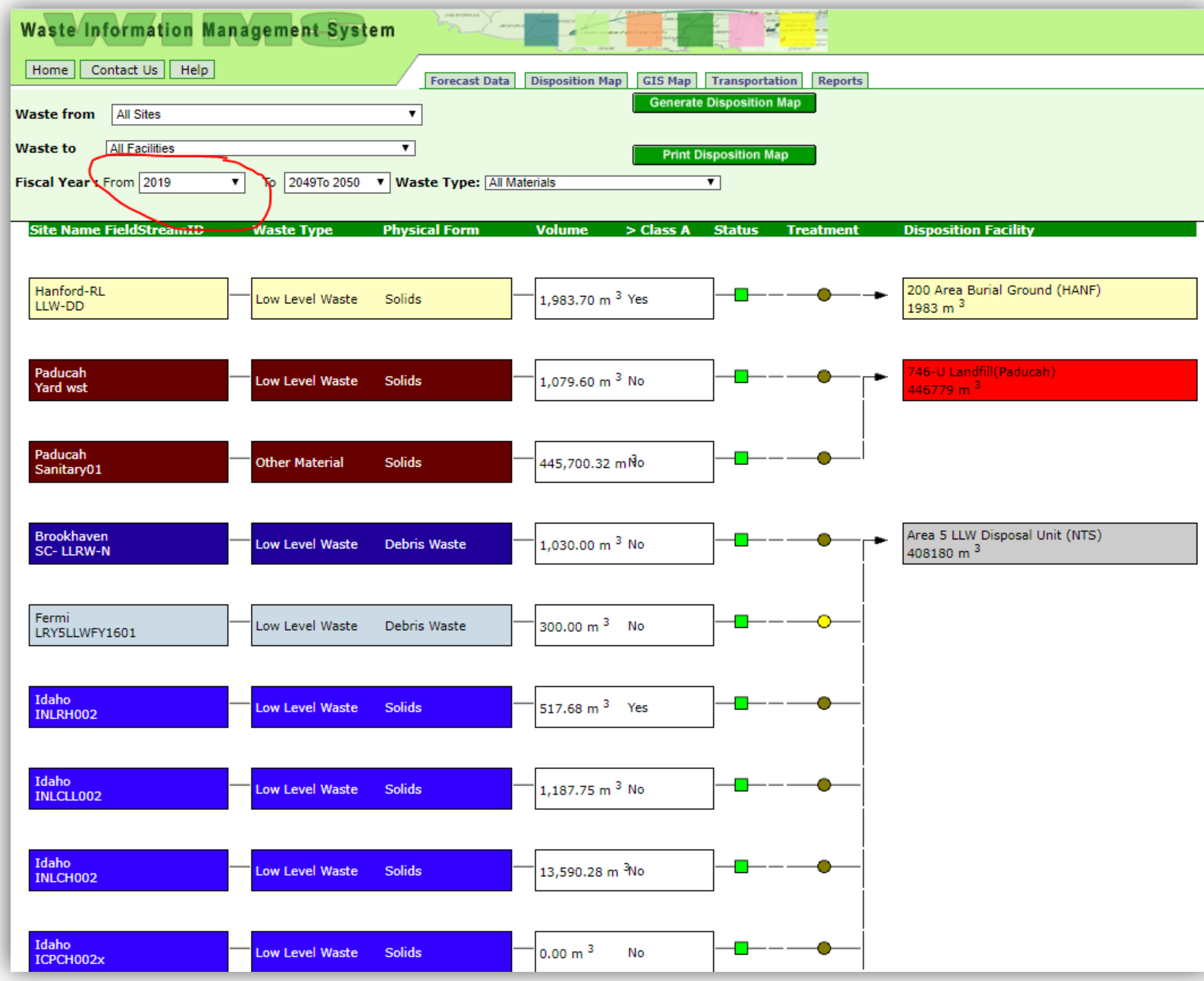


Figure 4. WIMS website showing disposition map data for 2019.

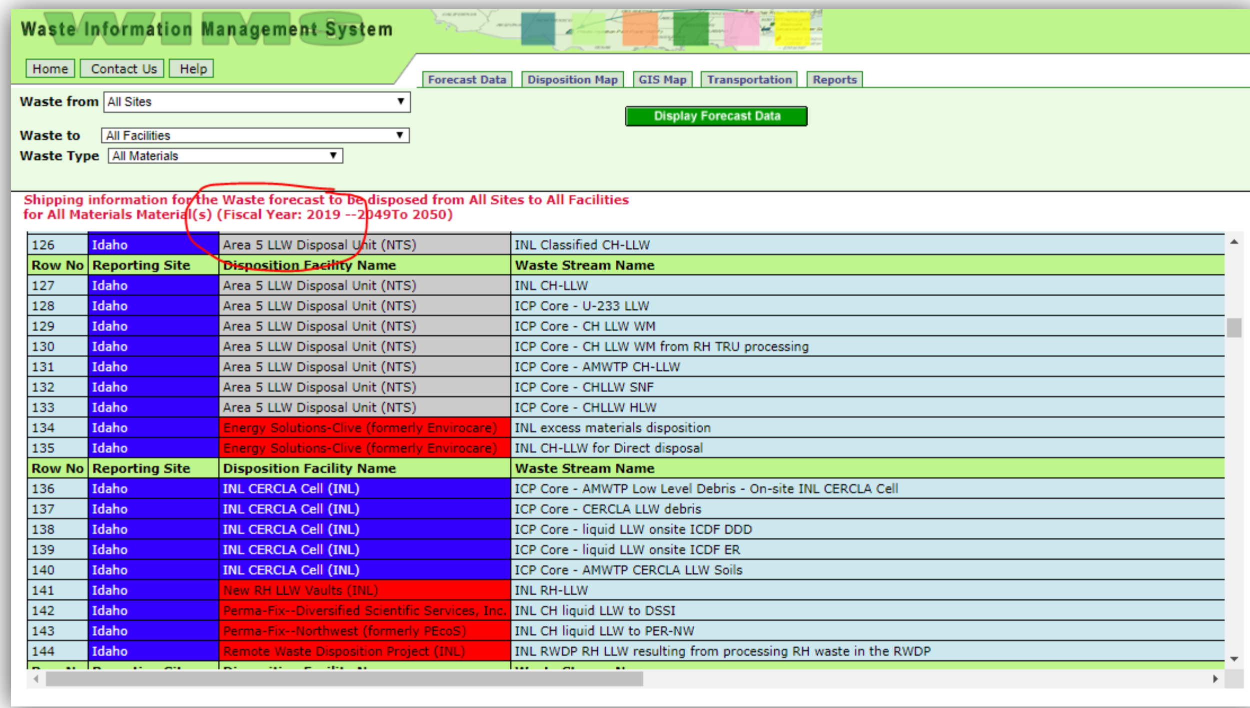


Figure 5. WIMS transportation module with 2019 data.

As of the end of 2019, the WIMS application supported the following waste types:

Waste type:

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

In addition, the waste can be forecasted among 36 sites and 32 disposition facilities. The names of each of the locations are listed below.

Table 1. List of Sites and Facilities Supported by WIMS

	SITES		FACILITIES
1	Ames Laboratory	1	200 Area Burial Ground (HANF)
2	Argonne National Laboratory	2	746-U Landfill(Paducah)
3	Bettis Atomic Power Laboratory	3	Area 5 LLW Disposal Unit (NTS)
4	Brookhaven National Laboratory	4	Area 5 MLLW Disposal Cell (NTS)
5	Energy Technology Engineering Center	5	Clean Harbors
6	Fermi National Accelerator Laboratory	6	Commercial TBD
7	Hanford Site-RL	7	E-Area Disposal (SRS)
8	Hanford Site-RP	8	EMWMF Disposal Cell (ORR)
9	Idaho National Laboratory	9	Energy Solutions-Clive (formerly Envirocare)
10	Kansas City Plant	10	Energy Solutions-TN (formerly GTS Duratek)

11	Knolls Atomic Power Laboratory - Kesselring	11	ERDF (HANF)
12	Knolls Atomic Power Laboratory - Schenectady	12	Impact Services-TN
13	Lawrence Berkeley National Laboratory	13	INL CERCLA Cell (INL)
14	Lawrence Livermore National Laboratory	14	Integrated Disposal Facility (HANF)
15	Los Alamos National Laboratory	15	New RH LLW Vaults (INL)
16	Naval Reactor Facility	16	Omega Waste Logistics
17	Nevada Test Site	17	OSWDF(Portsmouth)
18	NG Newport News	18	Paducah CERCLA
19	Norfolk Naval Shipyard	19	Perma-Fix Gainesville
20	Nuclear Fuel Services, Inc. (cleanup site)	20	Perma-Fix--Diversified Scientific Services, Inc.
21	Oak Ridge Reservation	21	Perma-Fix--Northwest (formerly PEcoS)
22	Paducah Gaseous Diffusion Plant	22	Perma-Fix/Materials & Energy Corp
23	Pantex Plant	23	Remote Waste Disposition Project (INL)
24	Pearl Harbor Naval Shipyard	24	River Metals
25	Pacific Northwest National Laboratory	25	RMW Trenches (MLLW/LLW) (HANF)
26	Portsmouth Gaseous Diffusion Plant	26	RMW Trenches/IDF (HANF)
27	Portsmouth Naval Shipyard	27	RWMC (LLW disposal) (INL)
28	Princeton Plasma Physics Laboratory	28	Siemens
29	Puget Sound Naval Shipyard	29	Smokey Mountain Solutions
30	Sandia National Laboratories - NM	30	TA 54/Area G (LLW disposal) (LANL)
31	Savannah River Site	31	To Be Determined
32	Stanford Linear Accelerator Center	32	Waste Control Specialists
33	Separations Process Research Unit		
34	Thomas Jefferson National Accelerator Facility		
35	Waste Isolation Pilot Plant		
36	West Valley Demonstration Project		

Subtask 1.1: Conclusions and Future Work

WIMS continues to successfully accomplish the goals and objectives set forth by DOE. 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 forecast data supplied by all DOE programs in addition to transportation information.

Under this subtask, FIU will receive and incorporate a set of revised waste forecast data files, expected in the March 2020 timeframe. The new waste data will replace the existing previous waste data and will become fully viewable and operational in WIMS.

Subtask 1.1: References

Office of Environmental Management (DOE-EM), https://www.energy.gov/em/office-environmental-management, U.S. Department of Energy.

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

Subtask 1.2: Upgrade WIMS Application Framework (NEW)

Subtask 1.2: Introduction

This subtask was a new subtask for FIU Performance Year 9. As mentioned earlier, the WIMS application was originally developed on a framework which has become outdated. Prior to this task being completed, the former WIMS system framework, platforms and development tools reflected those available during the 2003-2004 timeframe. This multi-year upgrade effort will include updating of the middle tier application to the latest Microsoft.Net framework using the current Visual Studio (2017) development environment and migration of the database and reporting services to the latest SQL database server.

Subtask 1.2: Objectives

The main objective of this task is to stabilize the WIMS application moving forward so it can be scaled according to the latest technology available. By upgrading the framework, the WIMS application will be able to provide a more reliable user experience while increasing its security.

The main benefits of this framework application upgrade are:

1. Increased reliability and cybersecurity of the system.
2. Increased efficiency for importing and deploying new data sets.
3. Improved user experience.

Subtask 1.2: Methodology

The task focused on upgrading the WIMS framework from the previous .NET framework (Version 1.1) to the current .NET framework (Version 4.6.1). Below is a graphic that shows the new features added as a new version of .NET became available.

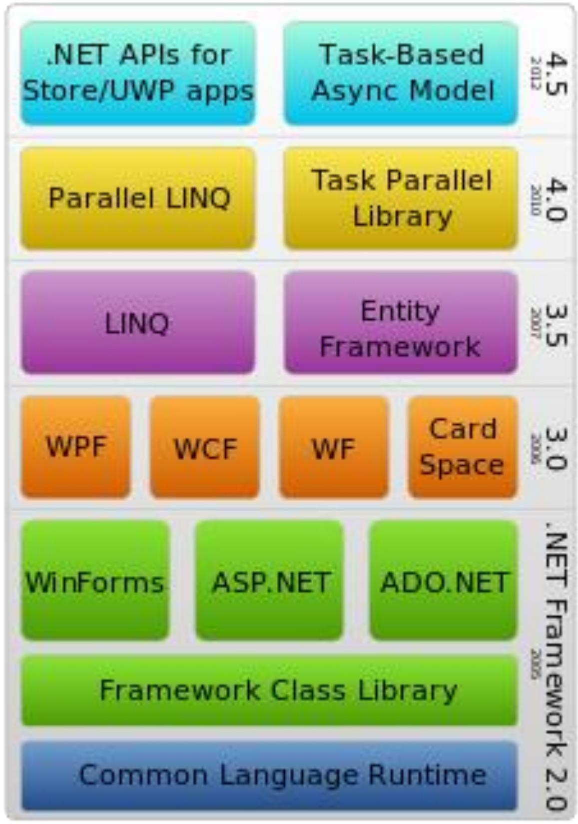


Figure 6. Microsoft .NET versions and features.

FIU first created two virtual servers (database server and application server) to host and deploy the upgraded WIMS application, and installed IIS and a Visual Studio 2017 development environment on the application server. FIU then procured a new database server to run the SQL server, a reporting server, an integration server, as well as SQL Server 2017 which was deployed on the database server. Integration services and reporting services were deployed on the same machine as the database server. Integration services were used for importing data into the database, and reporting services are required for publishing the waste forecast, waste streams and transportation reports on WIMS. The approach taken was to deploy the database/application environments and upgrade the WIMS application before the expected annual waste stream data update is received from DOE EM (details of this task can be found on Subtask 1.1). The reason was so that the new 2019 dataset will be imported directly into the upgraded WIMS application.

Subtask 1.2: Results and Discussion

By March 30, 2019, FIU had successfully upgraded the WIMS application to the latest Microsoft.Net framework 4.6.1 from framework 1.1 (Windows 2003). This is considered the first major task in this multi-year upgrade effort for WIMS. A few of the upgraded application screenshots are included below. Currently, the system will display all of the modules and all of the module links are displayed by default. The home page has been updated with a new look and all of the other modules have been updated to the new framework.

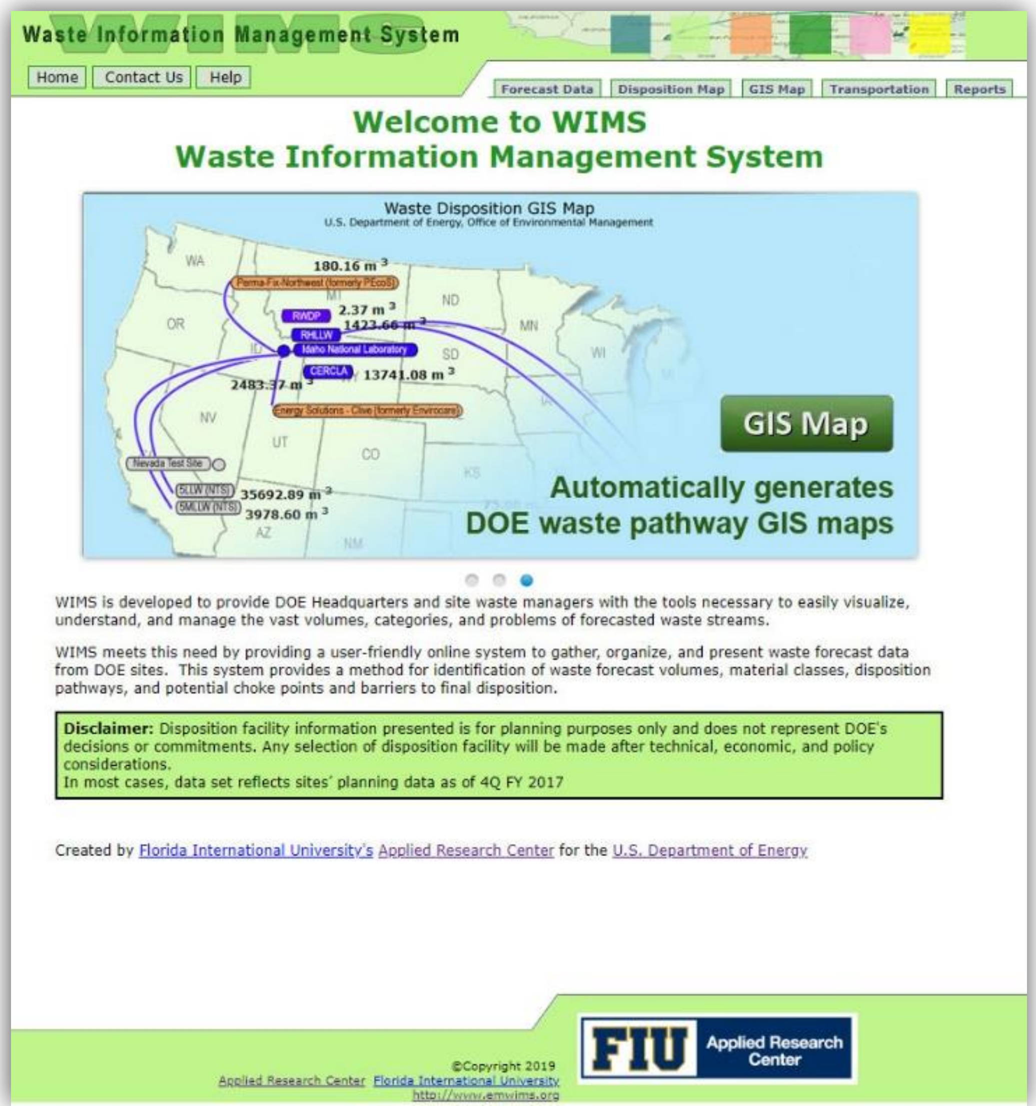


Figure 7. WIMS homepage after framework upgrade.

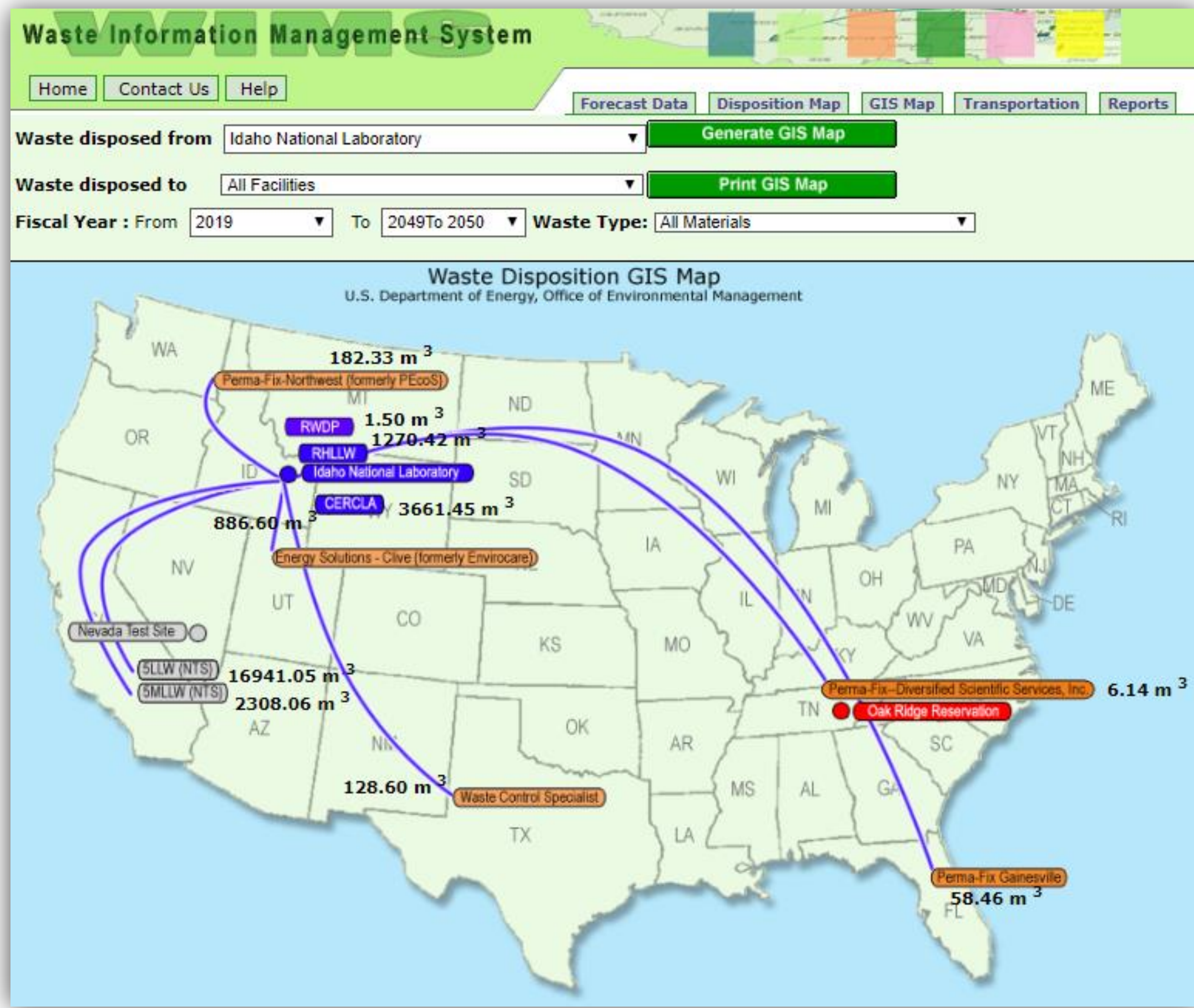


Figure 8. WIMS GIS module.

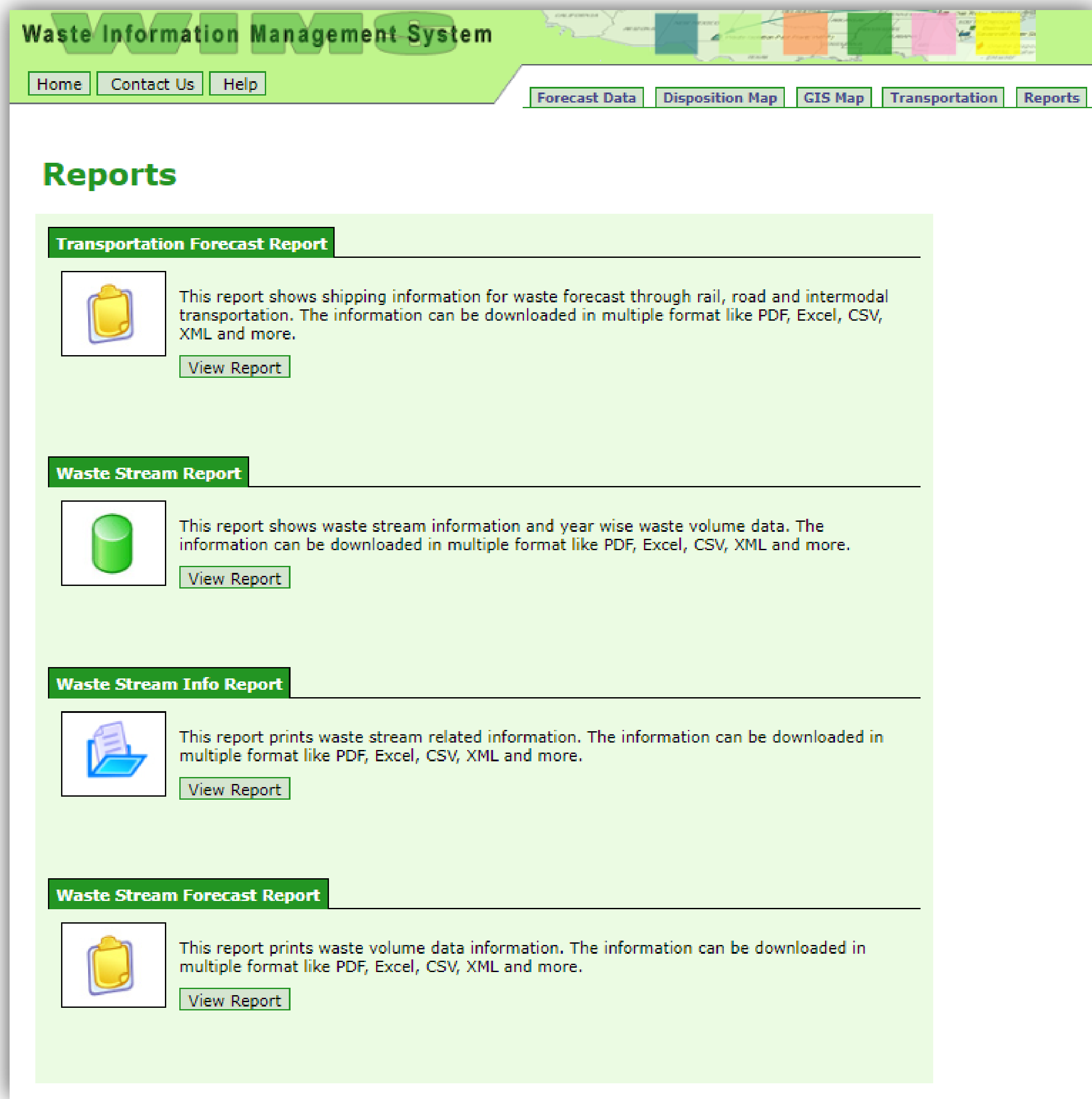


Figure 9. WIMS report module.

The login page from the old system is no longer available because the identity management was originally implemented in Windows Server 2003 and is not supported in the current framework. In the next performance year, FIU plans to develop this feature using the current framework for user login authentication and authorization.

Subtask 1.2: Conclusions and Future Work

After deploying the upgraded application in late March, FIU received very positive feedback from DOE. The WIMS application now performs faster and is more secure against potential cyber threats. As mentioned earlier, this task is considered the first of a multi-year upgrade process to make the WIMS application more robust, scalable and secure. The future work already proposed for Year 10 of the CA in relation to this task include:

WIMS Identity Management

As a result of the completion of Subtask 1.2 (Upgrade WIMS Application Framework), the old authentication/authorization security module has become obsolete and is no longer compatible with the new framework. Therefore, during FIU Performance Year 10, FIU will incorporate an identity management module to allow users to be authenticated. This feature will control user access, capture user interaction with the system, and manage the user accounts. This module will allow users to register, login to the system, and create a profile, as well as allow system administrators to control access based on assigned roles.

Upgrade of WIMS Report Server & Report Function

Now that the framework is upgraded for the SQL Server, the next task will be to upgrade to SQL Server reporting server from the existing 2015 to 2017 version. The WIMS report module for forecast data, and waste stream and transportation reports will be upgraded to the new reporting server infrastructure. These reports will be configured to run on the latest reporting server using advanced components and published over the web to be accessible to the users through a variety of web browsers.

Subtask 1.2: References

Office of Environmental Management (DOE-EM), https://www.energy.gov/em/office-environmental-management, U.S. Department of Energy.

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

.*NET Framework versions and dependencies* [Web log post] Retrieved January, 2020 from https://docs.microsoft.com/en-us/dotnet/framework/migration-guide/versions-and-dependencies

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

Task 2: Executive Summary

In support of the DOE-FIU Cooperative Agreement under Project 3 (Waste and D&D Engineering and Technology Development), Task 2 (D&D Support for Technology Innovation, Development, Evaluation and Deployment), the FIU Applied Research Center (ARC) focused its research activities on identifying, testing and evaluating commercial-off-the-shelf (COTS) intumescent material technologies as fire resistant fixative solutions that have a high potential to: 1) successfully address postulated contingency scenarios outlined in Basis for Interim Operations (BIO) / Safety Basis documents across the complex; and, 2) demonstrate a high probability of transitioning to an operational test and evaluation in a radioactive environment on site. This approach resulted in one intumescent coating technology being deployed in the Entry Hood to Process Cell 1 and Process Cell 7 at the SRS 235-F PUFF Facility in September/October of 2018. It has also led to the identification of another COTS intumescent foam technology that has demonstrated initial promise during proof-of-concept experiments this year in addressing an operational requirement for a rigid, fire resistant fixative technology to immobilize and/or isolate residual contamination within a 3-dimensional void space of various volumes at sites across the complex.

An operational concept has been developed and proposed using the intumescent foam technology as an internal barrier, or "plug", prior to cutting contaminated pipework during dismantling and demolition operations on nuclear sites. Phase I of this research activity involved down selecting a potential intumescent foam against some initial operational parameters outlined in ASTM E3191-18, Standard Specification for Permanent Foam Fixatives, specifically developed by the ASTM International E10.03 Subcommittee to support this broader activity. These included: 1) the ability to immobilize contamination and fill 3D spaces; 2) fire resistance to extreme temperatures and thermal stressors; 3) ability to withstand certain environmental factors such as water; 4) mechanical properties such as rigidity and adhesion to ensure the material can act as a "plug" in piping and not be adversely affected when exposed to expected impact stressors; and, 5) confirmation of temperature profiles related to curing and uniform application of the material. Based on the initial findings highlighted throughout this document, and through extensive discussions with SRNL and other stakeholders across DOE EM, a COTS intumescent polyurethane foam (naming convention "I-H") has been identified and down-selected as a technology that warrants further investigation. The research plan for the next phase is to develop, in close collaboration with SRNL and site personnel, an operationally-focused test plan designed to directly evaluate the technology in terms of immediate, high priority requirements from safety basis personnel in order to conduct an operational test and evaluation on a DOE EM site by 2021. This approach mirrors the highly successful phased test and evaluation model employed by ARC and SRNL for the intumescent coating technology deployed in support of the SRS 235-F PUFF Facility as highlighted in the December 2018 Defense Nuclear Facility Safety Board (DNFSB) report and SRNL promotional video on the activity.

An added benefit produced during the test and evaluation related to this research activity was the discovery of a novel nondestructive evaluation technique to confirm or deny the uniform application of the intumescent foam technology in 304 stainless steel pipes of various thicknesses and dimensions. By coupling the foam's temperature profile during curing with a highly sensitive thermal imaging camera, ARC researchers have had initial success in correlating "cold spots" in temperature of the external skin of the pipe to irregularities in internal application of the foam technology. ARC researchers postulate this technique has the potential to significantly assist in guiding site personnel with nuclear pipe dismantling operations by verifying the plug's integrity. This technique will be further explored by ARC researchers as an added feature to the intumescent foam plugging concept, and should mitigate risks associated with the anticipated operational test and evaluation in 2021.

Finally, another noteworthy result of the overall research portfolio has been the engagement with ASTM International's E10.03 Subcommittee on Radiological Protection for Decontamination and Decommissioning of Nuclear Facilities and Components. This collaboration has resulted in five (5) universally-recognized standards for fixative technologies since its inception, with two (2) of those being formally approved and promulgated during Performance Year 9. These standards have been referenced in Test Plans across the DOE EM complex, and have the potential to produce institutional impacts by providing essential data that could be used in revising DOE directives and handbooks. One such example is DOE-HDBK-3010, which serves as the primary reference used for calculating the Material-at-Risk (MAR) and Source Term, and by extension is used as the guiding document for certifying the impacts of fixative technologies. Project 3 D&D developed an extensive experimental design during Performance Year 9 that will be tested and evaluated on fixative technologies during Performance Year 10, with the explicit intent of quantifying release of fixatives when exposed to thermal, impact, and environmental stressors common to Open Air Demolition activities across the complex. These results could be used to update the aforementioned DOE Handbook and provide relevant data points for site personnel and decision makers as they select fixative technologies to mitigate the potential of release during demolition.

Subtask 2.1: Uniform Testing Protocols and Performance Metrics for D&D

Subtask 2.1: Introduction

The U.S. Department of Energy's Office of Environmental Management (DOE EM) has taken a leading role in investing in the research and development (R&D) of critical technologies to support the safe and efficient decommissioning of legacy nuclear facilities. In order to facilitate the complex-wide deployment and adoption of those technologies from the laboratory to end users, and to maximize return on investment of government-sponsored R&D projects, DOE EM proactively solicits and evaluates initiatives intended to enhance achievement of these goals. One such case study emerged and involved the successful deployment of an intumescent fixative technology in support of the SRS 235-F PuFF Facility Risk Reduction Program. A detailed analysis confirmed that a critical enabler and key contributor to this effort was a deliberate, methodical approach to leverage an international, consensus-based standards organization from the onset. There is a substantial body of literature that supports the crucial role of standards in technology programs across all phases of development - from concept, to deployment, to large-scale diffusion - in other industries. Formal standards are the result of a consensual negotiation process carried out by producers, regulators, end users and other interested stakeholders in a voluntary process within standardization organizations (WTO, 2011). Therefore, standard setting is often viewed as a self-regulatory process (Gupta and Lad, 1983), and can often yield better acceptance of technologies in certain industries, particularly if those standards are further referenced in government directives and regulations.

Despite significant funding by DOE EM for technology R&D, end users have been notoriously slow to accept the outputs for a variety of reasons, several of which center on uncertainty in the very risk-averse domain of nuclear site deactivation and decommissioning (D&D) activities. As highlighted by past U.S. Government Accountability Office (GAO) reports, site officials may not be familiar with innovative technologies and fear their use would present an unacceptable risk or be unacceptable to regulators, or could result in missing milestones if the technology fails to perform as expected. A lack of reliable information could contribute to this problem (GAO, 1997).

The concept of information asymmetry, first introduced by George Akerlof in his seminal work, "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism," provides the theoretical underpinnings that support the above observation. The potential role of quality standards in mitigating information asymmetry was introduced in Hayward Leland's, "Quacks, Lemons, and Licensing: A Theory of Minimum Quality Standards," and based on the above works, it was hypothesized that developing and promulgating consensus-based standards specifically tailored for fixative technologies could address some of the obstacles highlighted by contractors in the GAO reports and improve return on investments for development programs related to this type of technology. As highlighted by Mr. Andrew Szilagyi, Director for DOE EM's Office of Infrastructure and D&D, "There is an intuitive sense by the community on the utility of fixatives to immobilize residual contamination and mitigate risk during D&D activities, but a more formal process needs to be available for site personnel and regulators to confirm their capabilities. Uniform standards can play a significant role in this effort."

Leveraging the incombustible fixatives research and development activity being led by Savannah River National Laboratory (SRNL) and Florida International University's Applied Research Center (FIU ARC) on behalf of DOE EM's Office of Infrastructure and D&D, a holistic technology deployment approach was devised for the adoption of intumescent technologies as fire resistant fixatives. SRNL's close relationship with the SRS 235-F PuFF Facility Risk Reduction Team and FIU's involvement with the American Society for Testing and Materials (ASTM) International's E10.03 Subcommittee on Radiological Protection for D&D of Nuclear Facilities and Components provided an ideal vehicle to test the initiative. In the span of a 4-year period, five (5) new international standard specifications for fixative technologies have been formally published and promulgated by ASTM, and two additional protocols are currently in the final process. More importantly, this effort has been an important pillar for the test and evaluation of a fixative technology that has been successfully deployed in the entry hood and process cell #7 at the SRS 235-F PuFF Facility.

Subtask 2.1: Discussion and Case Study

FIU ARC, in collaboration with SRNL, introduced a fixative technology that mitigates the potential release of radioactive contamination under thermal and seismic stressors, and during the test and evaluation component of the activity it became readily apparent that the end-users at the site desired a more formal process that would assist in mitigating their risk exposure. In discussions with DOE EM, as well as commercial entities conducting the environmental restoration of various nuclear sites, it was determined many of these human factor concerns could be alleviated by:

1. Leveraging an international, consensus-based organization that develops and promulgates international standards and testing protocols for fixative technologies used in D&D, and
2. Referencing these new standards to update dated regulations and directives guiding the environmental restoration of nuclear sites.

Immediately addressing these concerns would provide tremendous credibility to the R&D effort and yield a significant return on investment as the fixative technology would be tested, evaluated, and compared to a set of uniformly accepted standards and metrics that ensure it satisfactorily addresses the three pillars of test and evaluation – quality, productivity, and safety. This requirement becomes even more pressing and prominent when technologies are on the higher end of the technology readiness level (e.g.; 7-9) and are ready for acquisition and deployment.

There are several documents and guiding policies that emphasize and are intended to institutionalize this requirement, particularly when federal agencies are involved. For example, Section 12(d) of the National Technology Transfer and Advancement Act (Public Law 104-113), directs federal departments to achieve a greater reliance on voluntary consensus standards, and this mantra is also required by the Office of Management and Budget's Circular A-119,"Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities."

The ASTM International E10.03 Subcommittee on Radiological Protection during Decontamination and Decommissioning of Nuclear Facilities and Components is answering this challenge. It boasts a robust international membership that spans the entire spectrum of stakeholders, and is perfectly postured to lead a collaborative process that bridges the organizational boundaries and cultures to achieve consensus on industry standards to facilitate uniform testing and evaluation of technologies and processes.

The E10.03 Subcommittee formed a D&D Fixatives Working Group that subsequently developed and published two new international standard specifications for fixative technologies that aim to immobilize radioactive contamination, minimize worker exposure, and protect uncontaminated areas against the spread of radioactive contamination during the decommissioning of nuclear facilities. The first specification, Specification for Strippable & Removable Coatings to Mitigate Spread of Radioactive Contamination (E 3104-17), establishes performance specifications for a coating that is intended to be removable during subsequent decontamination operations (ASTM, 2017). The second specification, Specification for Permanent Coatings Used to Mitigate Spread of Radioactive Contamination (E 3105-17), is for coatings that are intended to be permanent, non-removable, long-term material for fixing contamination in place during decommissioning (ASTM, 2017). The standards were formally approved and published by ASTM International in July 2017. These successes have ignited increased interest in the effort, and over the course of this Performance Year alone, two (2) additional standards have been developed, balloted, and formally promulgated.

This drive towards incorporating universally-recognized standards into the technology test and evaluation process for the fixative activity served as a critical enabler to the successful deployment of the technology into Process Cell #7 at the SRS 235-F PuFF Facility. It mitigated the risk to the end user by improving information symmetry on the technology for all the respective stakeholders.

Subtask 2.1: Conclusion and Way Ahead

The ASTM International E10.03 Subcommittee will continue pursuing further testing protocol and standards development for fixatives and other technology categories associated with D&D, creating consensus based standards for D&D technologies that are not only aligned with technical specifications, but also account for the safety, regulatory, and operational requirements encountered during D&D activities. Addressing existing shortfalls through standards will provide credibility, yield a significant return on investment and allow all types of D&D technologies (robotics, fixatives, characterization, decontamination, demolition, etc.) to be developed, tested, evaluated and compared to a set of uniformly accepted metrics.

International standards and testing protocol development plays a critical role in successful technology development and deployment programs. These standards lay the groundwork for setting the necessary conditions to successfully test, evaluate, compare, transition, and employ technologies in support of D&D activities in the highly regulated, safety conscience, risk adverse industry in which work is done. Universally accepted standards are essential in building the bridge to full field deployment of new technologies. This is particularly relevant when working at the higher ends of the TRL readiness scale, and addresses many concerns on the part of all stakeholders – from researchers and developers to end users, regulatory agencies, and the public.

Subtask 2.1: References

ASTM International. (2017). *E3104-17 Standard Specification for Strippable & Removable Coatings to Mitigate Spread of Radioactive Contamination.* Retrieved from https://doi.org/10.1520/E3104-17

ASTM International. (2017). *E3105-17 Standard Specification for Permanent Coatings Used to Mitigate Spread of Radioactive Contamination.* Retrieved from https://doi.org/10.1520/E3105-17

ASTM International. (2018). *E3191-18 Standard Specification for Permanent Foaming Fixatives Used to Mitigate Spread of Radioactive Contamination.* Retrieved from https://doi.org/10.1520/E3191-18

ASTM International. (2019). *E3190-19 Standard Practice for Preparation of Fixed Radiological/Surrogate Contamination on Porous Test Coupon Surfaces for Evaluation of Decontamination Techniques.* Retrieved from https://doi.org/10.1520/E3190-19

Subtask 2.2: Applications of Intumescent Foams to D&D Problem Sets

Subtask 2.2: Introduction

Discussions with representatives from the Department of Energy's Office of Environmental Management (DOE-EM), Savannah River National Laboratory (SRNL), and sites across the complex have identified an operational requirement for a fixative technology to immobilize and/or isolate residual contamination within a 3-dimensional void space of various volumes that might result from anticipated to unanticipated events. In addition, the decommissioning of contaminated pipework on nuclear sites remains a challenging process. A technology that can establish an internal barrier or "plug" to mitigate the release of residual contamination prior to cutting operations of contaminated pipework, would bring several benefits to decommissioning efforts.

The potential for commercial-off-the-shelf (COTS) polyurethane foams to meet this requirement and support deactivation and decommissioning activities is being investigated through a collaborative effort by SRNL and FIU. Foams can encapsulate large irregular void volumes whereas coatings can be difficult to apply in these scenarios. An intumescent polyurethane foam was further tested and evaluated to be used as a fixative for residual contamination in void spaces due to its superior fire-retardant capabilities.

Subtask 2.2: Objectives

Phase I of this research activity involved down-selecting a potential commercial-off-the-shelf (COTS) intumescent foam against some initial operational parameters outlined in ASTM E3191-18, Standard Specification for Permanent Foam Fixatives.

1. Evaluate the temperature profile during the curing process of the down-selected COTS intumescent foam.
2. Determine the uniformity of curing in various dimensions after application; and determine the potential impacts on the intumescent foam fixative when the pipes are subjected to various cutting techniques.

A subcomponent of this objective will include an initial assessment on the possibility of using temperature profile as a means to predict inconsistencies in the application and curing process.

3. Determine designated mechanical properties of the cured intumescent foam to ensure quality performance.

Subtask 2.2: Methodology

The COTS intumescent foam selected for evaluation is the I-H foam. This product is a two-component polyurethane foam that expands up to six times in volume upon application and cures in approximately one minute. The volume of foam produced per cartridge is up to 110 in^3. Per the application instructions, the first five pumps of the dispenser (or until the foam in the mixer nozzle has a consistent red color) will be discarded because this initial portion is unevenly mixed.

The Extech SDL200 datalogger is capable of measuring temperatures up to 2,372°F. The Extech TP870 Type K thermocouples have a temperature range of -40 to +482° F. The accuracy of the Extech SDL200 when using type K thermocouples is +/- 0.4% of the reading. Both of these components were essential for determining the maximum curing temperatures of the I-H foam.

The FLIR E53 thermal imaging camera was leveraged to assist in a non-destructive evaluation (NDE) method for using the foam's curing temperature profile to determine anomalies in application and/or curing of the intumescent foam. The FLIR E53 has the capacity to measure object temperatures up to 1,200°F and has a thermal sensitivity of < 0.07°F (40 mK). The measurement accuracy is ± 2% of reading. The supplemental FLIR software provides vast insight in terms of temperature data analysis. Multi-spectral Dynamic imaging (MSX) mode was used for all image analysis. MSX mode overlays both the thermal and digital images together and provides a more detailed thermal image.

Mechanical properties tested include: Tensile, Compression, and Adhesion. All mechanical properties tests were conducted using the MTS Criterion Series 43 Tensile Tester, which has a 40kN rated force capacity.

Tensile foam samples were prepared and tested according to ASTM D1623: *Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics*. Measurements of the test specimens' area and gage length will be utilized to enable calculations of the strain and stress experienced by the foam. The rate of crosshead movement used was 1.3 mm (0.05 in.)/min for each 25.4 mm (1 in.) of test section gauge length, as per the standard.

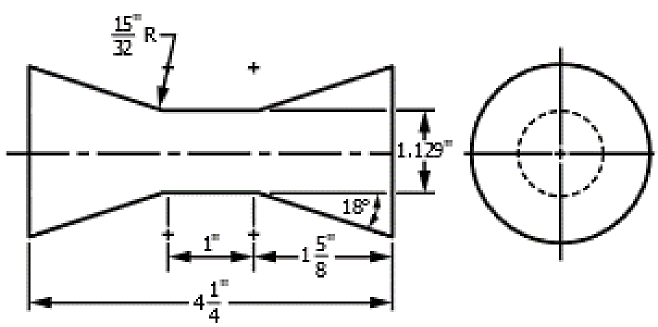


Figure 10. Tensile foam sample dimensions. (ASTM International, 2017)

Compression testing and foam sample dimensions complied with ASTM D1621: *Compressive Properties of Rigid Cellular Plastics*. Adhesion preparation and testing was also conducted according to ASTM D1623: *Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics*. The tensile adhesion strength was calculated to see the amount of force or stress it requires to pull the foam off the 304-stainless steel substrate in 3 to 6 minutes with a pill rate of 0.1 in/min, per the standard. The 304-stainless steel coupon dimensions are 2 inch by 2 inch by 0.125 inch thickness and the dimensions of the I-H foam samples are 2 inch by 2 inch by 2 inch.

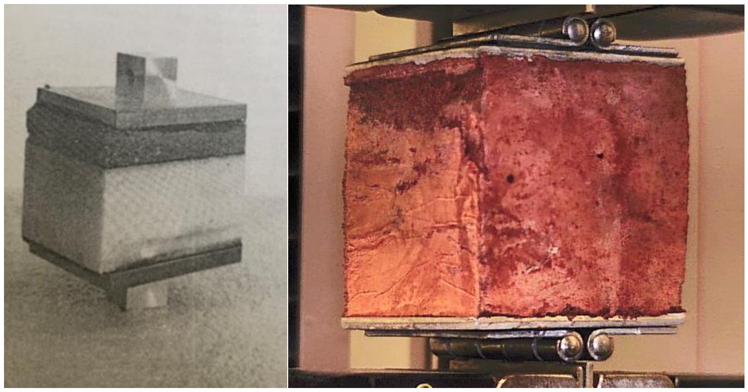


Figure 11. ASTM D1623 adhesion test sample (left) and FIU fabricated I-H foam adhesion sample (right).

Subtask 2.2: Results and Discussion

Foam Curing Temperature Profile

Three (3) polypropylene (PP) plastic containers with a volume of about 120 cubic inches was utilized with a single type K thermocouple placed at a height of 2 inches from the bottom, shown in Figure 13. For this experiment, each container has been filled with one foam cartridge. Each I-H foam cartridge expands to a volume of about 100 cubic inches.

The temperature profiles and maximum curing temperature for each container, when using one foam cartridge, is provided below in Table 2 and Figure 12. The maximum curing temperatures were very consistent and the highest temperature recorded was 276.0°F. The average maximum curing temperature for this experiment was 274.7°F.

Table 2. Maximum curing temperatures for each foam cartridge.

THERMOCOUPLE PER FOAM CARTRIDGE	MAX CURING TEMPERATURE (°F)
1	276.0
2	275.1
3	273.1
AVERAGE	**274.7**
STANDARD DEVIATION	1.5

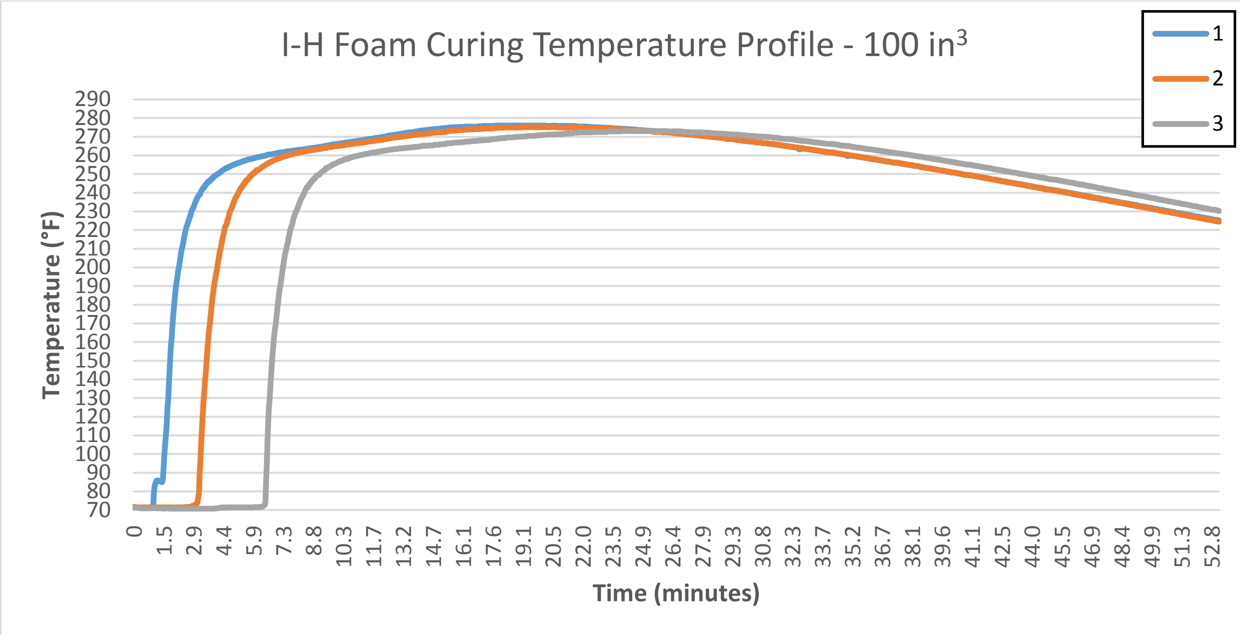
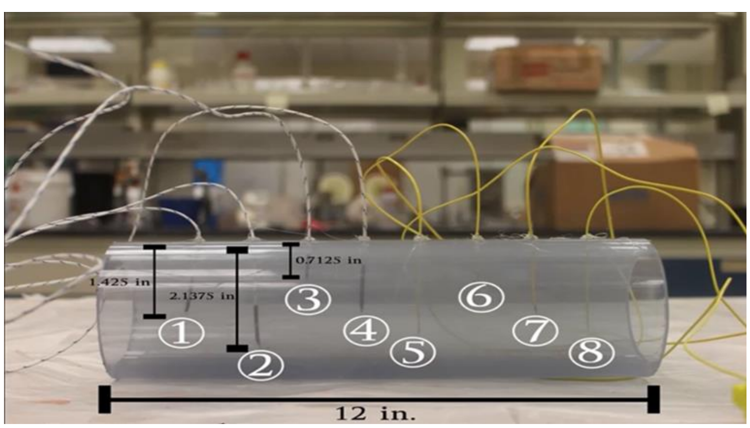


Figure 12. I-H foam curing temperature profile using one foam cartridge (about 100 in^3) per container.

Uniformity of Foam Application/Curing

A novel idea emerged to use the foam's curing temperature profile as an indicator of uniform application and/or curing within pipes. If proved successful, this technique will assist site personnel in the decision making process for determining areas where it is safe to cut pipework while mitigating the potential for a release and enhancing the safety of site operators, by using this non-destructive evaluation (NDE) method.

The initial proof-of-concept experiment was designed to determine if there is a correlation between curing temperature profile and anomalies in application and/or curing. Therefore, thermocouples were placed at varying heights along the pipe. Voids and artificialities were purposely created in order to evaluate the hypothesis.



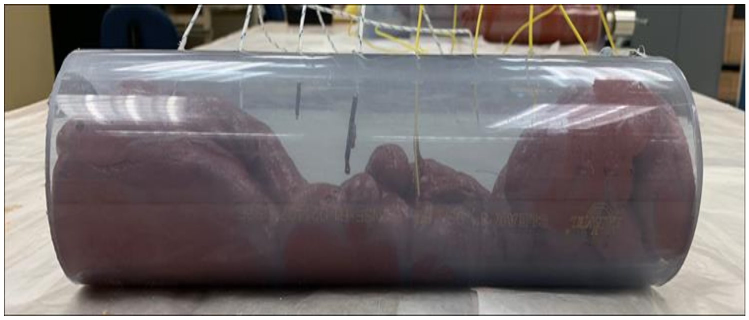


Figure 13. Experimental setup (top) and after foam application (bottom) to determine viability of NDE method.

The initial results provide support towards the confirmation of the NDE method that anomalies in application display much lower temperatures, which is illustrated in Table 3 and Figure 14. The close up visual inspection of the thermocouples in the clear PVC pipe provided additional information: the areas where the thermocouples were partially encapsulated (thermocouples 2, 5, and 7) had slightly higher temperatures than the thermocouples that were not encapsulated at all (thermocouples 3, 4, and 6).

Table 3. Maximum temperatures in areas of uniform application and anomalies.

	Thermocouple	Maximum Temperature (°F)
Uniform Application	1	263.8
	8	270.5
Anomalies in Application	2	232.1
	3	120.5
	4	146.6
	5	217.8
	6	131.7
	7	240.8

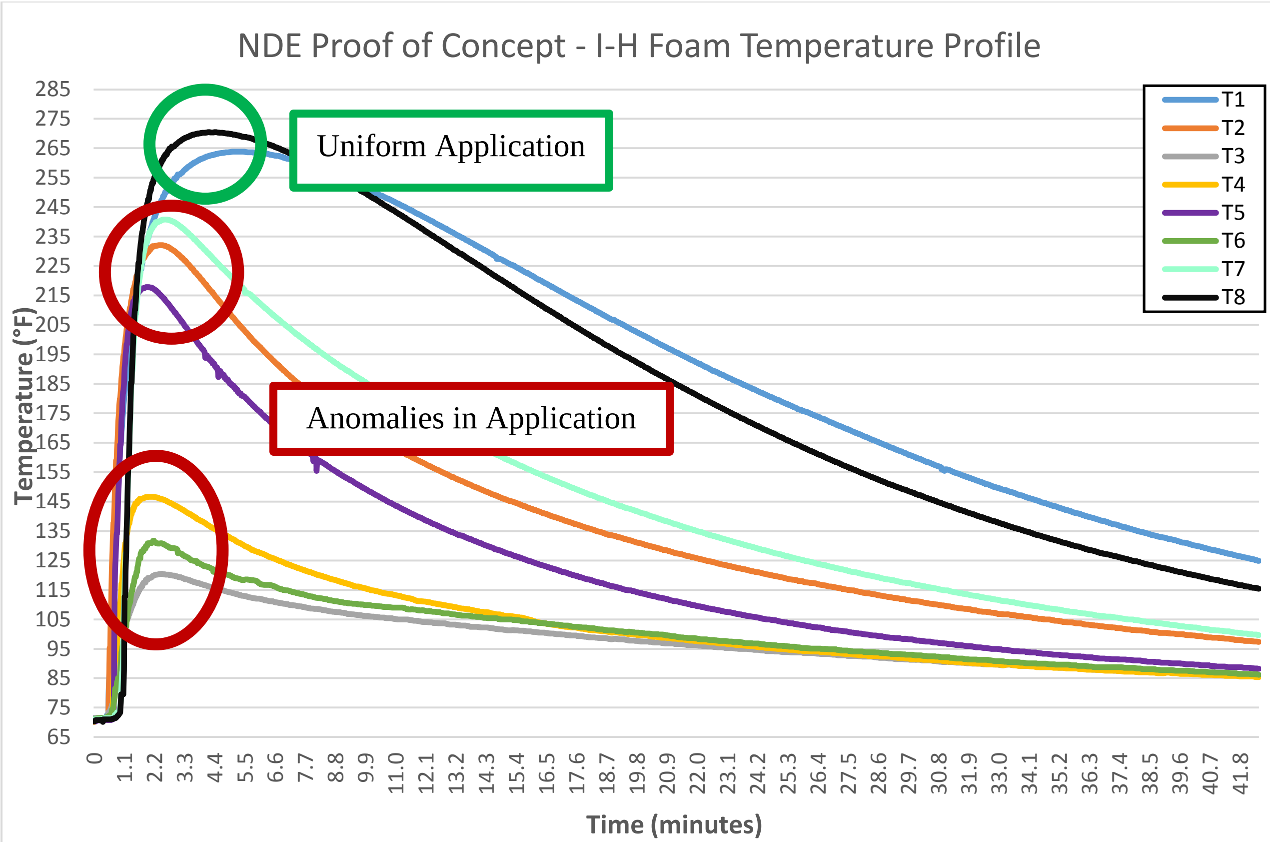


Figure 14. I-H foam temperature profile in clear PVC pipe with areas of uniform application and anomalies that were purposely created.

Based on the success of the initial proof-of-concept experiments, more substantial testing was performed in additional 304-stainless steel pipes. The purpose of this experiment is to provide more insight when using a thermal imaging camera as a non-destructive means to detect temperature differences in areas that could have a void or obstruction when filling a pipe with the down-selected intumescent foam, I-H. The specification of the 304-stainelss steel pipe used is as follows: 2 inch diameter, 12 inch length, and 0.154 inch wall thickness. The thermal image color palette was changed to "Rainbow HC (high contrast)" to amplify the subtle temperature variations on the substrate surface.

The control pipe was uniformly filled with the I-H foam without an obstruction. The other pipe contained a piece of Styrofoam that serves as the obstruction within the pipe. The obstruction was placed at a depth of 5.5 inches onto the wall of the stainless steel pipe. The obstruction Styrofoam piece had the following dimensions: 2.28 in. long, 1.64 in. wide, and 0.65 in. thick. Thermal image pictures were taken every 30 seconds for a total of 10 minutes. It is important to note that after 5 minutes there are not any other substantial findings to report. In the series of images shown below, the control and obstruction pipes were outlined in similar sections for comparison of the stainless steel substrate temperatures at the same time interval.

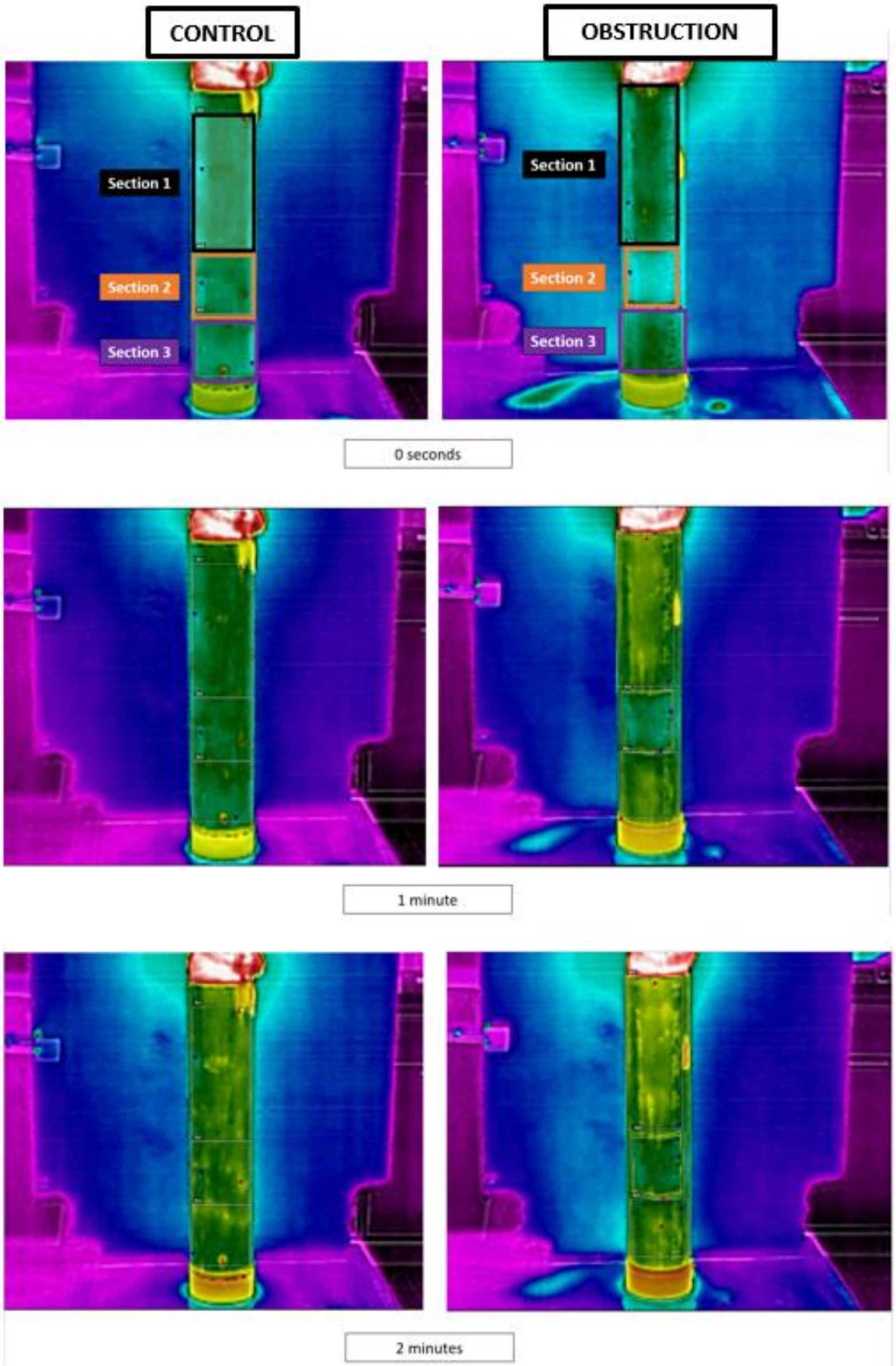


Figure 15. Thermal images of the control and obstruction pipes at varying time intervals after foam application.

In the obstruction pipe, the Styrofoam piece was in "Section 2" of the pipe and there is a cold spot that is visually distinguishable in the thermal images. There were no visual "cold spots" detected in the control pipe, implying a mostly uniform application.

The graphs in Figure 16 & Figure 17 confirm that the average temperatures in Section 2 (the obstruction) and Section 3 begin to converge and reach equilibrium with each other after three minutes.

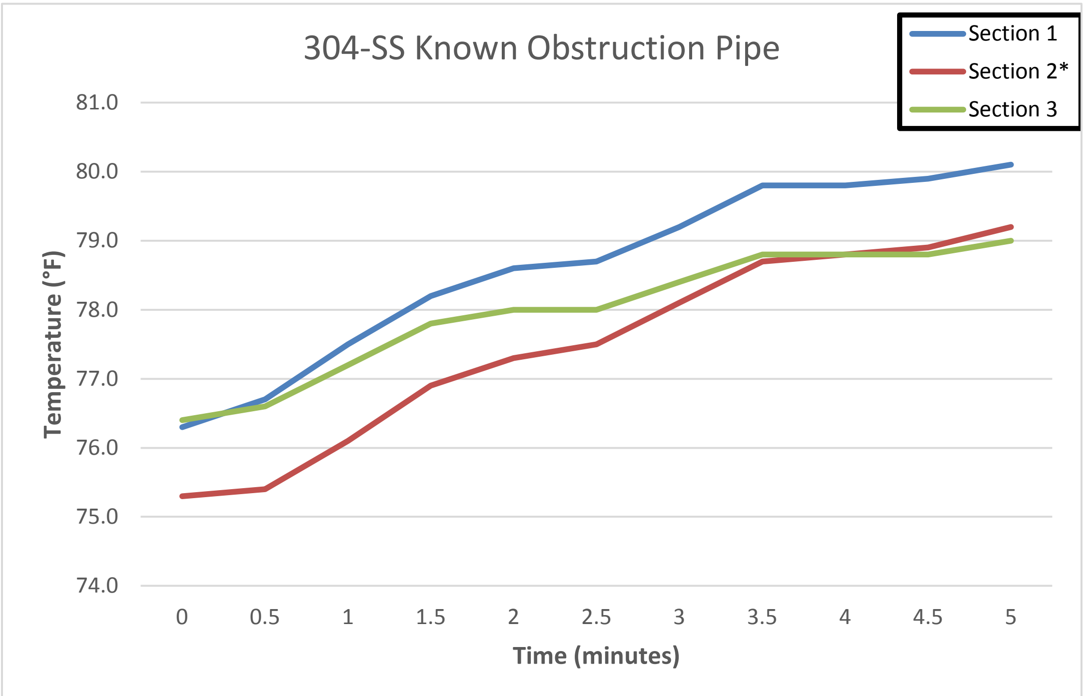


Figure 16. Graph of external temperature averages over time for the known obstruction pipe, with Section 2 containing the Styrofoam obstruction.

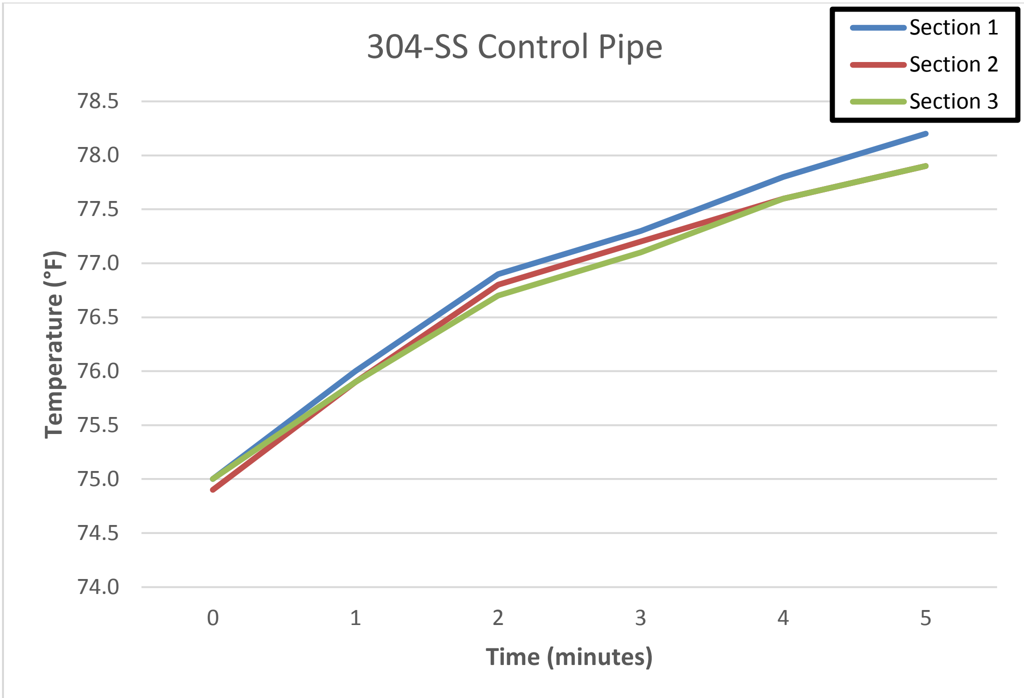


Figure 17. Graph of external temperature averages over time for the control pipe.

Overall, using a non-destructive evaluation technique as a means to detect anomalies or inconsistencies in application and/or curing when using intumescent foams as “plugs” for decommissioning of nuclear pipework seems extremely promising. Leveraging a highly sensitive thermal imaging camera is imperative for immediate visual detection of an anomaly in the first several minutes. Even more important is utilizing the temperature data analyzed with the FLIR Tools software for further detection and confirmation of anomalies even after there is no longer a visual cue. The temperatures produced in the area of an anomaly are significantly lower than the rest of the pipe. These “cold spots” correlate to areas that an operator should not perform any pipe cutting, because any cutting in that pipe section could result in potential release of residual contamination. Continued collaboration with SRNL and other site personnel will be critical in defining additional operational requirements for this technique.

Tensile Testing

A mold was 3D printed to dimensions that complied with the Type B tensile dye of ASTM D1623, shown in Figure 18. After a couple of minutes passed, the 304-stainless steel coupon was taken off and a handsaw was used to trim any excess foam from the top surface. The foam was then extracted very gently from the mold to produce the tensile testing sample.

Figure 18. 3D printed Tensile Testing Mold (left) and I-H foam cured inside mold (right).

Figure 19. Foam sample before failure (left) and after failure (right).

The initial tensile testing samples proved to be too thick for the tensile testing grips, which required the machine shop at SRNL to cut them into 0.3-inch-thick samples instead. However, many inconsistencies occurred due to the cutting, since most of the samples failed around 0.04-0.09 strain. The results of tensile testing are displayed in Table 4 which shows the maximum values experienced before failure. Samples 3 and 6 outperformed the others with the highest strain values (0.12 mm/mm^2 strain), which may be preferred in an operational sense.

Table 4. I-H Foam Tensile Test Results

SAMPLE	STRESS (N/MM^2)	LOAD (N)	LOAD (LBF)	STRAIN (MM/MM)
1	2.40	554.40	123.75	0.10
2*	0.77	177.87	39.70	0.04
3	1.70	392.70	87.65	0.12
4	1.64	378.84	84.56	0.05
5*	0.55	127.05	28.35	0.04
6	5.26	1215.06	271.21	0.12
7	2.29	528.99	118.08	0.04
AVERAGE	**2.09**	**482.13**	**107.61**	**0.07**

STANDARD DEVIATION	1.56	361.0	80.58	0.04

*Test run samples

<u>Compression Testing</u>

Two silicon molds were purchased locally (Figure 20) and the dimensions of each cavity in each mold complied with standard ASTM D1621: *Compressive Properties of Rigid Cellular Plastics*. Both rectangular and circular specimens will be considered as well as cubic samples that will be reused after adhesion testing.

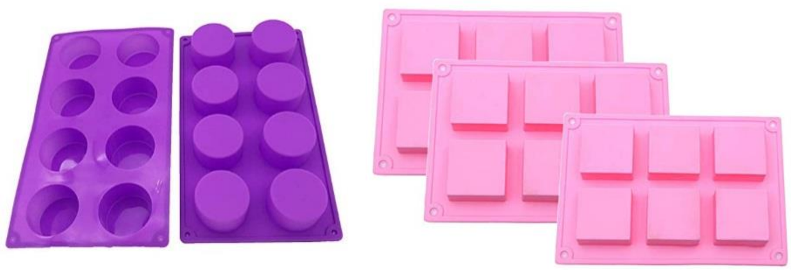


Figure 20. Compression sample molds.

The same process was followed as for the tensile testing samples. Any excess foam was shaved off and a total of 3-5 cylindrical, cubic, and rectangular samples were produced. All three specimens' dimensions were well above the minimum requirements of 20 mm in thickness and 2,500 mm^2 prescribed in ASTM D1621. The testing rate was 10% of the samples thickness, which is displayed in Table 5. The failure criteria for the machine to stop occurs when 13% of the samples' thickness is reached or 80% (40 kN) load capacity of the load cell is reached.

Table 5. Average Dimensions and Testing Rate for Compression Samples

	AVERAGE THICKNESS (MM)	AVERAGE AREA (MM^2)	AVERAGE TESTING RATE (MM/MIN)
CYLINDRICAL	29.39	2680	2.94
RECTANGULAR	23.50	3053	2.35
CUBIC	50.80	2580	5.08

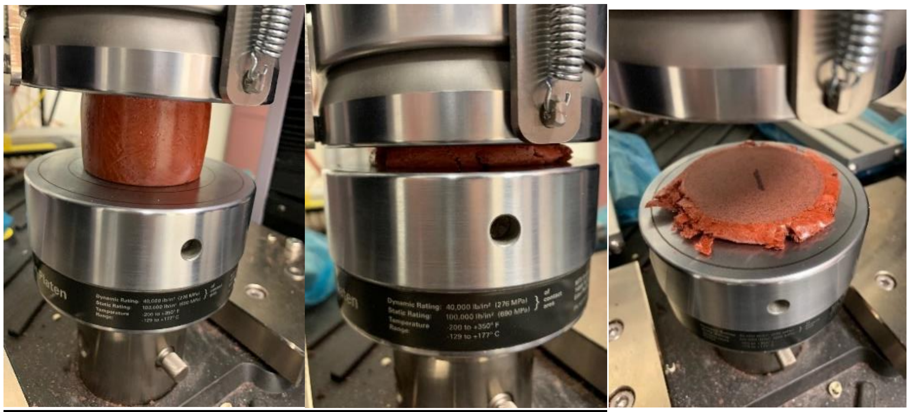


Figure 21. Compression process for I-H cylindrical sample.

The average stress-strain results of the testing are shown in Figure 22. The standard then requires the computation of the modulus of elasticity which describes the proportional limit a material can exhibit before permanent deformation occurs. The corresponding values are displayed in Table 6

.

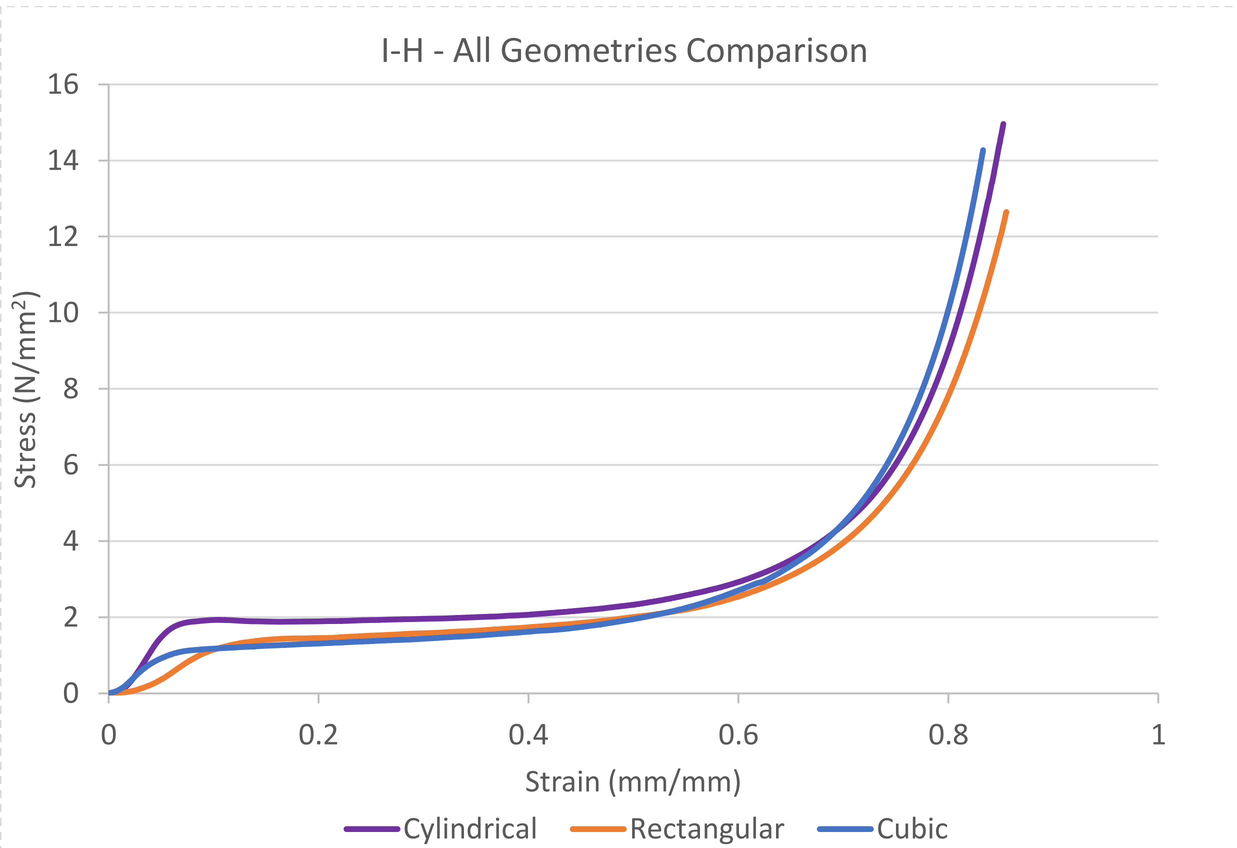


Figure 22. Stress-Strain graph of all geometries of I-H foam compression samples.

Table 6. Calculated Modulus of Elasticity and Final Thickness of Compression Samples

GEOMETRY	FINAL THICKNESS (MM)	THICKNESS DECREASE (%)	ELASTIC MODULUS (MPA)
CYLINDRICAL	8.34	72	27.09
RECTANGULAR	6.34	73	10.72
CUBE	12.82	75	16.84
AVERAGE	**9.17**	**73**	**18.21**
STANDARD DEVIATION	3.32	1.53	8.27

It is important to note that all the types of samples did not reach the final 13% strain requirement outlined in the ASTM standard. The load cell reached capacity at 40,000 N. It is imperative to know that there are no studies or any supporting material that explains what the criteria is for a sample being compressed or a tension that will induce the release of residual contamination. This testing was done in mind assuming a worst-case scenario in which the permanent foaming fixative is compressed to almost 90% of its original thickness.

<u>Adhesion Testing</u>

A mold was 3D printed with dimensions that complied with Type C specimens in ASTM D1623 (Figure 23). The inner dimensions of the rectangular mold were 2.25 inch by 2 inch by 2 inch. The two 304-stainless steel coupons were placed on the inner foams while the foam was applied and cured between them.

Figure 23. 3D mold with stainless steel coupons inside (left) and cured foam samples (right).

In order for the tensile testing machine to grip the adhesion sample, an attachment must be used. Four total hinges were super glued and sanded on the top and bottom surfaces as symmetrical as possible to ensure even stress distribution and to prevent any shearing. Preliminary testing was done to ensure the super glue would be strong enough to withstand the pulling. A rate of pull of 0.1 inches per minute was used and the experiment was a success as the top 304-stainless steel coupon was pulled off the I-H foam. The results are shown in Figure 24. The I-H foam experienced a maximum load of 450 N (100 lbf) before delaminating off the stainless-steel substrate. The sample experienced minimum strain as it only deformed 1% its original thickness (0.02 inches).

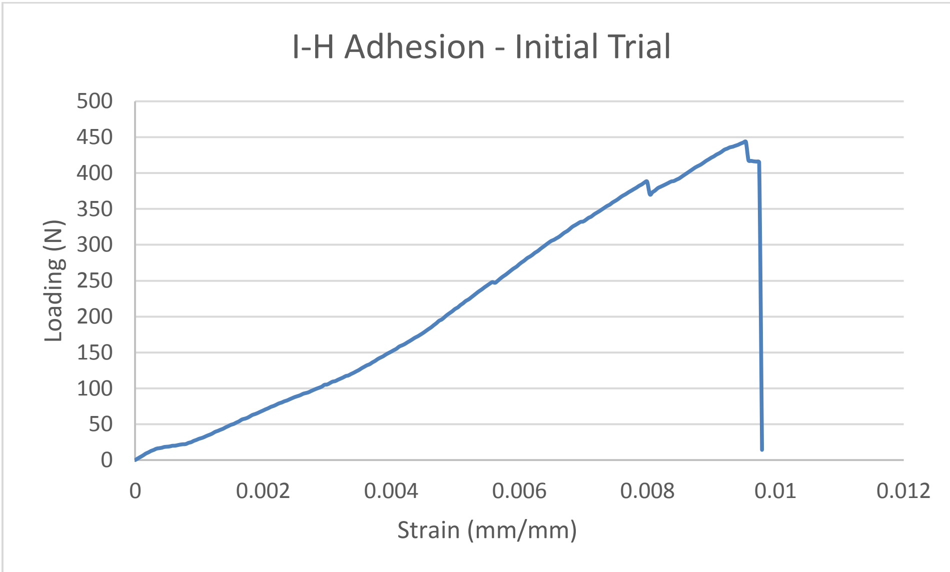


Figure 24. Initial foam adhesion test result.

The next set of samples did not fare as well as the initial trial since they experienced less than 180 N max loading. Sample 1 failed prematurely at 37 N. Since the loading was not high for three of the samples, it experienced much lower strain. The graph for Sample 4 shows the I-H foam experiencing almost 2,500 N (562 lbf) before the grip slipped off the hinges. This showcased excellent adhesion potential the I-H foam can potentially have in an ideal situation. It is worth noting that the stainless-steel coupons were clean and not contaminated which can increase the adhesion performance as the I-H foaming fixative.

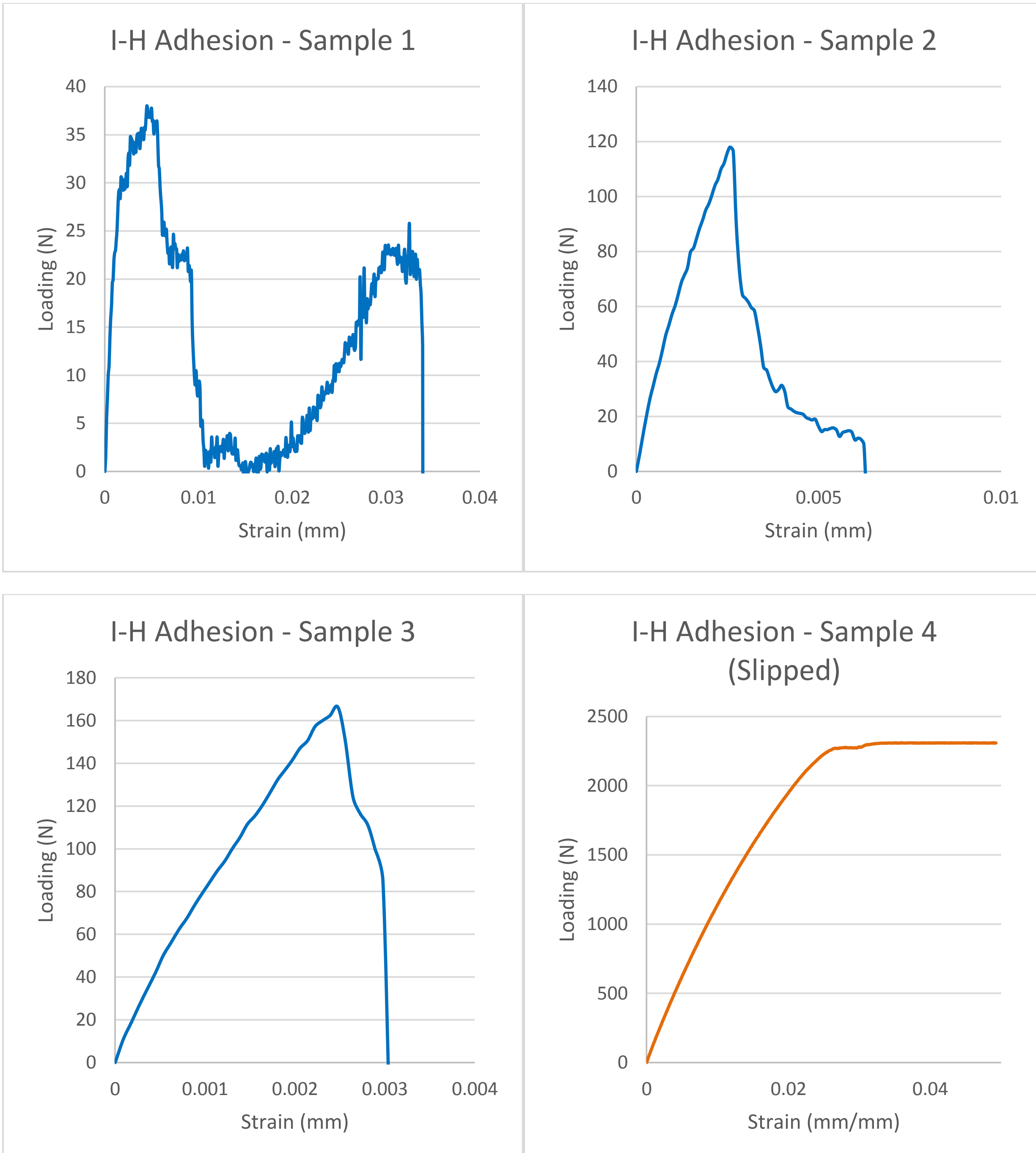


Figure 25. Adhesion results for each I-H foam sample.

Subtask 2.2: Conclusions and Future Work

FIU will continue collaboration with SRNL and leverage ASTM practices and principals to further define operational parameters and additional testing required to take this technology to a hot (radioactive) operational test and evaluation at a site designated by DOE in 2021. Mechanical testing will include overall "Plug Strength" to determine the force required to cause the foam to fail (delaminate or a combination of failures) when inside 304-stainless steel pipes. Future trials will focus on the system as a whole and evaluating its performance under relevant site conditions and some worst-case conditions.

Subtask 2.2: References

ASTM International. (2016). *D1621-16 Standard Test Method for Compressive Properties of Rigid Cellular Plastics.* Retrieved from https://doi.org/10.1520/D1621-16

ASTM International. (2017). *D1623-17 Standard Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics.* Retrieved from https://doi.org/10.1520/D1623-17

ASTM International. (2018). *E3191-18 Standard Specification for Permanent Foaming Fixatives Used to Mitigate Spread of Radioactive Contamination.* Retrieved from https://doi.org/10.1520/E3191-18

Extech Instruments. (2016). *Product Datasheet SDL200.* Retrieved from Extech: http://www.extech.com/resources/SDL200_DS-en.pdf

FLIR. (2019). *Electrical/Mechanical Applications FLIR EXX-Series.* Retrieved from https://www.flir.com/globalassets/imported-assets/document/17-3307-ins-e53-_-exx-series-datasheet-mfg-web.pdf

Hilti. (2015). *Hilti CP 620 Instruction for use.* Retrieved from Hilti: https://www.hilti.com/medias/sys_master/documents/h4a/9158089048094/Instruction-for-use-INT-CP-620-Instruction-for-use-PUB-5188045-000.pdf

Hilti. (2016). *Hilti Firestop Foam solid CFS-F SOL; CP 620 Safety information for 2-Component-Products.* Retrieved from Hilti: https://www.hilti.com/medias/sys_master/documents/hfc/9178915405854/Documentation-ASSET-DOC-APPROVAL-0564.pdf

Lagos, L., Sinicrope, J., Shoffner, P., Komninakis, M., Simoes-Ponce, T., Nuñez, J., & Rendon, J. (2019). *Testing and Evaluating Intumescent Foams in Operational Scenarios - Test Plan.* Miami: Applied Research Center - Florida International University.

Lagos, L., Sinicrope, J., Shoffner, P., Viera, J., Simoes-Ponce, T., & Nuñez, J. (2018). *Testing and Evaluating Radiological Shielding Foams Resistance to Thermal Stressors - Test Plan.* Miami: Applied Research Center - Florida International University.

MTS Criterion® Series 40. (2014). Retrieved from Product Information: https://engineering.jhu.edu/labs/wp-content/uploads/sites/76/2016/04/MTS-Criterion-40-Product-User-Manual.pdf

Nicholson, D., Peters, B., Washington, D., & Wilson, J. (2016). *FABRICATION AND EVALUATION OF RADIATION HARDENED POLYURETHANE FOAMS FOR D&D ACTIVITIES (SRNL-L3100-2016-00231).* Savannah River National Laboratory.

Subtask 2.3: Support to SRNL and SRS 235-F for Onsite Hot Demonstration

Subtask 2.3: Introduction

FIU has supported SRNL with follow up activities for the intumescent coating fixative hot test and evaluation at SRS. The hot field test, conducted in September 2018, involved the use of a selected intumescent coating within Process Cell 7 and a contaminated entry hood to Process Cell 1 of the Plutonium Fuel Form Facility (PuFF) at SRS Building 235-F. The objective of this research was to select and validate the operational performance of fire resilient fixative coating material(s) for residual surface contamination after gross decontamination is completed in a hot, radioactive environment in support of the 235-F Risk Reduction Project.

Subtask 2.3: Objectives

FIU continued to monitor a set of control coupons developed at FIU for comparison to the results from the SRS hot demonstration. These control coupons were coated with the same selected intumescent coating being used at SRS and are being aged at FIU under cold (non-radioactive) conditions similar to the environmental conditions at SRS. Comparison of the control coupon results will support the hot demonstration objective to determine the mechanisms of failure that the material may experience due to long-term alpha/gamma radiation exposure.

Subtask 2.3: Methodology

One control coupon is being maintained in ARC’s indoor laboratory under ideal conditions at ~72ºF and 30% humidity. The second is being maintained outside in ARC’s hot cell testbed at Miami’s ambient high temperatures and humidity. Weather conditions were also being monitored and a monthly average temperature and humidity will be documented.

Monitoring data collected by FIU is being evaluated for changes to the baseline data collected in December 2018. If a monthly measurement falls within the min-max range established, then that provides evidence that there has been no significant degradation of the coating or change in thickness. If a monthly reading falls outside of the min-max range, some amount of degradation or change in thickness has occurred.

Subtask 2.3: Results and Discussion

The following tables provide the thickness measurements to date for the two 304-stainless steel control coupons coated in intumescent fixative.

Table 7. Monthly Measurements of Control Coupon 1 (indoors) at FIU

Control Coupon 1 - Indoors											
	Baseline		Monthly Measurements								
Point	Minimum Average Tolerance Range (mm)	Maximum Average Tolerance Range (mm)	January	February	March	April	May	June	July	August	September
1	4.16	4.44	4.26	4.28	4.28	4.23	4.25	4.27	4.26	4.26	4.24
2	4.80	5.12	4.95	4.88	4.88	4.91	4.90	4.90	4.89	4.95	4.88
3	-	-	-	-	-	-	-	-	-	-	-
4	4.29	4.57	4.39	4.49	4.47	4.41	4.43	4.43	4.45	4.42	4.37
5	3.92	4.19	4.03	4.04	4.02	4.00	4.02	4.04	4.02	4.03	4.06
6	4.19	4.47	4.37	4.35	4.35	4.30	4.38	4.38	4.34	4.38	4.40
7	4.12	4.69	4.24	4.31	4.33	4.23	4.29	4.25	4.22	4.21	4.25
8	3.79	4.04	3.90	3.92	3.91	3.88	3.91	3.91	3.91	3.90	3.89
9	4.20	4.48	4.33	4.32	4.31	4.35	4.33	4.33	4.31	4.36	4.28
10	3.89	4.15	4.02	4.02	4.02	4.02	4.04	4.04	4.01	4.01	3.98
11	3.28	3.51	3.44	3.41	3.44	3.43	3.43	3.42	3.41	3.44	3.46
12	4.05	4.32	4.16	4.20	4.21	4.20	4.18	4.18	4.16	4.18	4.16
13	3.55	3.79	3.64	3.67	3.65	3.63	3.67	3.68	3.64	3.66	3.63

Table 8. Monthly Measurements of Control Coupon 2 (outdoors) at FIU

Control Coupon 2 - Outdoors											
	Baseline		Monthly Measurements								
Point	Minimum Average Tolerance Range (mm)	Maximum Average Tolerance Range (mm)	January	February	March	April	May	June	July	August	September
1	3.23	3.45	3.40	3.42	3.39	3.34	3.37	3.37	3.39	3.38	3.38
2	3.39	3.62	3.53	3.57	3.52	3.46	3.53	3.52	3.52	3.51	3.49
3	3.03	3.24	3.15	3.13	3.12	3.10	3.11	3.10	3.12	3.12	3.10
4	3.92	4.19	4.10	4.15	4.12	4.01	4.05	4.07	4.09	4.07	4.06
5	3.75	4.00	3.87	3.94	3.91	3.84	3.87	3.87	3.89	3.87	3.85
6	4.39	4.68	4.56	4.58	4.59	4.49	4.55	4.54	4.54	4.52	4.54
7	4.19	4.47	4.33	4.36	4.34	4.26	4.29	4.32	4.33	4.33	4.30
8	3.67	3.92	3.80	3.79	3.78	3.75	3.74	3.75	3.79	3.76	3.77
9	3.59	3.83	3.75	3.74	3.71	3.65	3.68	3.69	3.70	3.72	3.67
10	3.33	3.55	3.48	3.43	3.44	3.39	3.40	3.42	3.42	3.43	3.44
11	3.25	3.47	3.38	3.39	3.37	3.34	3.36	3.36	3.37	3.37	3.32
12	3.32	3.55	3.46	3.43	3.42	3.42	3.41	3.42	3.41	3.41	3.41
13	3.01	3.22	3.15	3.10	3.09	3.10	3.08	3.07	3.11	3.12	3.11

Subtask 2.3: Conclusions and Future Work

All the thickness measurements across all points on the 12”x12” coupons remained within tolerances of the established baseline range, indicating that there has been no significant degradation in coating thickness. FIU will continue to monitor these control coupons on a monthly basis for one year from baseline measurements. In collaboration with SRNL, FIU will also assist with additional data analysis, reporting, and documentation for the SRNL Close Out report of the hot demonstration.

Subtask 2.3: References

Lagos, L., Sinicrope, J., Shoffner, P., Awwad, A., & Rivera, J. (2015). *Enhancing Operational Performance of Fixatives and Coatings for D&D Activities: Phase I - Baselining and*

Proof of Concept - Test Plan. Miami: Applied Research Center - Florida International University.

Lagos, L., Sinicrope, J., Shoffner, P., Viera, J., Simoes-Ponce, T., & Nuñez, J. (2018). *Potential Applications of Intumescent Coatings to Address Safety Basis Requirement - Technical Progress Report.* Miami: Applied Research Center - Florida International University.

Subtask 2.4: Support for Open Air Demolition Activities (NEW)

Subtask 2.4: Introduction

This is a new subtask under which FIU is initiating an evaluation of open air demolition solutions including contamination control products (e.g., fixatives) under impact stressors in response to a high operational priority requirement identified across the DOE complex. This research effort has the added benefit of potentially providing essential data points on the positive effects of fixative technologies on mitigating airborne release fractions, respirable fractions, and resuspension rates.

Subtask 2.4: Objectives

Develop testing protocols and a viable experimental design to meet the scientific rigor of end user requirements to quantitatively determine the selected technology's ability to fix and immobilize contaminants on a variety of surfaces under ideal conditions, as well as when exposed to stressors (i.e. impact, heat, etc.).

Subtask 2.4: Methodology

There are four principals in order to collect accurate data to evaluate the performance of fixative technologies:

<u>Surrogate Contaminant and Controlled Contamination of Test Coupons</u>

These methods and protocols ensure a degree of uniformity between replicate samples within a batch, while allowing control over the extent of contamination between sample batches. For these studies, only powder surrogate (non-radioactive) contamination is considered.

Soluble forms of surrogate contamination offer relatively simple chemical processing for analysis. Many chemical quantification techniques require the analyte to be dissolved in solution, thus presenting a challenge for analysis of non-soluble surrogates. A suggested alternative to the standard non-soluble surrogates (i.e. CeO_2 and ZrO_2) is bismuth trioxide (Bi_2O_3). Bismuth trioxide is a light yellow to white solid powder that is not soluble in water but can be completely dissolved in mineral acids.

Evaporative techniques, sometimes referred to as "drop casting", are a convenient way to deposit homogenous mixtures onto a substrate. Provided that the quantity of liquid on the surface is known, and that the liquid is truly homogeneous, then the quantity of surrogate contaminant deposited can easily be determined. This can also be confirmed, to a certain degree of precision, by mass change. Initial experiments will be done using small coupons so that the initial contamination loading can be quantified by gravimetric analysis.

Delivery of Stressor

A given stressor (i.e. impact, heat, etc.) will function as the independent variable for any given trial. It is therefore imperative that this is an easily measurable and controllable parameter. Initial trials will focus on impact stressors which are delivered by means of a pneumatic piston. A pneumatic piston could also accommodate a variety of different impactor heads of various materials and shapes. The impact force can be adjusted by varying the pressure from a simple air compressor and triggered with a push button valve or solenoid valve controlled via a computer. Figure 26demonstrates the anticipated setup with the pneumatic piston.

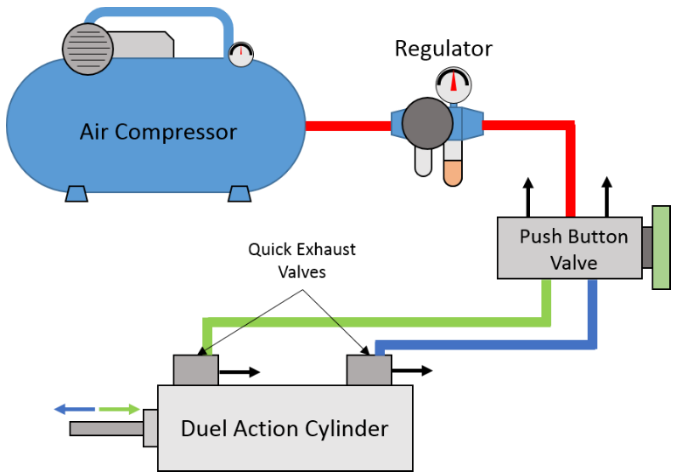


Figure 26. Simple pneumatic system. Black arrows represent exhaust flow.

The force delivered to the test coupon by the pneumatic piston can be quantified by integrating a high-speed load cell and piezoelectric force sensor. Piezoelectric force sensors can only measure dynamic forces but are high capacity (50,000 lb) units with fast data sampling rates (>50 kHz).

Figure 27. Load cell/piezoelectric setup to measure the impact force applied to samples.

Future iterations may include thermal and water stressors.

<u>Contamination Release Collection</u>

In order to quantify a total release, effective collection methods must be used to ensure accuracy of the data. Leveraging common practices found in air quality control standards, collecting the released particulates involve a pumping device and a filter cassette or stack. A typical filter stack/cassette will have three layers of polymer-based membrane filter and a common choice for air sampling is a mixed cellulose ester (MCE). MCE membrane filters are easily capable of capturing airborne and respirable fractions (10 µm and 2.5 µm diameter) and can also be completely digested in nitric acid, conforming to the recommended means of processing for inductively coupled plasma (ICP) analytical techniques. Polyvinyl chloride (PVC) filters are another strong candidate material, often used in standards-based testing, however these filters typically have a pore size of 5.0 µm.

An alternative collection technique is the use of a cascade impactor in place of a filter cassette. Cascade impactors require similar pumps and flow rates to operate, however, they are also capable of separating collected dust into size fractions. Particles are usually collected on collection plates on polytetrafluoroethylene (PTFE) membranes. These can be removed and chemically processed, although complete dissolution by acid is not possible with PTFE, soluble particles can be dissolved with several hours of soaking.

Pumping devices for collection systems typically have variable flow rates (2-30 L/min) to accommodate different filtering devices. It might be necessary to use the air outlet as a means of creating a recirculating air flow. This would create a closed flow system that ensures that no particulate matter can escape.

<u>Processing and Analysis</u>

The released surrogate contamination collected, insoluble Bi_2O_3 or soluble CsCl, is dissolved in an acidic medium, preferably nitric acid as this is already commonly used as the default matrix for ICP techniques. These methods provide data on the concentration of contamination in each sample, it is therefore of high importance to accurately track the quantities of acid used to allow for the back calculation to an absolute mass.

ICP-MS and ICP-OES are common analytical techniques for detecting the presence of elements in a sample and quantifying those specific elements. Both these techniques begin by vaporizing and ionizing a liquid sample, usually acidic medium, through the use of an inductively coupled plasma. Once ionized, the specific elements can be detected and quantified in different ways. Mass spectroscopy detects charged particle impacts following a deflection by a magnetic field that separates ions by mass/charge ratios.

Subtask 2.4: Results and Discussion

Initial trials were carried out to aid in the method development for uniformly contaminating samples with the surrogate contamination, bismuth trioxide (Bi_2O_3). The material was supplied by Sigma Aldrich (99.9% purity) as a 10 µm powder. A small quantity was suspended in isopropyl alcohol by means of sonication for 5 minutes. The suspension was only stable for a few minutes; long enough to apply, but a more stable suspension should be sought to allow for longer working times.

The suspension was applied to a stainless-steel coupon using two methods. The first method was a drop casting method that did not produce satisfactory coverage of the coupon. The second method utilized a spray bottle as a crude dispersal device. The suspension was sprayed with no trouble and was successfully deposited on the coupon. Once the solvent was evaporated, the coverage of the oxide was observed to be non-uniform at mm scales, but somewhat uniform at an inch scale. The slow evaporation of the solvent gave rise to agglomeration sites that disrupted the uniform coverage.

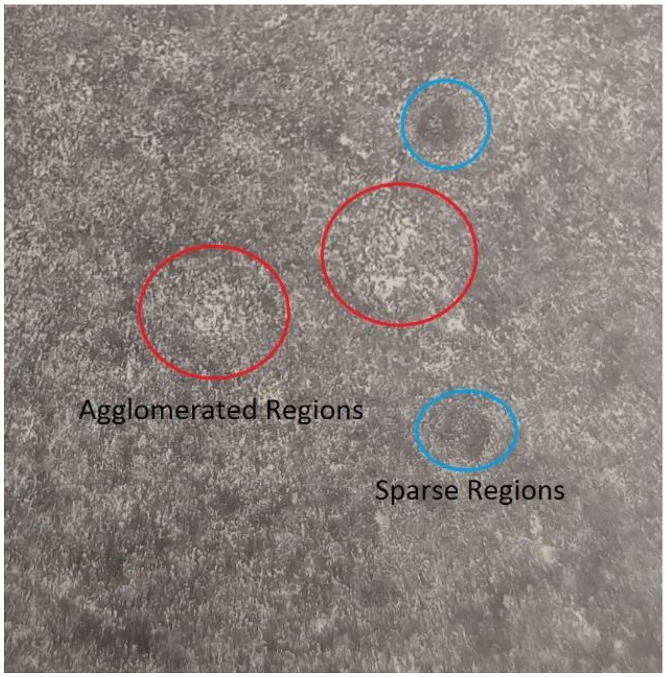


Figure 28. Stainless steel coupon with surrogate contamination (bismuth trioxide).

As a crude method, this was a satisfactory result that suggests better uniformity can be achieved with only minor adjustments to the method. Those adjustments may include:

1. Developing a more stable suspension of Bi_2O_3.
2. Improving the method for aerosolization/dispersal.
3. Reducing the evaporation time by gentle heating.

Subtask 2.4: Conclusions and Future Work

Preliminary tests are being conducted to assess the viability of certain aspects of the experimental design (i.e. uniform contamination procedures, accurate impact force measurements, etc.). Once the design is confirmed, FIU will proceed with conducting thorough experiments for evaluating fixatives under impact stressors.

Subtask 2.4: References

Donoclift, T. (2019). *Experimental Design for the Quantification of Contamination Release during Open Air Demolition Operations.* Miami: Applied Research Center - Florida International University.

TASK 3: D&D KNOWLEDGE MANAGEMENT INFORMATION TOOL

Task 3: Executive Summary

The Knowledge Management Information Tool (KM-IT) is a web-based system developed to maintain and preserve the EM 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, 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 KM-IT is a community driven system tailored to serve the technical issues faced by the EM workforce across the DOE Complex.

During FIU Performance Year 9, FIU focused efforts on outreach and marketing for KM-IT, enhancement of a web crawler to search and retrieve information related to D&D from internet sources, continued content management/web analytics and cybersecurity research to secure KM-IT infrastructure.

Subtask 3.1: Outreach and Marketing (EM Community Support)

Subtask 3.1: Introduction

FIU's activities for outreach and marketing of KM-IT included the following:

Newsletters and Mass Communications**:** Newsletters and online promotions are a great way to bring waves of traffic to the website. By using the registered users as recipients, users were kept up-to-date on new features and content on the D&D KM-IT.

Conferences and Workshops**:** Participation and presentations of KM-IT at industry conferences boosts awareness of the website and its capabilities to the target users. FIU presented KM-IT at conferences, such as the Waste Management Symposia, through a combination of oral and poster presentations as well as individual and small-group demonstrations and workshops hosted in the exhibition hall. At these events, the site features can be explained in detail and participants can share their feedback and ideas.

User Support and Ad Hoc Specialized Reports: This task includes supporting KM-IT users with a help desk role to resolve issues on a day-to-day basis as well as developing specialized reports for unforeseen data requests using the KM-IT system from DOE or the EM community of practice.

Subtask 3.1: Objectives

The objective of this task is to reach the D&D community and educate them on the features available on the D&D KM-IT system. There are many industry leaders who work at various DOE sites and national labs that can benefit greatly from the capabilities that the system has to offer. In many cases, these individuals are not aware of the system, so by doing outreach and marketing, the system usage can be promoted while helping the D&D community meet their knowledge management needs.

Outreach and marketing is a critical element towards the long-term sustainability of knowledge and is essential for the long-term strategic vision of D&D KM-IT. This task will allow D&D KM-IT to continue to grow and mature into a self-sustaining system through the active participation of the D&D community it was designed to serve.

Subtask 3.1: Methodology

This task is an ongoing process that is executed over the course of the year. When new features or content is added to the system, DOE is notified and others in the industry are reached via email to get feedback and comments. This is done not only to communicate with DOE regarding accomplishments and milestones, but also to involve other leaders in the industry in the process of spreading the word about D&D KM-IT. When sending newsletters, FIU uses the D&D KM-IT as its recipients. Currently, there are 1,053 registered users in the system. FIU has also used the public distribution list provided by the Waste Management Symposia (WMS) to make announcements about the D&D KM-IT training workshop typically held at the FIU booth during WMS.

FIU uses a third party application/service called Mailchimp to send newsletters to a large distribution list. This service supports email stats like opened emails and read emails, and it also tracks clicks. However, for official announcement of milestones and deliverables, FIU uses a typical email system to notify its stakeholders. During the course of this year, several emails were sent to DOE notifying them about new features, such as the development of a sub-module on the KM-IT platform to highlight current EM research efforts and activities in support of D&D. This particular effort will be discussed in detail in the following subtask.

Below is a sample screenshot of a newsletter sent to the 2019 Waste Management attendees announcing the FIU booth location and other FIU activities during WMS.

FIU Applied Research Center | Environment & Energy | Cyber Security & IT | Aerospace & Defense

FIU at Waste Management 2019

Stop and visit the FIU booth (#409) as well as the University Pavilion at WM19 during exhibitor hall hours. One-on-one demonstrations of the D&D M-IT system will be offered at the FIU booth to share the current capabilities and available features. This system was developed by Florida International University - Applied Research Center (FIU-ARC) in collaboration with the Department of Energy Office of Environmental Management (DOE EM). In addition, some of the robotic technologies being developed at FIU will be on display and showcased at the FIU booth and University Pavilion. This will include our miniature rover and pipe crawlers.

Dr. Leonel Lagos, FIU staff and DOE Fellows with Andrew Szilagyi (DOE EM-4.11) and Mark Gilbertson (DOE EM 4) at the FIU exhibiter booth at WM18.

Also at Waste Management 2019

FIU students (known as DOE Fellows) from the DOE-FIU Science and Technology Workforce Development Program will be presenting their research posters, along with students from other academic institutions, during the student poster session in the exhibit hall on Monday, March 3 from 1:30-5:00 pm.

The DOE Fellows will also be assisting with staffing the FIU booth (#409) throughout the exhibit hall hours so come by to meet and talk to these talented future engineers and scientists.

Figure 29. FIU newsletter to attendees of the 2019 Waste Management Symposia

FIU participated in relevant meetings and conferences in support subtask 3.1 where D&D KM-IT was presented, including multiple workshops and as mentioned above the Waste Management Symposium, March 3-8. 2019, in Phoenix, AZ.

FIU prepared and presented a professional paper titled, “Robotics on KM-IT Platform,” during the Waste Management 2019 conference in Phoenix, AZ with an oral presentation by Walter Quintero focused on the newly developed platform for knowledge management of robotics technologies.

Subtask 3.1: Results and Discussion

The task of outreach and marketing is a continuous process due to the growing number of members of the D&D community. As a result, new relationships and collaboration opportunities continue to emerge by executing this task. In addition, the marketing portion of this task supports the online presence and growth of the system. Compared to the previous year, the system’s web analytics show a growth of about 16% in user activity, with double digit increases in sessions and page views as well.

Subtask 3.1: Conclusions and Future Work

As mentioned earlier, outreach and marketing is a critical element towards the long-term sustainability of knowledge and is essential for the long-term strategic vision of D&D KM-IT. Moving forward, FIU will continue to participate in industry conferences (such as Waste Management Symposia) and other workshops to demonstrate and promote the KM-IT system. This allows for collaboration with other centers, facilities and DOE sites to increase usage and subject matter specialist participation.

In addition, FIU will continue to develop newsletters for mass communication via email to keep users informed of new system features and other related activities. Finally, user support, including ad hoc specialized reporting as requested, will continue to be provided to the D&D user community under this task.

Subtask 3.1: References

Deactivation and Decommissioning Knowledge Management Information Tool (D&D KM-IT), https://www.dndkm.org/, Applied Research Center, Florida International University.

Waste Management Symposia, https://wmsym.org/, Waste Management (WM) Symposia, Inc.

Himanshu Upadhyay, Walter Quintero, Leonel Lagos, Peggy Shoffner. Robotics on KM-IT Platform. Waste Management 2019 Conference, Phoenix, AZ, March 2019.

Subtask 3.2: KM-IT Development and Enhancement

Subtask 3.2: Introduction

In this subtask, FIU performed some development and enhancement to the D&D KM-IT system. One of the tasks was to enhance and optimize the web crawler to search and retrieve information related to D&D from identified internet sources/websites. This search feature allows the user to search the web in a manner similar to a Google search for robotic information without leaving the KM-IT system. The different features of the search module will be enhanced:

- Search KM-IT: Searches document and pages located within the D&D KM-IT system
- OSTI Search: Searches documents located in the OSTI repository at osti.gov
- Search Web: Searches D&D related information across predefined list of D&D websites outside D&D KM-IT

On the development front, FIU developed a sub-module on the KM-IT platform to highlight current EM research efforts and activities in support of D&D, starting with FIU/SRNL research on fixatives and intumescent products.

Subtask 3.2: Objectives

The objective of the enhancement and optimization of the web crawler is to improve the capabilities of this module. Unlike the typical Google search, the KM-IT web crawler will only retrieve information from predefined websites which helps to reduce irrelevant results. The crawler will also provide a search of the entire KM-IT repository across all of the modules (ALARA Reports, Technology, Lessons Learned, Best Practices and more). The custom crawler will provide the user with a list of the best-matching web pages with a preview or short summary of the contents.

As stated before, FIU also developed a sub-module on the KM-IT platform to highlight current EM research. This module focuses on efforts and research activities in support of D&D. To start, FIU populated the module with FIU/SRNL research on fixatives and intumescent products.

Subtask 3.2: Methodology

FIU enhanced the search module by updating each of its features. It also completely redesigned the way the D&D KM-IT retrieves the OSTI information by moving from a widget type of search box to using OSTI's API.

Below are key features of the enhanced module:

- Search KM-IT - The search KM-IT feature was optimized by updating the search index on the backend. The index crawls through documents, pdfs, htmls and any other types of readable documents stored on the site. The latest index captured a total of 6,665 documents.
- OSTI Search - FIU has taken advantage of the OSTI's Web API and has completely changed the architecture and redesigned how the KM-IT retrieves the data from OSTI. The OSTI.GOV API allows client applications to query the Department of Energy's repository for research information resulting from DOE research funding.
- Search Web - The backend of this feature is very similar to the Search D&D KM-IT. FIU has updated the D&D website URLs that the crawler uses to retrieve the information by removing the old and outdated URLs and replacing with correct and current URLs. New D&D sites have also been added to the list.

For the research module development, FIU populated the new sub-module with fact sheets, photographs, and videos from research performed by and in collaboration with the Applied Research Center in recent years, including research on industry fixatives, intumescent coatings as fire resilient fixatives, FX2 fogging, the ICM crawler, and robotic inspection tools.

Subtask 3.2: Results and Discussion

FIU completed enhancing and optimizing the web crawler to search and retrieve information related to D&D from within KM-IT as well as from OSTI and identified internet sources/websites. The custom crawler provides the user with a list of the best-matching web pages with a preview or short summary of the contents. The associated milestone with this activity was completed by December 7, 2018. Below is the screenshot of the search module landing page.

Figure 30. The D&D KM-IT web crawler landing page.

Search KM-IT - Enhancements

The search KM-IT feature was optimized by updating the search index on the backend. This index crawls the D&D KM-IT website and stores key information about each document so that when users perform a search, the information can be returned in less than a second to the user. The index crawls through documents, pdfs, htmls and any other types of readable documents stored on the site. The latest index captured a total of 6,665 documents.

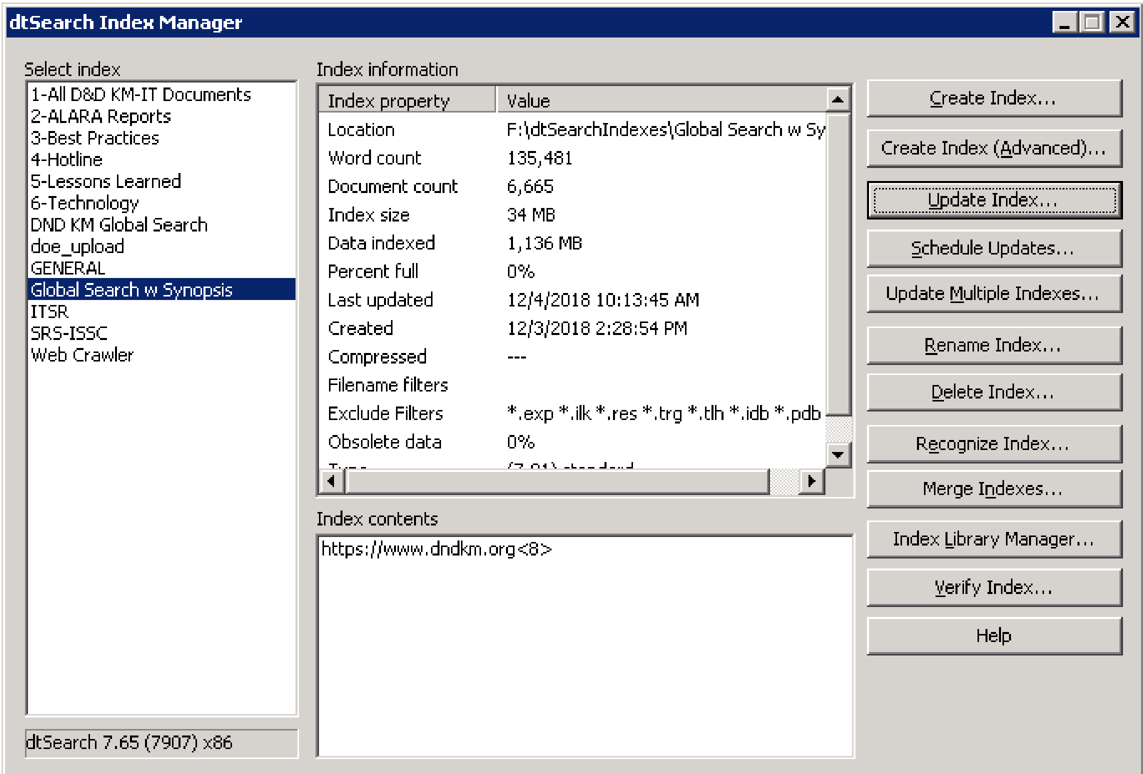


Figure 31. Search D&D KM-IT index crawler information

OSTI Search

A significant effort was focused on the OSTI search feature. OSTI recently released a public REST Web API that exposes their data to the web for consumption. The OSTI.GOV API allows client applications to query the Department of Energy's repository of research information resulting from DOE research funding. The API is built on a REST architecture, providing predictable URLs that promote application integration with multiple platforms. As a result, the HTTP-based API can be accessed using a wide variety of clients. FIU has taken advantage of this Web API and has completely redesigned how the KM-IT retrieves data from OSTI. The diagram below represents the data flow from KM-IT and the OSTI Web API.

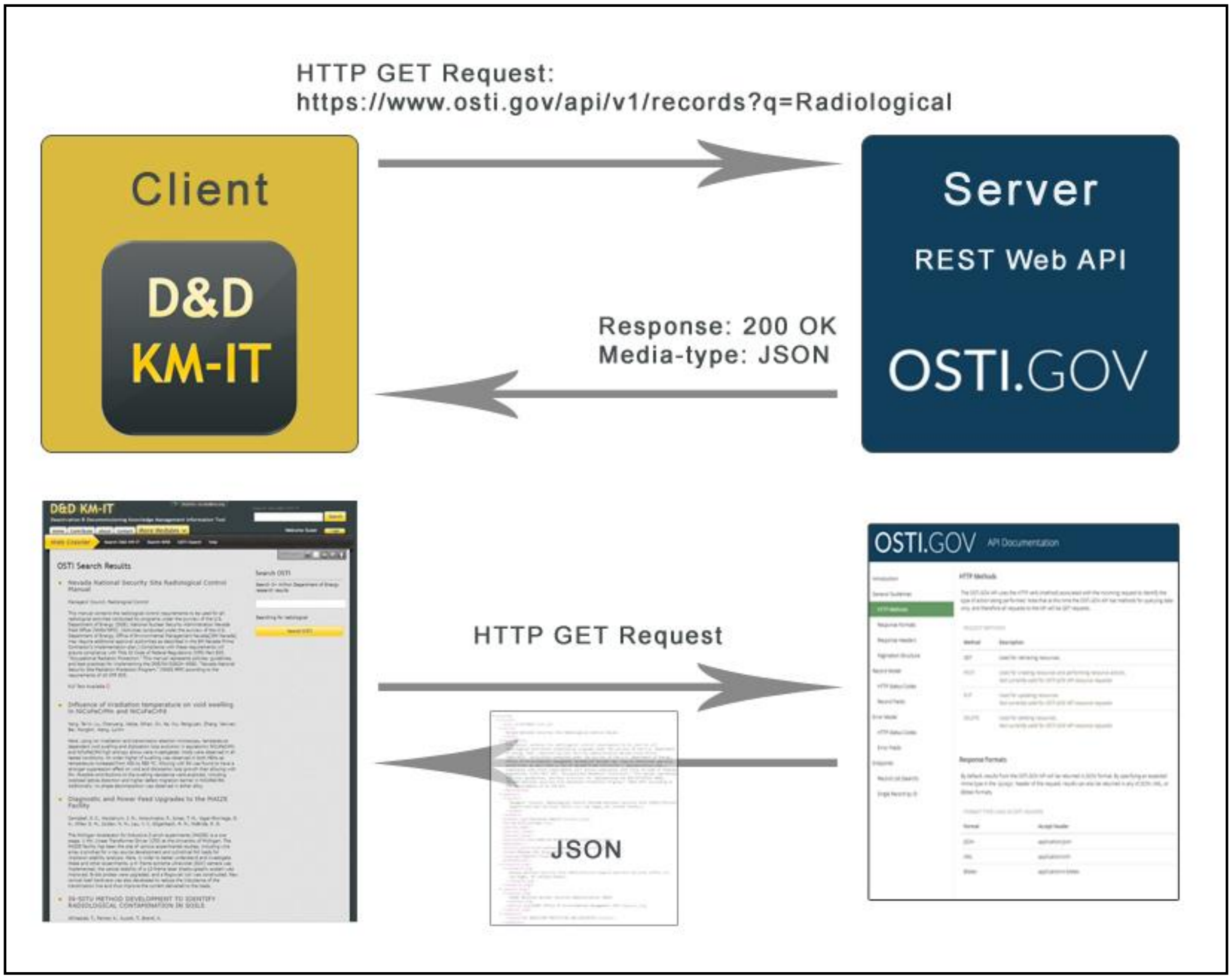


Figure 32. D&D KM-IT data flow interaction with OSTI Web API

Two new pages were created on KM-IT to support the OSTI Web API integration. The search results summary page and the results detail page. When a user performs a search using the OSTI Search, the search term is sent to the OSTI Web API, which sends back a JSON list of all the results from the query. The JSON gets processed on the backend where the results are formatted to be displayed properly on the HTML page. A sample of the search result summary page is shown in the figure below. Notice that “radiological” was used in the search example.

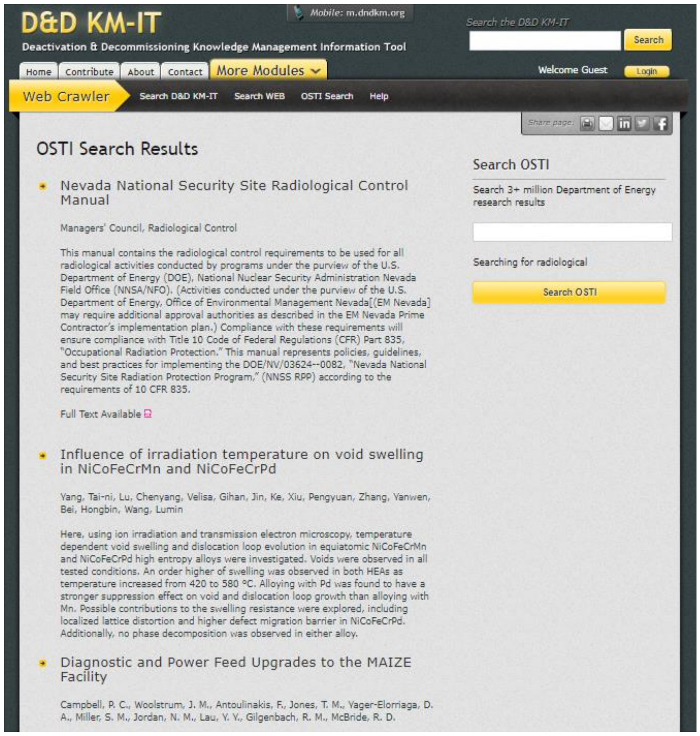


Figure 33. OSTI Search summary using radiological as the search term.

From the results summary, a user can click to get more details on any of the results. The details page also gets the information from the OSTI Web API. This information includes document title, abstract, author(s), publication data, research and sponsoring organization(s), OSTI identifier, report number(s), DOE contract number and country of publication. There are links to the full text of the document and citation if available from OSTI. A sample of a search result details display can be viewed below.

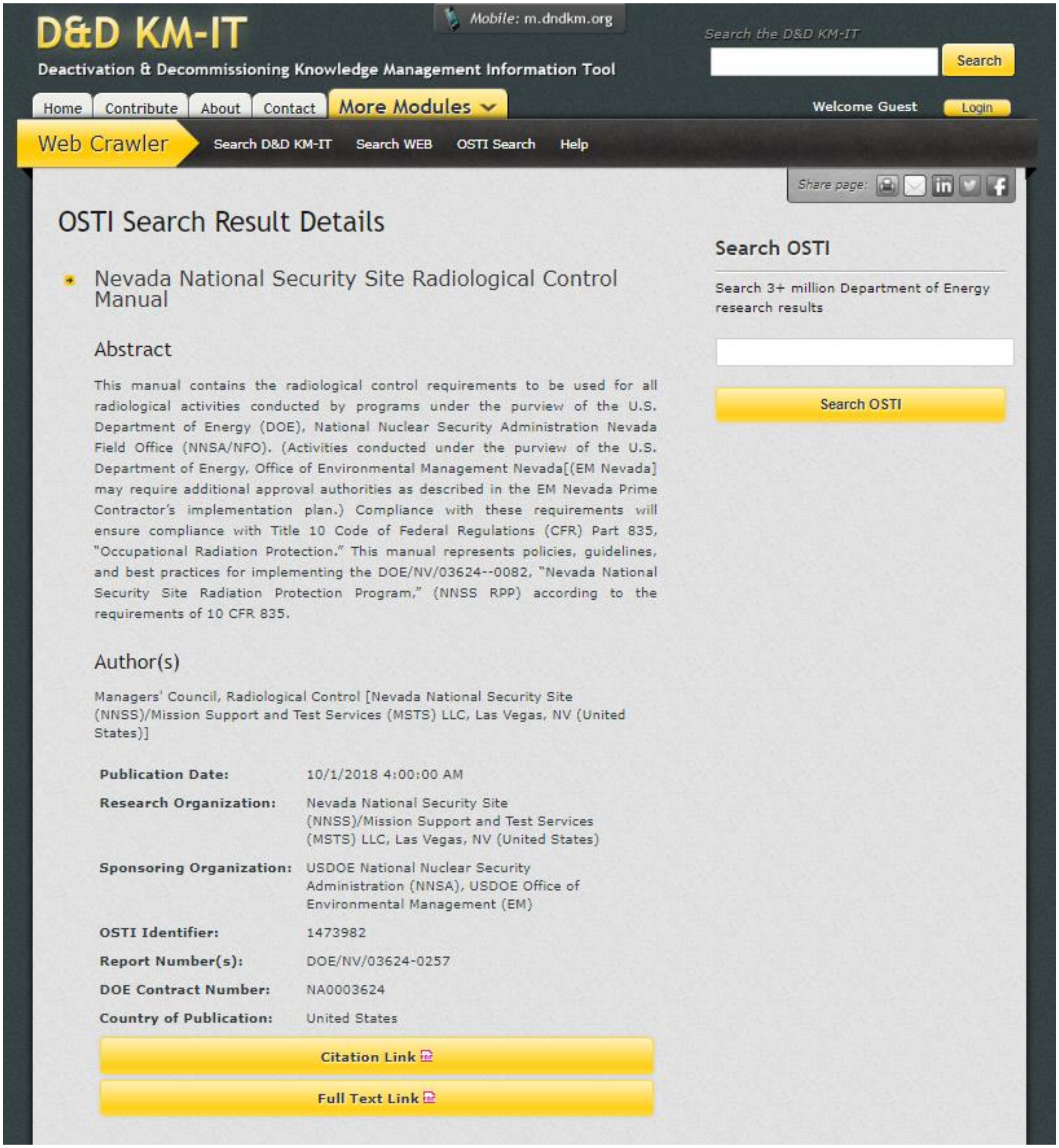


Figure 34. OSTI search result details view showing details for the document and associated links.

Search Web

The search web feature was also enhanced. The backend of this feature is very similar to the Search KM-IT. The only difference is that instead of focusing on results from the D&D KM-IT site, it searches through a predefined set of D&D related websites. This search engine crawls these D&D websites and stores their metadata on the FIU server. When a user performs a search using this feature, the results get displayed immediately to the user from the information stored in the metadata. If the user is interested in one of the results, they get redirected to the original source of the information by clicking on the result link. FIU has updated the D&D website URLs that the crawler uses to retrieve the information by removing the old and outdated URLs and replacing with correct and current URLs. New D&D sites have also been added to the list.

Finally, FIU completed milestone 2018-P3-M3 by January 25, 2019, by completing the integration of a new sub-module on the KM-IT platform to highlight current research efforts and activities in support of D&D, starting with recent FIU/SRNL research on fixatives and intumescent products. The new submodule can be accessed directly at the following link https://www.dndkm.org/Research/ or by clicking on the D&D Research button on the KM-IT homepage (https://www.dndkm.org/) under the Additional Features ribbon.

The information in this module has content taken from fact sheets, pictures and videos of relevant D&D research. Below is a list of the different research topics added to this module and the screenshot of the research landing page.

Research topics added and URL link for direct access:

- Fixative (in general) - https://www.dndkm.org/Research/Fixatives.aspx
- Intumescent Coatings - https://www.dndkm.org/Research/Intumescent-Coatings.aspx (like to include video if available)
- Fire Resiliency - https://www.dndkm.org/Research/Fire-Resiliency-in-Industry-Fixatives.aspx (like to include video if available)
- FX2 Fogging - https://www.dndkm.org/Research/FX2-Advanced-Fogging-Technology.aspx (like to include video if available)
- ICM Crawler - https://www.dndkm.org/Research/ICM-Crawler.aspx
- Robotic Inspection Tools (Pipe Crawler, Mini Rover, Wall Climber) - https://www.dndkm.org/Research/Robotic-Inspection-Tools.aspx

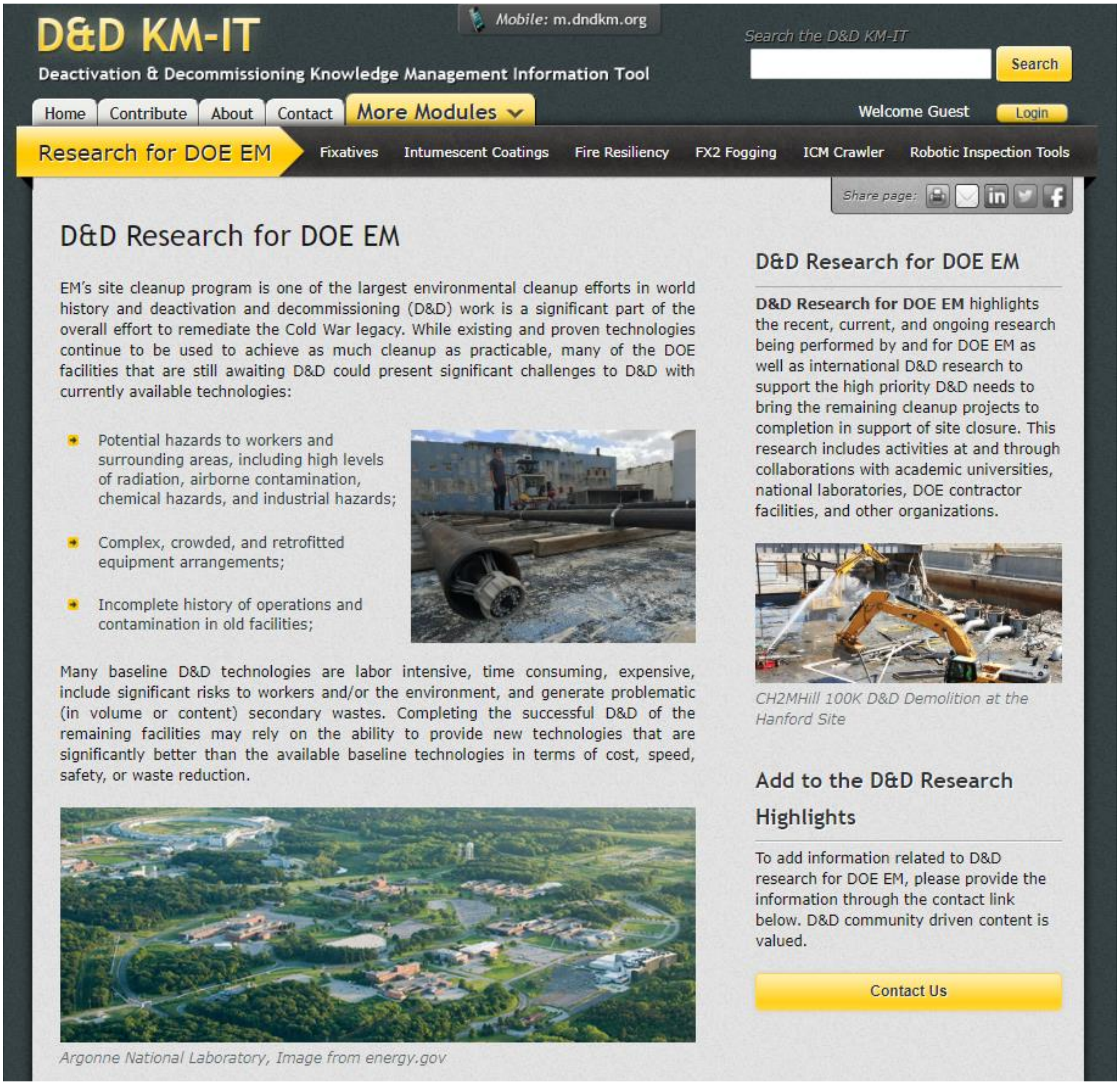


Figure 35. D&D KM-IT DOE Research for DOE EM module.

Subtask 3.2: Conclusions and Future Work

By enhancing the D&D KM-IT Search module, users have greater access to information from both inside the D&D KM-IT and from outside sources like OSTI. The amount of indexed documents has increased and the user interface to search OSTI documents has been improved significantly. Users no longer have to leave the D&D KM-IT site in order to interact directly with the information store in OSTI. The performance and user experience allows users to easily and effectively get the information they need. Moving forward, FIU will continue to optimize the search indexes to include any recently added information and monitor any changes to the OSTI API to make sure this feature continues to run smoothly.

FIU will continue to update the DOE Research Module with additional media for the currently highlighted research as well as additional D&D research activities by FIU. FIU will also reach out to other universities and national laboratories to encourage the D&D community-driven population of information. FIU also plans to solicit reviews, comments, and recommendations for improvement of this new sub-module from a variety of end users at the national laboratories and DOE sites.

Subtask 3.2: References

Deactivation and Decommissioning Knowledge Management Information Tool (D&D KM-IT), https://www.dndkm.org/, Applied Research Center, Florida International University.

U.S. Department of Energy Office of Scientific and Technical Information (OSTI), https://www.osti.gov/, U.S. Department of Energy Office of Scientific and Technical Information.

D&D Research for DOE EM, https://www.dndkm.org/Research/, Deactivation and Decommissioning Knowledge Management Information Tool (D&D KM-IT), Applied Research Center, Florida International University.

Subtask 3.3: Content Management and Data Analytics

Subtask 3.3: Introduction

This task focuses on capturing, reviewing and publishing information in KM-IT as well as capturing the usage and search data on KM-IT.

- Content Management: Content management includes researching relevant additional information from various sources that can be added to or linked from KM-IT, including relevant vendors, technologies, videos/pictures, and documents, as well as conferences, training opportunities, and news items of interest to the EM community.
- Data Analytics: This activity includes Google analytics, text data mining using on premise research with machine learning and 3rd party tools, visualization, server log analysis, and metrics reporting and uses various tools and codes. The data will be analyzed and used to market the site, measure the site's usage, and support decisions for ongoing content development to ensure that it remains relevant to the needs of the community the system serves.

Subtask 3.3: Objectives

This subtask will involve the continuation of the data mining process by DOE Fellows and staff to add to the knowledge management information of D&D KM-IT. This information includes new D&D vendors, D&D technologies, videos/pictures, and documents, as well as D&D conferences, training opportunities, and news items of interest to the EM community.

The data analytics portion of this subtask focuses on tracking user activity on the D&D KM-IT system. This effort helps FIU address issues with the D&D KM-IT system by examining and analyzing the traffic on the website. By analyzing the data, developers can identify and address performance issues with the site and see what topics of interest are more popular to visitors. With this information, the team can either fix issues or optimize the navigation of the site so that visitor can quickly find the information that they are looking for.

Subtask 3.3: Methodology

DOE Fellows continue to support content management efforts with the help of FIU staff by performing data management activities in order to add current and relevant data to the KM-IT. Their efforts have involved identifying and including additional D&D vendors and technologies from industry journals, conference publications, and news announcements, as well as researching additional relevant D&D technologies offered by existing vendors.

First, technologies are identified as D&D technologies used in the industry. Then, details of the technologies are gathered and reviewed by the subject matter experts. Next, these details (i.e., description, pictures, video and factsheets) are uploaded to D&D KM-IT. Finally, the technologies are approved and published on the system. This process is followed for each topic added the system such as vendor, journals, conferences, news announcements and more.

Some of the maintenance and development tasks also involve keeping up with Windows OS updates and patches provided from Microsoft and updating antivirus definitions and the software engine. These technical tasks are performed on both the web server and database server. In addition, backups and other system administration tasks are necessary to keep the application running smoothly and stable.

For the data analytics portion, FIU primarily uses Google Analytics (GA) to track user activity on the site. The GA code is placed in each of the D&D KM-IT webpages. When a user visits the site the script captures information about their visit including referring page, time on the site, pages visited, geolocation and more. The information is then analyzed by the team to detect issues with the site, popular content and any anomalies that may need to be addressed. Each quarter, a summary of the GA is included in a quarterly report to DOE.

Subtask 3.3: Results and Discussion

As mentioned before, DOE Fellows and technical staff continue to add technologies, vendors and other significant D&D related information to the D&D KM-IT. For instance, last quarter 274 technologies were added to the system. Below is a list of technologies added during the month of November.

1. Lead Wool Blankets
2. KeeLine®
3. Rooftop Crossovers
4. Kee® Anchor
5. HX30 Vacuum Excavator
6. HX50 Vacuum Excavator
7. HX75 Vacuum Excavator
8. BDD™ (Bacdown® Detergent Disinfectant)
9. Epicor RC – 8
10. HC Series Cold Water Pressure Washers
11. HEPA Wet+Dry Vacuum

12. JT10 Horizontal Directional Drill
13. JT100
14. JT5 Horizontal Directional Drill
15. Liqui-RAD Transport Unit
16. MIRA- Gamma Dose Rate Detection
17. Pipe Tapping Tools
18. Safkeg-HS
19. Safkeg-LS Model # 3979A
20. Borated Polyethelene Pellets
21. Lead Bricks
22. PREDATOR Force Feedback Manipulator
23. High Density Concrete Block
24. Lead Wool Shielding Blankets
25. Lead Wool Snakes
26. Abem Terrameter LS 2 Resistivity Meter
27. Lead Storage Containers
28. Liquinox®
29. Mrem Electronic Personal Dosimeter
30. Portable Tritium in Air Monitor
31. Lead Lined Cabinets
32. ABEM Terraloc Pro 2 Seismograph
33. ABEM WalkTEM Transient Electromagnetic
34. Lead Pour
35. LED Apollo 100K TM Floodlight System (Low-level radiation tolerant)
36. LED Helios 100K TM Reactor Core Lighting System (High-level radiation tolerant)
37. Reactor Head Maintenance Tooling
38. Reactor Head Nut Runners
39. Reactor Head Stud Turnout Tool
40. Reactor Vessel Stud Hole Plugs
41. Mini-Vacuum System
42. ICI Cutter System
43. LED Helios 75K TM Arealite System
44. LED Helios 75K™ CoreLite System
45. LED Helios 75K TM Drop Floodlight System
46. Core Plate Plugs
47. Debris Canisters
48. EPI Auxiliary Refueling Bridge
49. RCCA Recovery Tooling
50. Menzi Muck M320/325
51. Menzi Muck M340
52. Menzi Muck M545x
53. vLoc3-Pro Receiver
54. Pipeline Defect Mapper

The following image (Figure 36) is an example that shows the technology HX30 Vacuum Excavator on the D&D KM-IT website. This technology belongs to the vendor Ditch Witch. Other information is attached to the technology, in this case, the manual/datasheet.

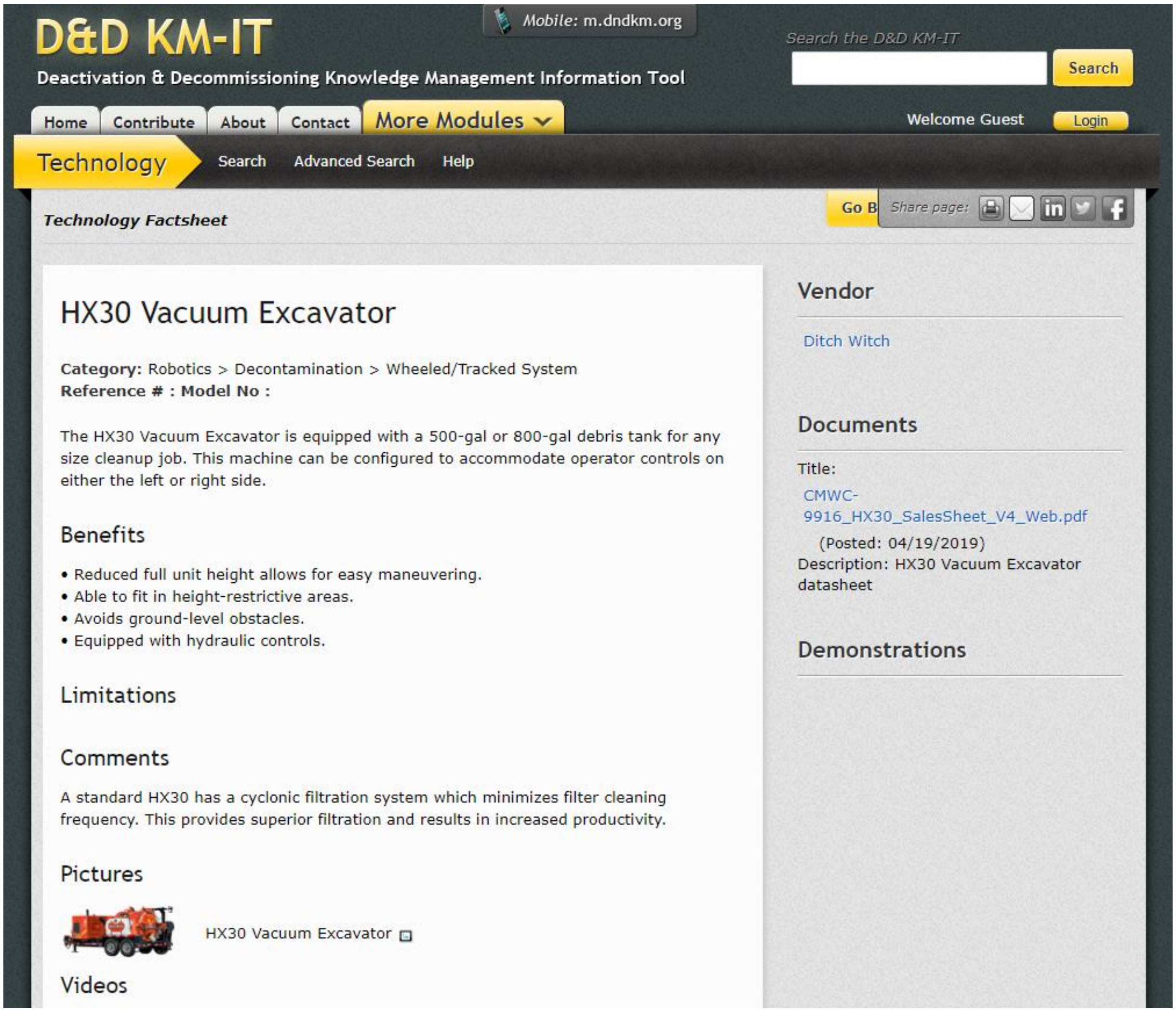


Figure 36. Technology HX30 Vacuum Excavator

In addition to technologies and vendors added to the system, eight (8) lessons learned bulletins from EM 5.22, additional training and conference opportunities related to D&D, and recent D&D fixative research were also incorporated.

Content management has allowed the D&D KM-IT to increase its content. The graph below summarizes the growth over the years. As of January 2020, the system has 985 D&D technologies, 1045 registered users, 980 D&D vendors, 195 Hotline questions/solutions and 103 subject matter specialists.

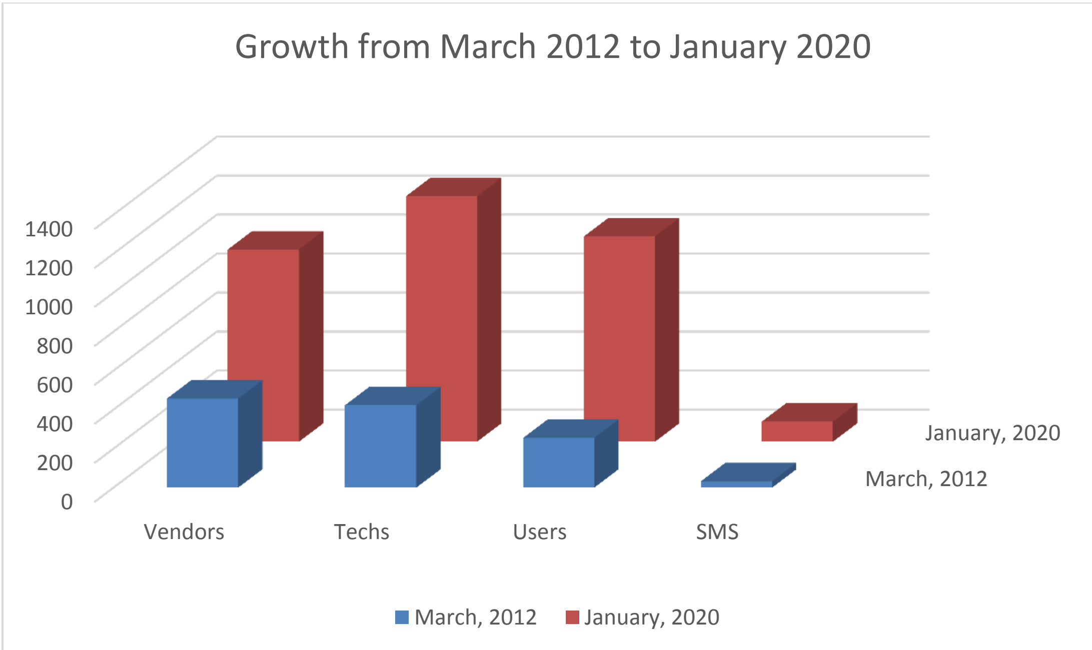


Figure 37. D&D KM-IT growth from March 2012 to January 2020

The data analytics portion of this subtask also tracks web activity on the D&D KM-IT website. The following figure shows the most relevant key metrics from Google Analytics (GA). Notice that by comparing 2018 vs. 2019, the system has shown significant growth in multi areas. Some of these areas have double digit percentage growth during this period, like the number of users with a 16.45% increase. This metric basically says that 16.45% more users visited the site from 2018 to 2019. Related to this metric is the number of new users which also had substantial growth of 15.69%. Rounding up the double-digit increases are the number of sessions with 12.45% and page views with 20.29%.

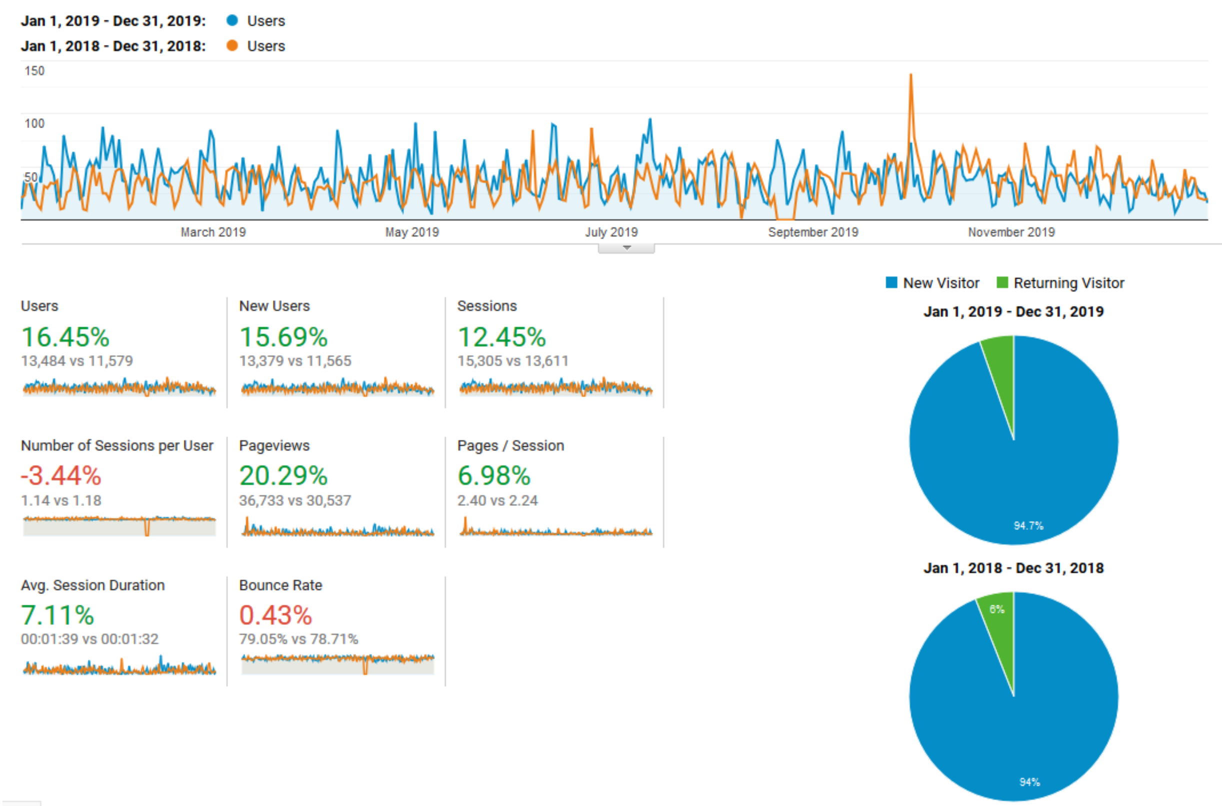


Figure 38. D&D KM-IT Google Analytic activity (2018 vs. 2019)

The GA data analytics captures some interesting information, for instance below is a map of the United States. It shows changes in the amount of activity by state. Notice the shading of each of the states. The darker color shows more activity, so from this image it is clear that during the year 2019, more users started to visit the system from the state of Illinois. A closer look shows that the city of Chicago is where most of those visits originated.

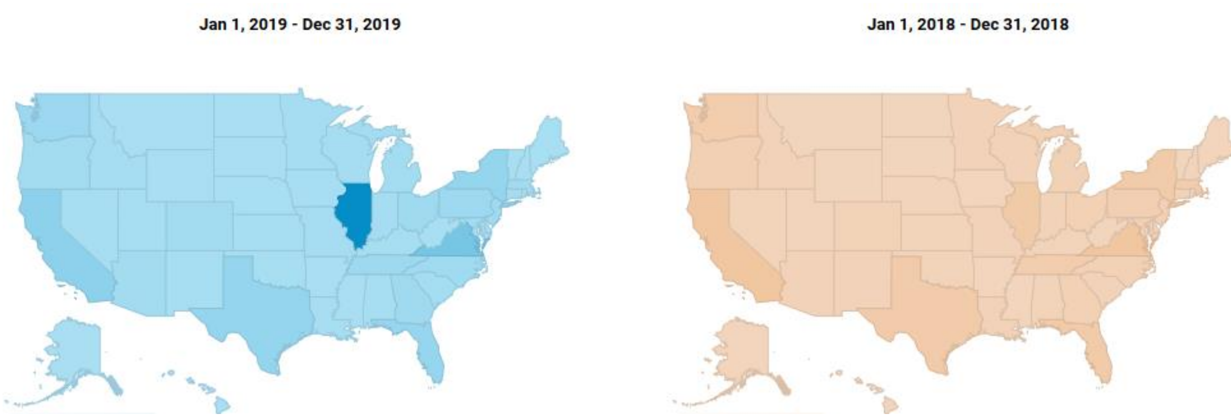


Figure 39. D&D KM-IT activity by state (2018 vs. 2019).

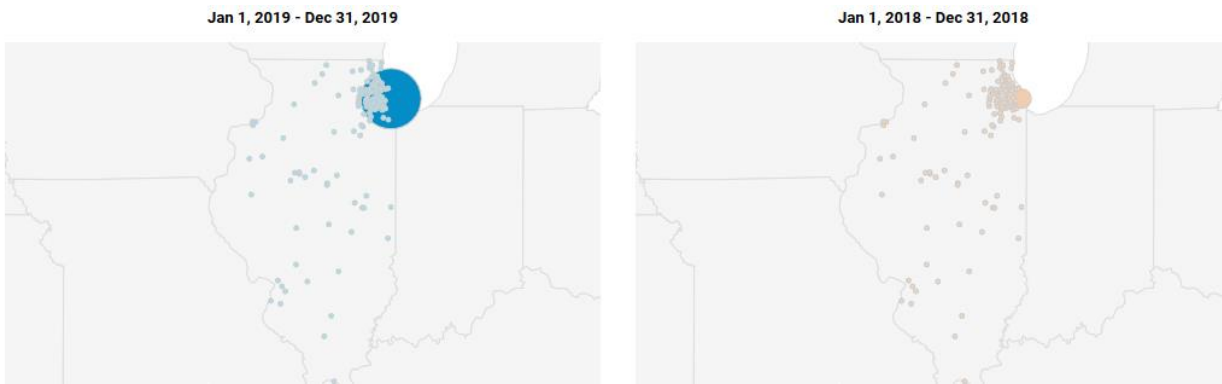


Figure 40. Map showing Chicago, IL web activity on D&D KM-IT.

Subtask 3.3: Conclusions and Future Work

FIU will continue to publish additional technologies, vendors and lessons learned on the KM-IT platform in addition to other relevant resources for the community, such as D&D related training, conferences and workshops. During Year 10, FIU will emphasize the addition of information and research related to open air demolition issues, including inside DOE EM as well as other industries and internationally.

Data analytics is a critical task. It allows the FIU team to discover user interest on the site so that it can be updated to make popular information easier to find. Most importantly, data analytics help the team discover any issues that may go unnoticed by the developer but captured by the GA. This may include broken pages, links or images, slow pages and even cyber threats which can be identified by data analytics.

Subtask 3.3: References

Deactivation and Decommissioning Knowledge Management Information Tool (D&D KM-IT), https://www.dndkm.org/, Applied Research Center, Florida International University.

U.S. Department of Energy Office of Scientific and Technical Information (OSTI), https://www.osti.gov/, U.S. Department of Energy Office of Scientific and Technical Information.

Google Analytics, https://analytics.google.com, Google Analytics, Google Inc.

Subtask 3.4: Cybersecurity Research for KM-IT

Subtask 3.4: Introduction

The KM-IT infrastructure is deployed, secured and maintained within the FIU facility. Researchers and DOE Fellows will continue to research the latest penetration testing tools, malware analysis and digital forensics tools in the DOE Cyber Lab. These will be used to test the KM-IT system and infrastructure.

Subtask 3.4: Objectives

The objective of this task is to secure the D&D KM-IT system. Since the system is housed at FIU, the team is responsible for keeping it secured. This means enforcing security measures that apply to both the software and hardware portions of the system. The application has to be secure to prevent cyber threats from gaining unauthorized access to the system. The hardware and operating system running the application have to be secure as well to prevent outdated patches and/or updates from making the system vulnerable, which can eventually lead to it being exploited.

Subtask 3.4: Methodology

DOE Fellows assist technical staff in performing routine security tests on the system. These tests include intrusion detection, malware analysis, web log analytics focusing on abnormal activity, patching and updating the operating system, as well as virus definition. Other tasks include backup, validating backup and performing downtime simulation. The security research portion involves staying up-to-date with new security threats and learning about how they can be used against the D&D KM-IT. Penetration testing tools, malware analysis and reverse malware engineering techniques are used in the DOE Cyber lab to test and secure the KM-IT infrastructure. These tests are performed against the infrastructure in a sandbox environment to see if they could affect the application. They are carefully conducted so as to not interfere with the production application.

The FIU-ARC system administrators also take advantage of the capabilities of the FIU Cybersecurity Department who routinely test the application from an external location. These tests are done independently and the results are sent to the FIU-ARC system administrators to address any security vulnerabilities that may be found.

Subtask 3.4: Results and Discussion

Due to these proactive technical security tasks, the D&D KM-IT has not suffered any downtime due to security breaches. The application has remained stable and secure over the last 7 years. Although this specific task was added recently, it has proven to be very valuable because it adds a certain peace of mind that the team is doing everything possible to protect the system from security threats.

Subtask 3.4: Conclusions and Future Work

Moving forward, DOE Fellows will continue to support the technical staff with penetration testing, malware analysis and other security tasks performed in the DOE Cyber lab to test and secure the KM-IT infrastructure.

Subtask 3.4: References

Deactivation and Decommissioning Knowledge Management Information Tool (D&D KM-IT), https://www.dndkm.org/, Applied Research Center, Florida International University.

Cybersecurity Office at FIU, https://security.fiu.edu/, Cybersecurity Office, Florida International University.

Penetration Test, https://en.wikipedia.org/wiki/Penetration_test, Wikipedia, Retrieved January 2020

TASK 6: ANALYSIS OF IMAGE DATA USING MACHINE LEARNING/DEEP LEARNING AND BIG DATA TECHNOLOGIES (NEW)

Task 6: Executive Summary

Structural health monitoring is imperative to the ongoing surveillance and maintenance (S&M) across the DOE complex. Machine Learning and Deep Learning are state-of-start technologies capable of facilitating the assessment of structural integrity in aging nuclear facilities. Convolutional Neural Networks are used to implement the deep learning approach. The process starts by collecting images from a mock-up wall, created in the FIU outdoor test facility, simulating nuclear facility environments. The images are labeled and stored across the local network storage and made available for processing. The images are divided into two categories. The first category is a "baseline" while the second category is an "anomalous" category. A 10-layer deep convolutional neural network was created to learn the characteristics and patterns in the images collected. The trained model is then used to predict the category of new images that have not been seen before. This approach was 99.96% accurate and had very low Type I and Type II statistical errors.

Task 6: Introduction

The nuclear industry is experiencing a steady increase in maintenance costs even though plants are maintained under high levels of safety, capability, and reliability. Surveillance and maintenance of nuclear-decommissioning infrastructure provide many challenges with respect to maintenance or decommissioning of the buildings. As these facilities await decommissioning, there is a need to understand the structural health of these structures. Many of these facilities were built over 50 years ago and in some cases, these facilities have gone beyond operational life expectancy. In other cases, the facilities have been placed in a state of "cold and dark" and they are sitting unused, awaiting decommissioning.

In any of these scenarios, the structural integrity of these facilities may be compromised, so it is imperative that adequate inspections and data collection/analysis be performed on a continuous and ongoing basis. There is a need for a framework to analyze the huge amount of data generated by the sensors on the nuclear reactor components as well as structures, to monitor the conditions of these buildings over a period of time.

Task 6: Objectives

The overall objective of this new task is to investigate specific applications of machine learning and big data technologies to satisfy DOE-EM problem sets and challenge areas, including potential applications of existing state-of-the-art technologies (e.g., imaging, robotics, big data, and machine learning/deep learning) to assess the structural integrity of aging facilities in support of ongoing surveillance and maintenance (S&M) across the DOE complex. FIU continued the initial development of a pilot-scale infrastructure to implement structural health monitoring using scanning technologies, machine learning/deep learning and big data technologies. In addition to utilizing existing data sets, FIU is investigating a light detecting and ranging (LiDAR) technology to be deployed in FIU testbed mockups to collect structural data.

Resulting data will be processed and analyzed using machine learning/deep learning and big data technologies. The proposed pilot system is intended to serve as a starting point to engage the DOE field sites on related data sets and their decision making needs. It is anticipated that proposed machine learning/deep learning and big data technologies can be effectively employed using anomaly detection to solve EM challenges in surveillance and maintenance of the D&D facilities.

Task 6: Methodology

To accomplish the objectives, the FIU team used a four-step implementation geared towards machine learning and deep learning. The first step was to collect all the data necessary to achieve the desired goal (data collection). The second step was to save/store the collected data in the local network storage for future processing (data storage). The third step was to build deep learning models using convolutional neural networks trained with the stored data (model building). The last step was to use the trained neural network models to infer and predict a never before seen data sample (inferencing). Each one of these steps was critical and involved multiple minor tasks that drive the enterprise artificial intelligence environment.

The data collection process is very labor-intensive and time-consuming. During this process, the FIU team set up a mock-wall in the outdoor test facility that simulates D&D conditions across multiple complexes. The wall was subdivided into 16 sessions that represent the categories for the physical conditions. Some of the divided sections were in pristine condition, while others were deteriorated with holes, abrasions, and discoloration. The sections of the wall which constituted normal wear and tear conditions were used to build a baseline. The baseline sections are identified by a "CL" tag as shown in Figure 41. The rest of the sections were considered distressed and thus categorized as anomalous. No tagging was done for the anomalous sections. The tagging is just for visual identification and is never used in the neural network training phase.

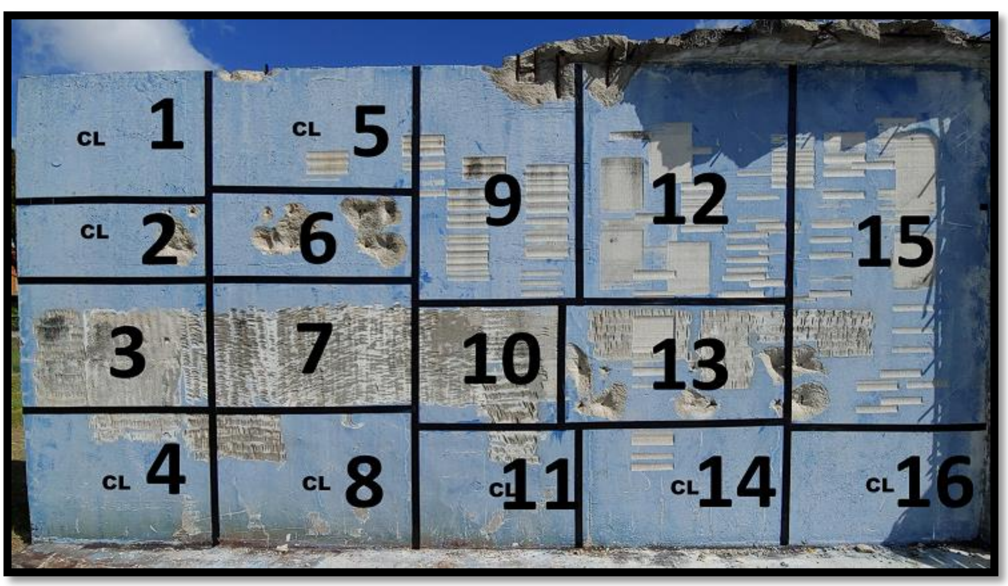


Figure 41. Mock-wall in the outdoor test facility simulation D&D conditions.

A total of 28,000 images were collected from the outdoor test facility mock-wall using a digital camera. The images were gathered at different times of the day to simulate environmental conditions as well as lighting exposures. The camera was placed at different angles while taking pictures to introduce variance in the data set. Images were collected at different distances to have multiple scales of the stresses in the sections. Half of the images collected were from the baseline sections and the other half was from the anomalous section. Overall this approach led to a robust image data set that contained a high variance for the simulated physical environment.

The entire image data set was stored in the local network storage and was properly categorized. Each section of the wall was saved into a corresponding folder named with the section number. All the folders which belong to a baseline were then placed in an individual folder and the same was done for the folders containing the anomalous images. This hierarchical storage setup made it easy and simple to store the files while manually classifying the images. For performance considerations, a duplicate dataset was created by reducing the size of the image and saving them with a fixed aspect ratio of 160 pixels by 90 pixels.

During the model building process, the FIU team selected the convolutional neural network algorithm to tackle the image classification task. Convolutional neural networks are exceptionally well at learning and abstracting features from images. The goal was for the model to learn the features from the baseline and anomalous images during the training phase and then predict whether a new image was from the baseline distribution or not. To implement the convolutional neural network the team used TensorFlow, which is an open-source software library for machine learning and deep learning. Another open-source library known as Keras was used to interact with TensorFlow. Keras is a wrapper that allows for a fast implementation of neural networks by using the built-in functions. The Python programming language was selected to interface and instantiate the implementation.

The FIU team designed a 10 layer deep convolutional neural network that takes in an image as an input and outputs the result as either “Baseline” or “Anomalous”. The network is composed of convolution layers which are the core building blocks of the neural network and do most of the heavy computation. The network has max-pooling layers that progressively reduce the spatial size of the problem to reduce the number of parameters and computation in the network. It also contains drop-out layers to implement regularization which makes the network less prone to overfitting. There are also dense layers which are linear operations in charge of flattening the information present in the network to fully connect the input to the output. The overall architecture is shown in Figure 42.

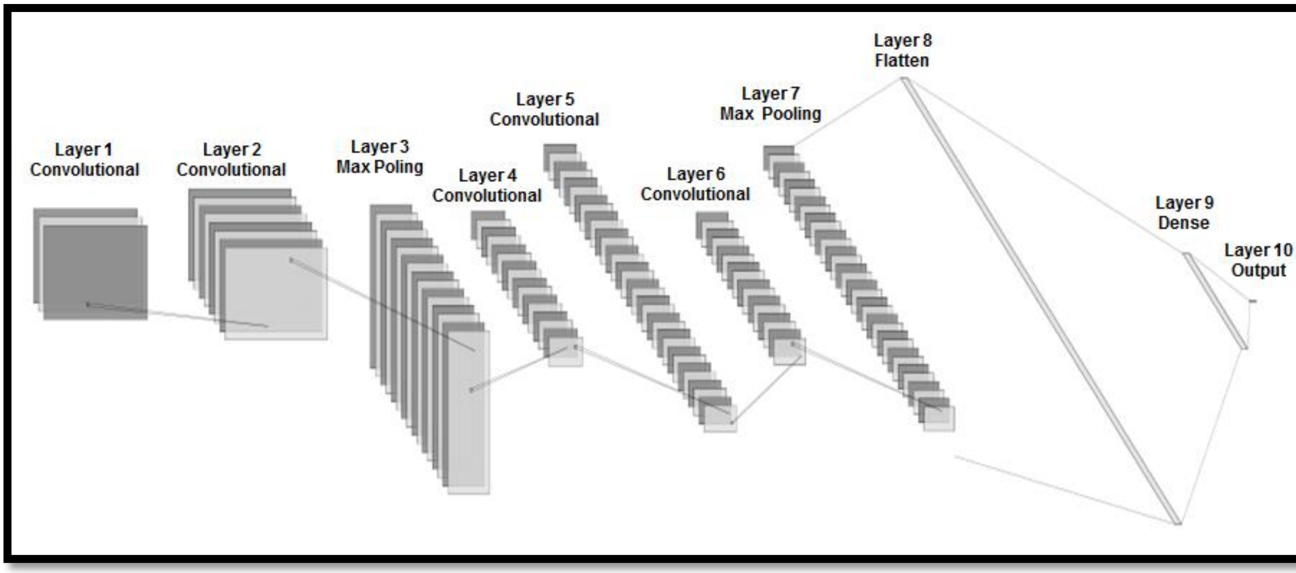


Figure 42. Convolutional Neural Network architecture for image classification.

The network was trained with an 80/20 train-test-split. 80% of the image data set collected during the data collection process was used to train and update the weights in the neural network connections. The remaining 20% of the data was left unseen by the model and used to test the performance of the network. During the training phase, 10% of the training data was used for internal model validation. The 80/20 split was done at random using a python library called Scikit-Learn which accepts a random seed. The model was trained for 9 epochs (iterations) using central processing units (CPUs) and graphical processing units (GPUs).

Task 6: Results and Discussion

The 10 layer deep convolutional neural network achieved an overall accuracy of 99.96% after hyper parameter tuning and sufficient training. It was able to learn and extract the relevant features from the baseline and anomalous images. As seen in Figure 43 the model learns very fast and starts to converge right after the second epoch (iteration). Accuracy in itself does not show the full story of the performance. It is important to know how and where the model is failing. For this type of analysis the standard confusion matrix can be used, which shows “false positives” (statistical Type I error) and “false negative” (Statistical Type II error). The final trained model only had 1 Type I error and 1 Type II error (Figure 44).

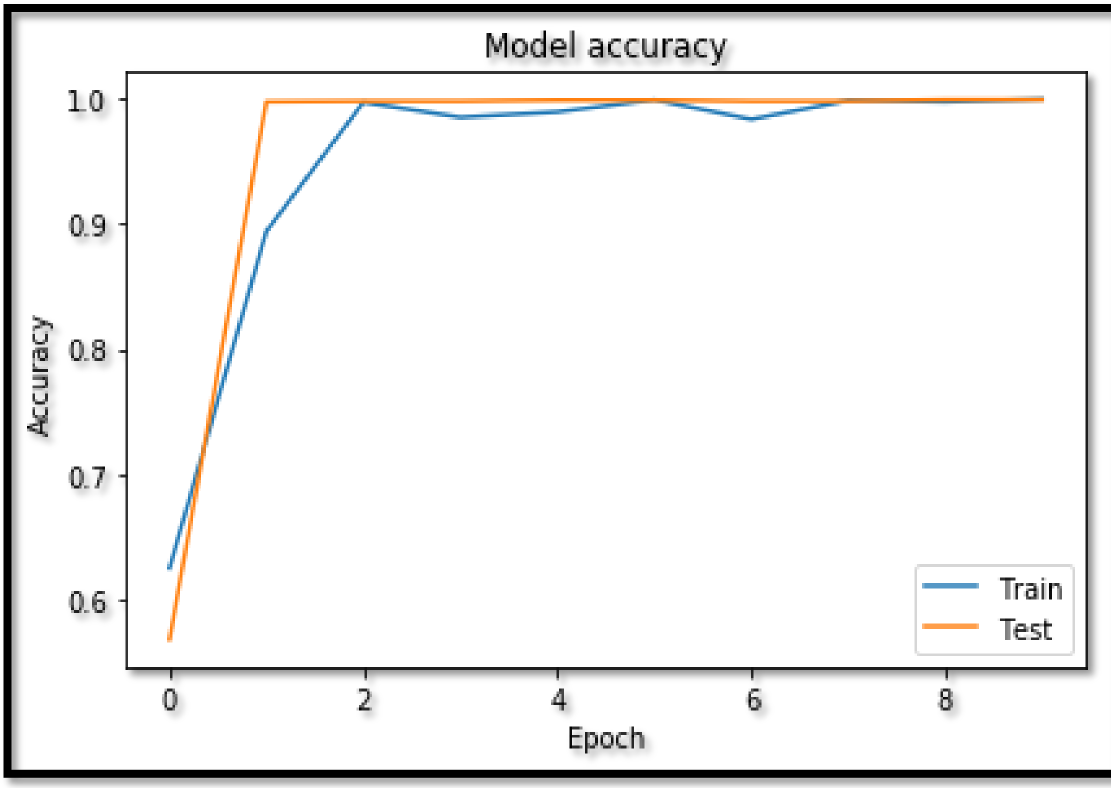


Figure 43. Accuracy plot for 10 layer deep convolutional neural network.

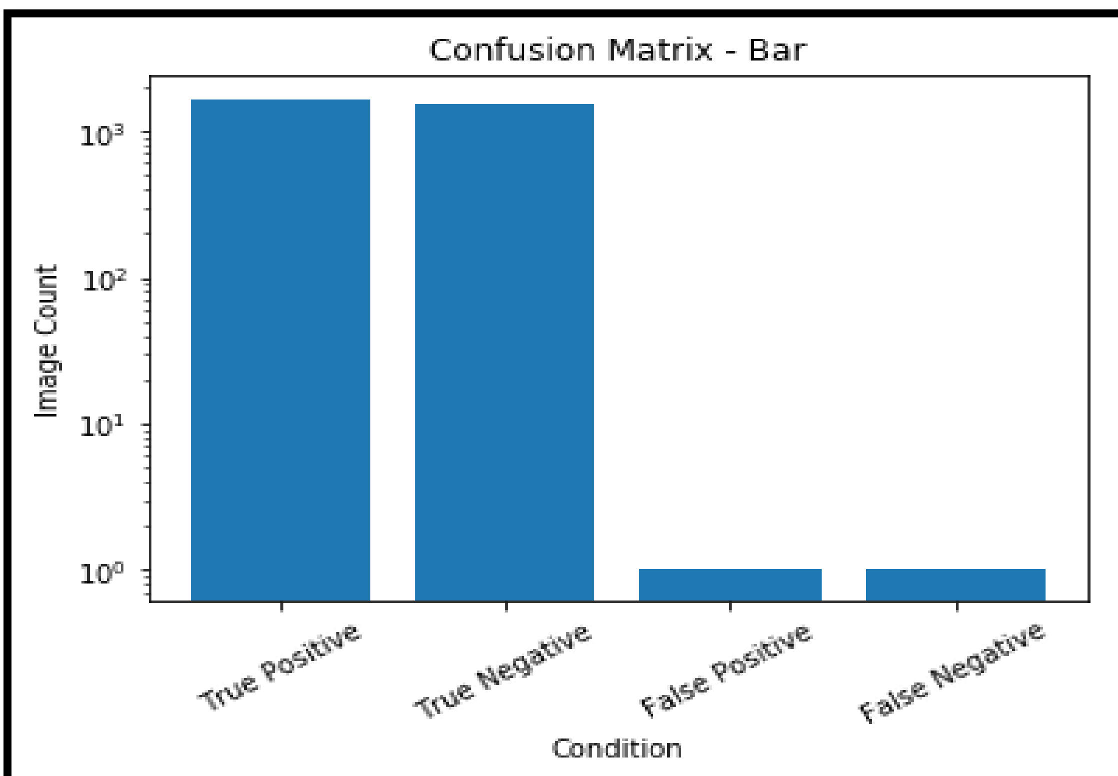


Figure 44. Confusion matrix showing Type I and Type II errors.

Task 6: Conclusions and Future Work

The results of the research conclude that deep learning is a viable option for structural health monitoring. The high accuracy and low Type I/Type II errors are strong indicators that neural networks can learn from a baseline and thus infer the health condition of a structure. Further modifications and additional research are required to make the model more robust and adaptable to different environments.

Determining if an image belongs to a baseline or an anomalous category is also not enough. It is desirable to identify and locate where cracks, holes, and stresses are in an image. This task belongs to object detection and can help operations quickly see where the anomalous feature is. Furthermore, identifying and locating cracks on a structure is imperative in monitoring the induvial progression of an anomaly. This type of analysis can lead to the forecasting of future events and possibly the prevention of catastrophic incidents.

Using images for structural health monitoring is a stepping stone in the advancement of monitoring systems but it has limitations. Images do not contain the full story of the environment it captures. 2D images represented by pixels using red, green, and blue (RGB) lack depth information. Depth is extremely important and necessary to accurately determine the health of a structure. Using light detection and ranging (LiDAR) scans is the next step in the data collection process to accurately capture the 3D space of a structure.

Task 6: References

Li Deng and Dong Yu (2014), "Deep Learning: Methods and Applications", http://dx.doi.org/10.1561/2000000039

D. C. Dennett, "Introduction to deep neural networks", https://deeplearning4j.org/documentation2015

TensorFlow - An open source software library for machine intelligence,

https://www.tensorflow.org/2015

CONFERENCE PARTICIPATION, PUBLICATIONS & AWARDS

Professional Conference Presentations and Proceedings

**Sinicrope, J., Shoffner, P., Szilagyi, A., Nicholson, J., and Lagos, L. (2019). International Standards as Critical Enablers to Development and Diffusion of D&D Technologies – 19372, Waste Management Symposia 2019, Phoenix, AZ.

**NOTE: This paper and presentation was awarded “Best in Track”, and received a “Superior Paper” rating for the oral presentation and a “Paper of Note / Best in Track” rating for the paper itself.

Nicholson, J.C. (SRNL), J. Sinicrope, A. Washington (SRNL), P. Shoffner, L. Lagos, M. Serrato (SRNL). Uses of Intumescent Coatings as a Pu-238 Contamination Fixative in SRS Building 235-F. Waste Management 2019 Conference, Phoenix, AZ, March 2019.

Nunez, J. (DOE Fellow), J. Sinicrope, J.C. Nicholson (SRNL). Applications of Intumescent Technologies in Support of D&D Activities across the DOE Complex. Waste Management 2019 Conference, Phoenix, AZ, March 2019.

Himanshu Upadhyay, Walter Quintero, Leonel Lagos, Peggy Shoffner. Waste Information Management System with 2018-19 Waste Streams. Waste Management 2019 Conference, Phoenix, AZ, March 2019.

Himanshu Upadhyay, Walter Quintero, Leonel Lagos, Peggy Shoffner. Robotics on KM-IT Platform. Waste Management 2019 Conference, Phoenix, AZ, March 2019.

**Himanshu Upadhyay, Leonel Lagos, Anthony Abrahao, Walter Quintero, Santosh Joshi. Big Data Framework with Machine Learning for D&D Applications. Waste Management 2019 Conference, Phoenix, AZ, March 2019.

**NOTE: WM Symposia awarded the rating of a “Superior Paper” for the “Big Data Framework with Machine Learning for D&D Applications” paper.

Graduate Research Activity – Presentations and Proceedings

Simoes-Ponce, T. (2018). Mechanical Properties of Polyurethane Foam for D&D Activities. DOE Fellows Poster Exhibition 2018.

Núñez, J. (2019). The Characterization of Thermal Properties of Intumescent Foams for D&D Activities. Waste Management Symposia 2019, Phoenix, AZ.

Simoes-Ponce, T. (2019). Mechanical Properties of Polyurethane Foam for D&D Activities. Waste Management Symposia 2019, Phoenix, AZ.

Student Awards

Tristan Simoes-Ponce – DOE Fellow of the Year; 2nd Place DOE Fellows Poster Exhibition 2018

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, *Project Technical Plan,* Project 3: Waste and D&D Engineering and Technology Development, October 2018.
2. Florida International University, *Testing and Evaluating Intumescent Foams in Operational Scenarios*, Test Plan, January 2019.
3. Florida International University, *Intumescent Foams in Operational Scenarios*, Technical Report, 2019.