DOE-FIU Cooperative Agreement Annual Research Review – FIU Year 3

Wednesday, August 23, 2023		
9:00 - 9:05 am EDT	Kick-Off /Welcoming Remarks (DOE-EM)	Rod Rimando (Acting Director, Technology Development) – DOE EM-3.2
9:05 - 9:10 am EDT	Welcoming Remarks (DOE-LM)	Ms. Jalena Dayvault (Site Manager) – DOE LM
9:10 - 10:40 am EDT	Project 2: Environmental Remediation Science & Technology	FIU, DOE HQ, SRNL, PNNL, ORNL, LANL, LBNL, CBFO
10:40 am - 12:10 pm EDT	Project 1: Chemical Process Alternatives for Radioactive Waste	FIU, DOE HQ, PNNL, WRPS, SRNL, SRS
LUNCH BREAK [12:10 – 1:30 pm]		
1:30 - 3:00 pm EDT	Project 3: Waste and D&D Engineering & Technology Development	FIU, DOE HQ, SRNL, PNNL, LBNL, INL, ANL
Thursday, August 24, 2023		
9:00 - 10:30 am EDT	Projects 4 & 5: STEM Workforce Development and Training	FIU, DOE HQ (EM & LM), SRNL, PNNL, WIPP, SRS, ORP, LBNL, WRPS, INL, Grand Junction
BREAK [10:30 – 10:35 am]		
10:35 - 12:00 pm EDT	Wrap Up (FIU Projects 1, 2, 3, 4 & 5)	FIU, DOE HQ (EM & LM)

PROJECT 1

Chemical Process Alternatives for Radioactive Waste

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FIU Personnel and Collaborators

Project Manager: Dwayne McDaniel

Faculty/Staff: Amer Awwad, Anthony Abrahao, Aparna Aravelli, Mayren Echeverria Boan, Jose Rivera, Mackenson Telusma

DOE Fellows/Students: Sebastian Story, Joel Adams, Brendon Cintas, Josue Estrada Martinez, Phillip Moore, Bryant Pineda, Nicholas Espinal, David Rojas, Theophile Pierre, Gabriel Cerioni, Rafael Velasquez

DOE-EM: Genia McKinley, Robert Seifert, Latrincy Bates, Kurt Gerdes, Jean Papon

DOE-ORP: Erik Nelson

SRNL: Michael Poirier, Connie Herman, Bruce Wiersma, Christine Langdon, William Wells, Mark Kranjc, Eric Skidmore, Andrew Priest

PNNL: Kayte Denslow, Carl Enderlin, Matt Fountain, Matthew Asmussen

WRPS: Jason Gunter, Kayle Boomer, Glenn Soon, Joe Rice, Doug Reid, Jason Page, Ruben Mendoza

SRS: Jane Carter, Saiying Bowers

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Project Tasks and Scope

Task 17: ADVANCED TOPICS FOR HLW MIXING AND PROCESSES	
Subtask 17.2	Evaluation of Pipeline Flushing Requirements for HLW at Hanford and Savannah River Site
TASK 18: TECHNOLOGY DEVELOPMENT AND INSTRUMENTATION EVALUATION	
Subtask 18.3	Development of a Coating Deployment Platform for the H-Canyon Exhaust Tunnel
Subtask 18.4	Long-Term Surveillance of Nuclear Facilities and Repositories using Mobile Systems
Subtask 18.5	Development of Robotic Systems for DOE Sites
TASK 19: PIPELINE INTEGRITY AND ANALYSIS	
Subtask 19.1	Pipeline Corrosion and Erosion Evaluation
Subtask 19.2	Evaluation of Nonmetallic Components in the Waste Transfer System
TASK 20: CORROSION PROTECTION AND CHARACTERIZATION OF EM INFRASTRUCTURE	
Subtask 20.1	Evaluation of Coatings for the H-Canyon Exhaust Tunnel
Subtask 20.2	Corrosion Evaluation of Steel Canisters for Hanford Integrated Disposal Facility (NEW)

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Task 17

Advanced Topics for HLW Mixing and Processes

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Subtask 17.1: Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River Site

Site Needs:

- The Defense Nuclear Facilities Safety Board (DNFSB) indicated a need for further investigation on the technical basis for the prescribed guidelines of flushing operations at Savannah River Site (SRS) and Hanford.
- Further tests investigate optimal conditions that will assist the US DOE in waste remediation, preservation of tank storage, prevention of additional waste creation, and processing.

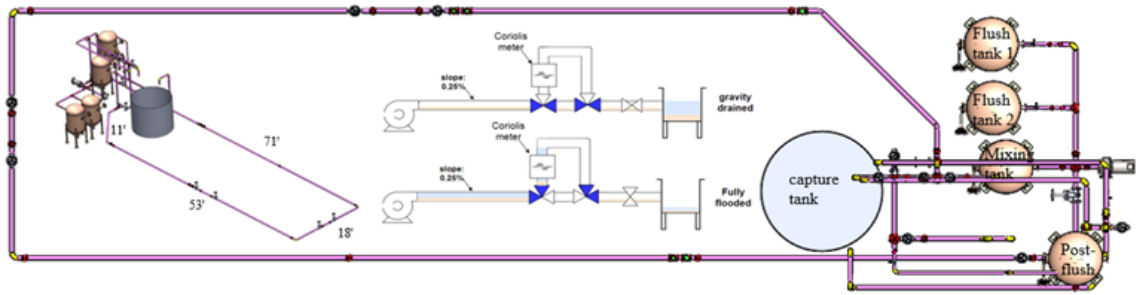
Objectives:

- Simulate flushing operations of non-radioactive slurry simulants within an extendable, 3-inch diameter carbon steel experimental pipe loop.
- Investigate parameter effects on the efficiency of flushing operations at various concentrations and flush modes (fully-flooded, gravity-drained sediment conditions and continuous and pulsation flush velocity modes).

Subtask 17.1: Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River Site

FIU Year 3 Research Highlights & Accomplishments:

- Completed all testing for the 330 ft test loop.
  - Includes fully flooded and gravity drained conditions at 10, 15 and 20% by volume.
  - Conducted tests with 1 day and 2 weeks settling time.
- Improvements to instrumentation and pipeline.
  - Upgraded data acquisition system.
  - Addition of gravity drain discharge valve to remove pockets of air.
  - Data analysis improved to provide FTLV ratio as a function of time.



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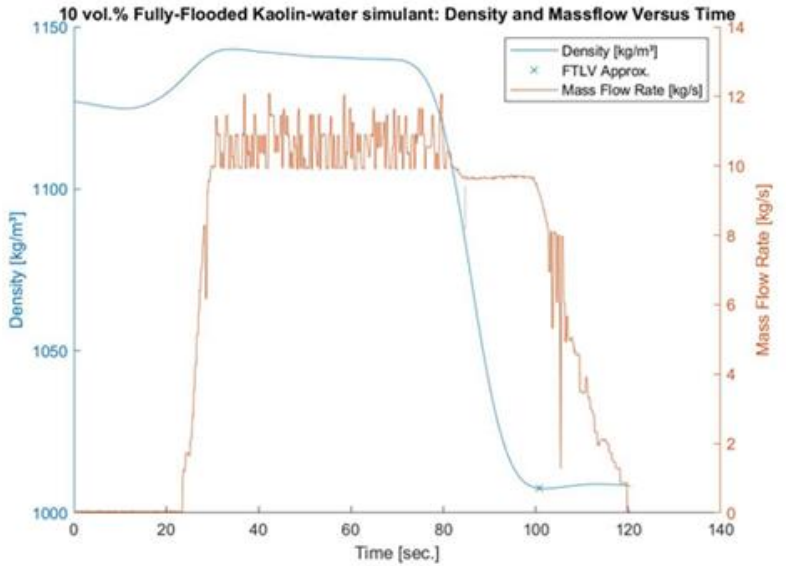
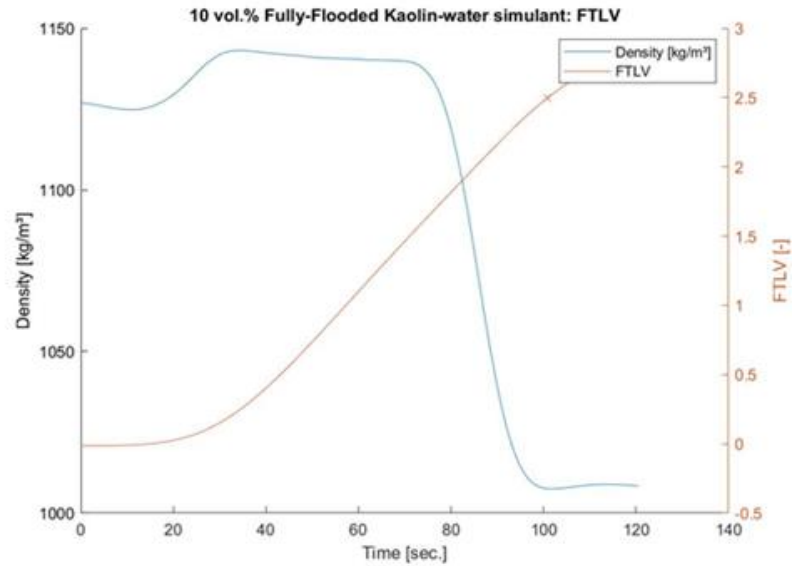
Subtask 17.1: Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River Site

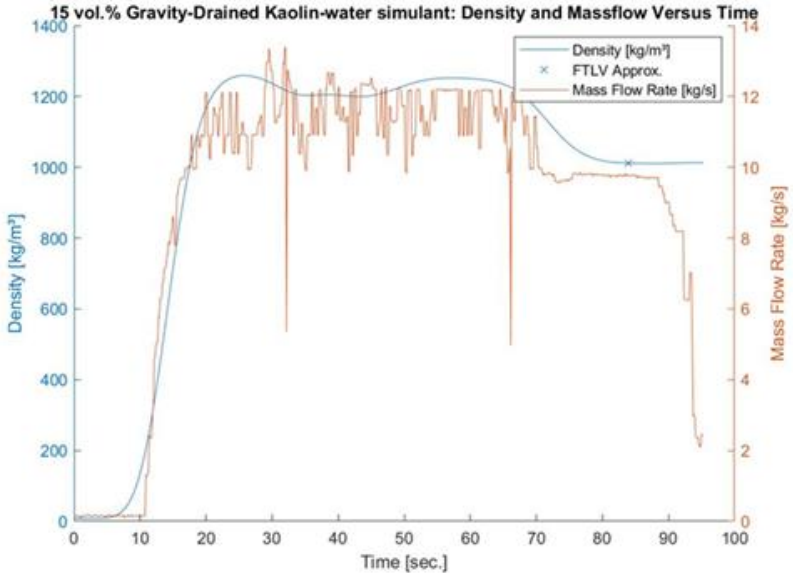
FIU Year 3 Research Highlights & Accomplishments:

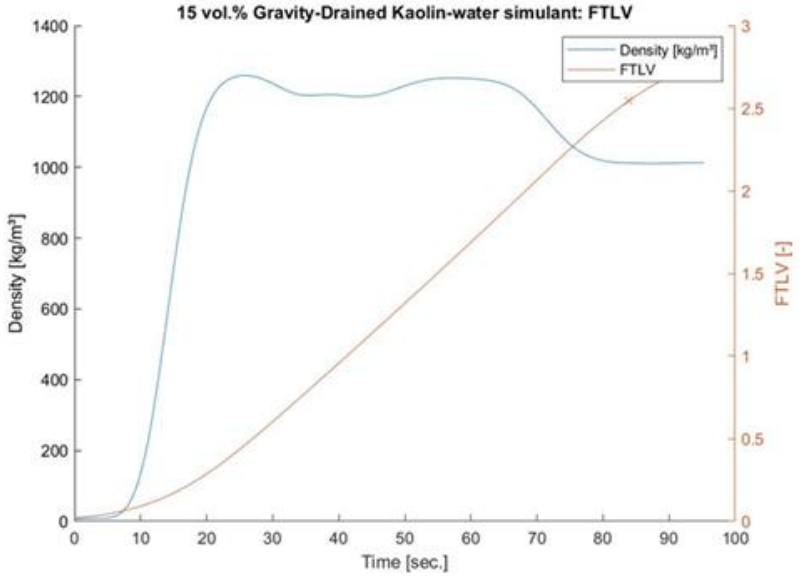
10% fully flooded





15% gravity drained





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Subtask 17.1: Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River Site

FIU Year 3 Research Highlights & Accomplishments:

$$FTLV = \frac{\text{volume used to flush}}{\text{pipeline volume}} = \frac{\Delta V_T}{V_{pl}}$$

Table 1. Flush-to-Line Volume Ratio Results, One-Day Sedimentation

One Day Sedimentation FTLV Results		
	Fully Flooded	**Gravity Drain**
10%	2.479	2.586
15%	2.544	2.617
20%	3.081	2.814

Table 2. Flush-to-Line Volume Ratio Results – Extended Settlement

10 vol% Variable Sedimetation Results	
One Day	2.586
2 Weeks	2.751

Subtask 17.1: Evaluation of pipeline flushing requirements for HLW at Hanford and Savannah River Site

FIU Year 4 Projected Scope

- Alter scope to address needs of Savannah River Site.
- Objective:
  - Determine the effectiveness of flushing a settled transfer with a slurry and preventing the formation of plugs.
- Investigate how settling time affects flushing operations.
  - Flushing will be conducted with a slurry instead of water after initial transfers have occurred and some specified time has passed.
- Alterations to the pipeline will be made and anticipated pipe lengths include 125, 165 and 330 ft.

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Task 18

Technology Development and Instrumentation Evaluation

Subtask 18.3: Development of a Coating Deployment Platform for the H-Canyon Exhaust Tunnel

Site Needs:

Visual inspections of the H-Canyon exhaust (HCAEX) tunnel showed degradation of the concrete walls. Also, a recent tunnel fragility analysis identified safety issues of the affected concrete regarding their strength.

The identification, evaluation and application of protective coatings to prevent further degradation of the concrete walls is needed to mitigate the damage.

Objectives:

Develop a robotic platform that can navigate on the tunnel walls and apply protective coatings using an integrated coating application system.

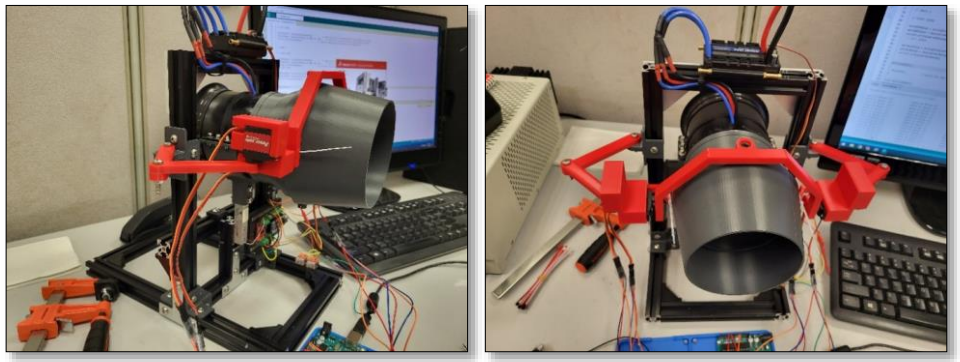
Tunnel view

Degraded concrete exposing the steel rebar (red arrows).

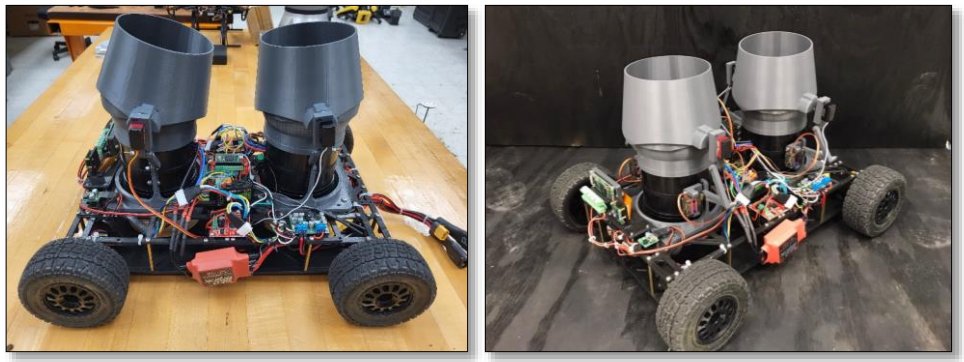
Subtask 18.3: Development of a Coating Deployment Platform for the H-Canyon Exhaust Tunnel

FIU Year 3 Research Highlights & Accomplishments:

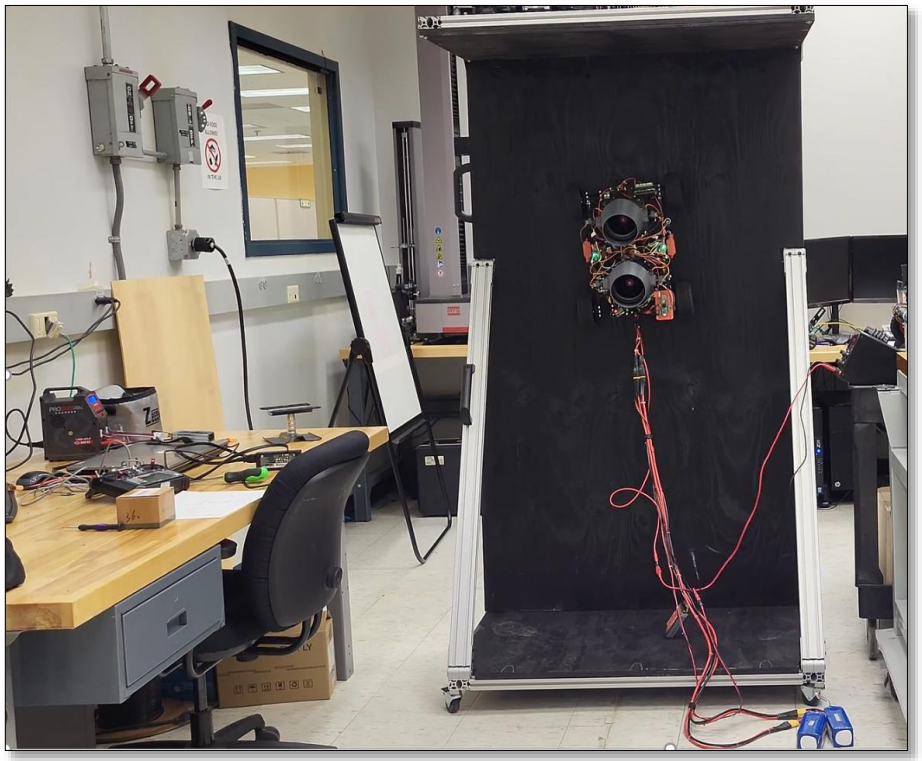
- **Vector Thrust Unit**
  - The unit is composed of two sections that move independent of one another allowing for 2-DOF.
  - It has a maximum angle deviation of 30 degrees from vertical center line which allows for appropriate clearance from other onboard hardware.
  - Actuation is handled by utilizing micro metal gear servos with position feedback.



Assembly and testing of vector thrust modules for performance output.



Integration of the vector thrust modules onto the dual EDF platform.

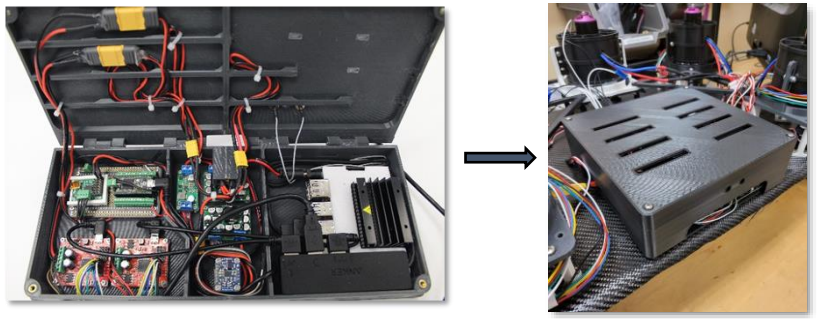


Successful testing of the dual EDF platform equipped with the vector thrust units.

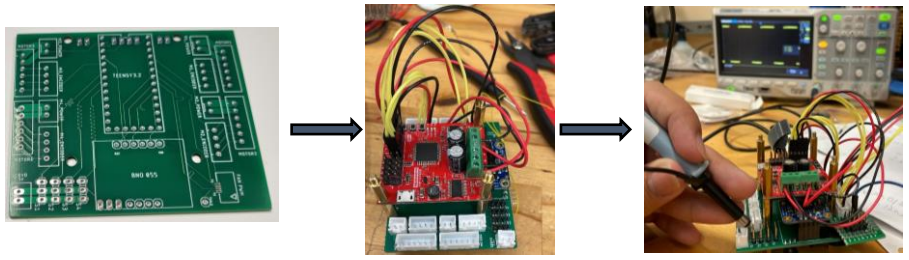
Subtask 18.3: Development of a Coating Deployment Platform for the H-Canyon Exhaust Tunnel

FIU Year 3 Research Highlights & Accomplishments:

- **Platform Control Unit**
  - Eliminated the need for excess 3D printed material for component securement.
  - Reduced electronic footprint along with the number of wires needed for power and communication.
  - Simplified method of communication between electronic components and microcontroller.



Previous iteration of the EDF platform control unit.



Current version of the EDF platform control unit.

- **Large Scale Mockup Design**
  - Selection of area of large scale mock up construction.
  - Preliminary design of mockup which includes the top entry port for tunnel access.

Outside testing area for constructing a segment of the H-Canyon tunnel mockup.

CAD model of the proposed H-Canyon tunnel segment with entry port and fan locations.

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Subtask 18.3: Development of a Coating Deployment Platform for the H-Canyon Exhaust Tunnel

FIU Year 4 Projected Scope

- **Platform Development**
  - Continue to incorporate semi-autonomous functionalities into the platform and develop methods to minimize power consumption.
  - Develop a power distribution unit tailored for extended-duration trials, ensuring consistent performance during testing.
  - Optimize the vector thrust unit's design to facilitate integration onto the large EDF (Electric Ducted Fan) platform for performance evaluation.
- **Support Arm**
  - Increase the degrees of freedom (DOFs) within the existing support arm design for enhanced flexibility and range of motion.
  - Integrate the essential hardware and software components to enable precise control of the support arm unit, efficiently utilizing the platform as an end effector.
- **Coating System**
  - Incorporate coating elements onto the large EDF platform and conduct preliminary tests to demonstrate the platform's modularity and versatility.
- **Testing**
  - Development of a high-fidelity mockup of a segment within the H-Canyon, designed for experimentation of the wall crawling platform. The mockup will offer the flexibility to control environmental parameters, including temperature and humidity, enhancing the accuracy of testing scenarios.

Subtask 18.4: Long-Term Surveillance of Nuclear Facilities and Repositories using Mobile Systems

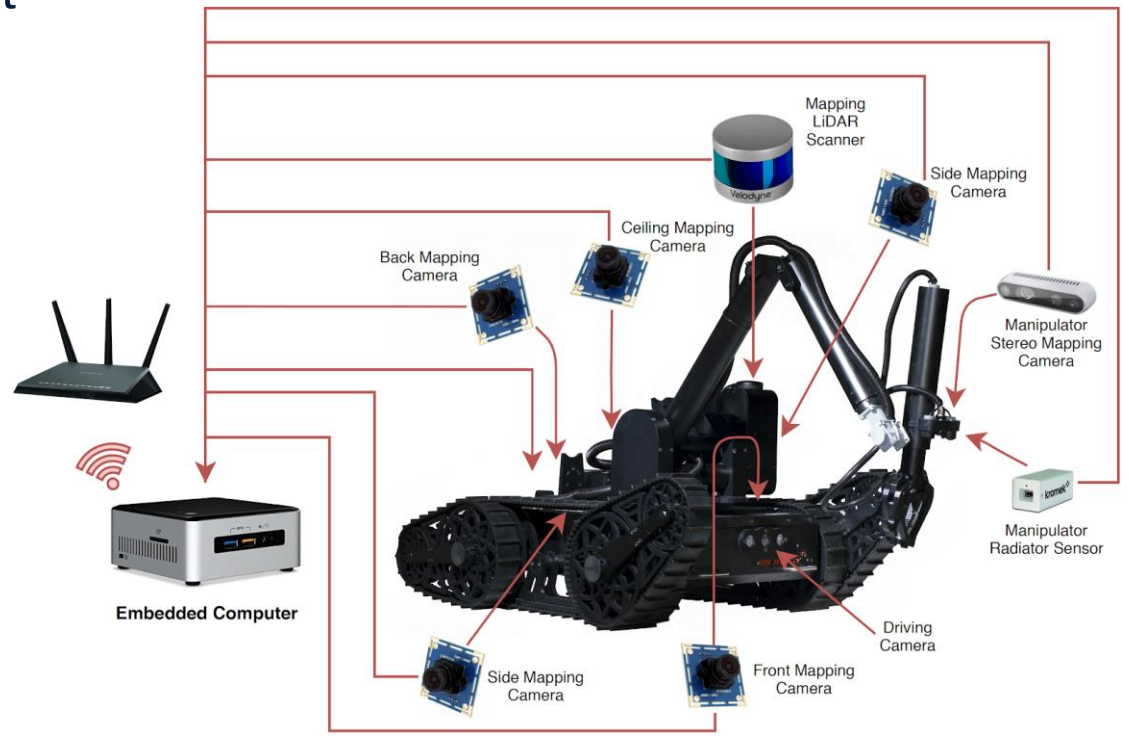
Site Needs

Continuous surveillance of nuclear facilities and repositories is a critical element in successfully controlling and understanding radiological environmental impact, among other hazards, planning cleanup efforts, and meeting quality assurance objectives established by the United States Department of Energy standards and guidelines

Conventional Site Inspections

Objectives

Automate aboveground routine inspections, surveillances, and emergency response at Hanford's thank farms.



FIU's Autonomous Surveillance Framework

Subtask 18.4: Long-Term Surveillance of Nuclear Facilities and Repositories using Mobile Systems

FIU Year 3 Research Highlights and Accomplishments

Reconnaissance and Frist Response Mobile Platform
Donated by WRPS

Software and Hardware Upgrade
+
Sensors Integration
GPS, Cameras, Lidar and Radiation Detector
+
FIU's Navigation and Mapping Framework

WRPS' Cold Test Facility Summer Technology Demonstration

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Subtask 18.4: Long-Term Surveillance of Nuclear Facilities and Repositories using Mobile Systems

FIU Year 3 Research Highlights and Accomplishments

Demonstration at WRPS's Cold Test Facility

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Subtask 18.4: Long-Term Surveillance of Nuclear Facilities and Repositories using Mobile Systems

FIU Year 3 Research Highlights and Accomplishments

Demonstration at WRPS's Cold Test Facility

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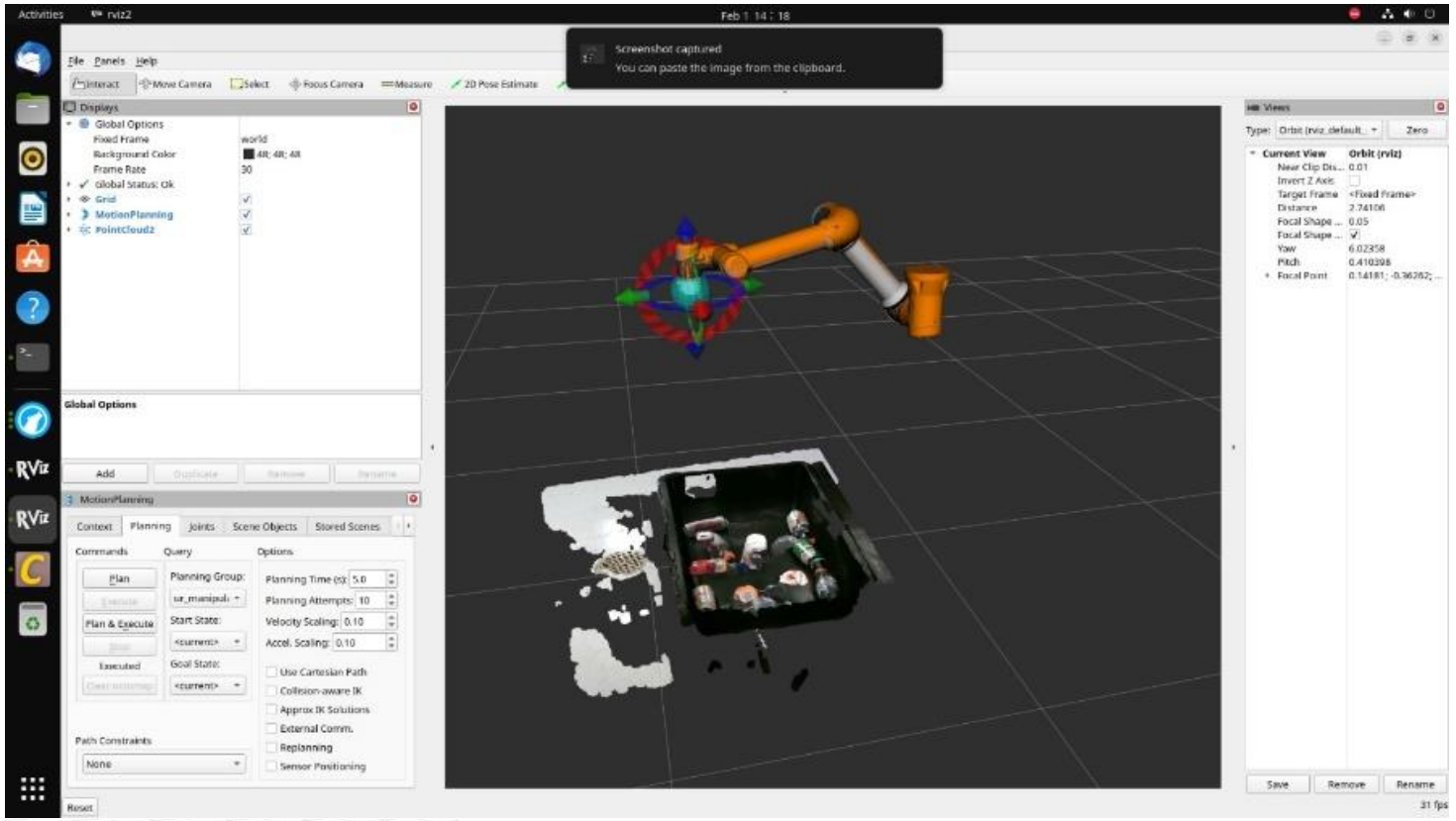
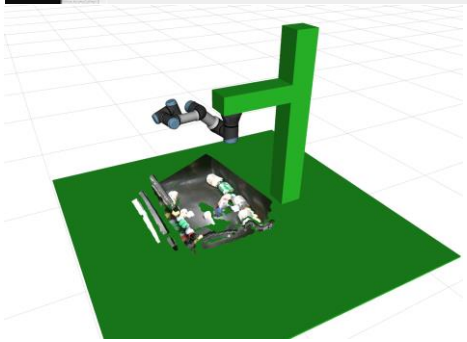
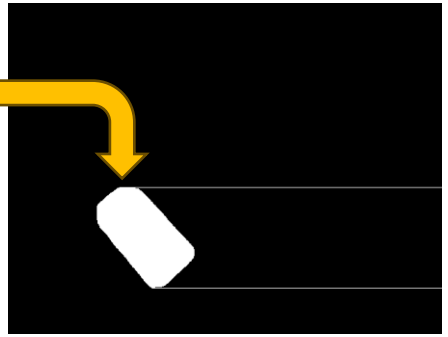
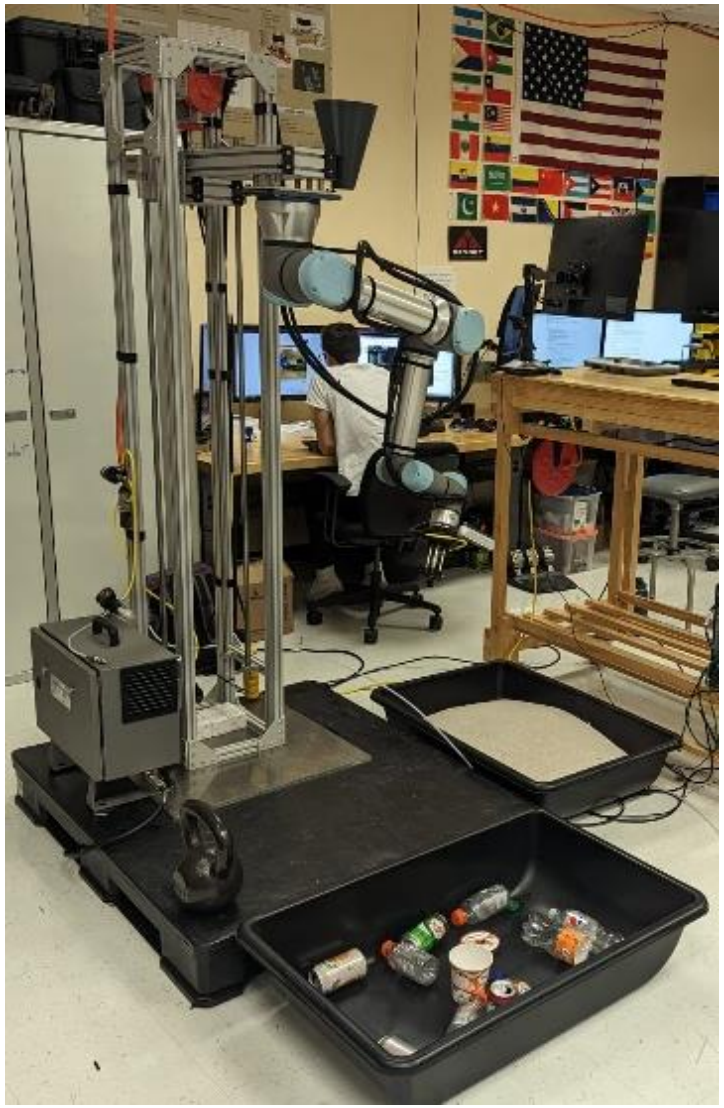
Subtask 18.4: Automated Waste Segregation Support to Project 3 (Task 9)

FIU Year 3 Research Highlights and Accomplishments









Waste Segregations

Subtask 18.4: Long-Term Surveillance of Nuclear Facilities and Repositories using Mobile Systems

FIU Year 4 Projected Scope

- Continue streamlining FIU's autonomous surveillance framework.
- Expand routines for autonomous outdoor surveillance.
- Continue enhancing the onboard terrain risk-awareness framework.
- Implement robust information-driven planning and control algorithm.
- Improve radiation field reconstruction algorithm.
- Implement an organic operator interface considering feedback from WRPS engineers and field technicians received during the summer demonstration.
- Redeploy at WRPS's Cold Test Facility next summer.
- Continue robotic support for Project 3's Waste Segregation Task.

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Subtask 18.5: Development of Robotic Systems for DOE Sites

Site Needs

Hanford's site scientists and engineers are constantly evaluating innovative technologies to alleviate the operational issues related to inspecting and sampling aging single-shell and double-shell tanks containing highly radioactive nuclear waste. Since the primary linear failed in AY-102, there is significant concern regarding the health of other underground tanks at Hanford, prompting the need for developing specialized inspection tools that can assess the health of the primary liners in the Hanford Tanks.

Objectives

To develop and deploy novel inspection and sampling tools suitable for tank integrity assessments and residual waste removal. FIU engineers and DOE Fellows will continue to work directly with site engineers to build and test systems that can improve site personnel's operational efficiency and safety. This includes:

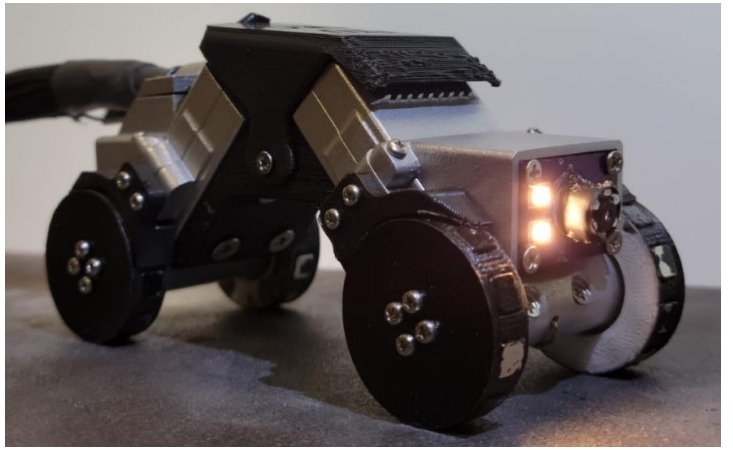
- Streamlining and adding functionalities and strengthening the multiple inspection tools developed at FIU.
- Leveraging lessons learned from site personnel interactions and deployments.
- Deploying and demonstrating technologies at the Hanford site during the summer.

Subtask 18.5: Development of Robotic Systems for DOE Sites

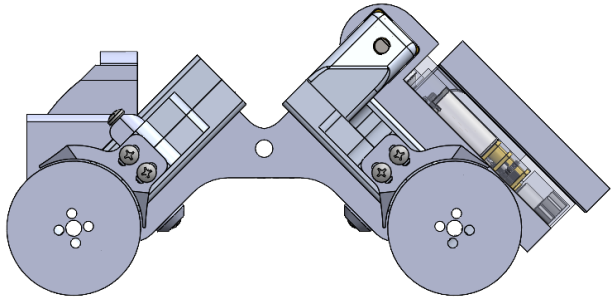
FIU Year 3 Research Highlights and Accomplishments

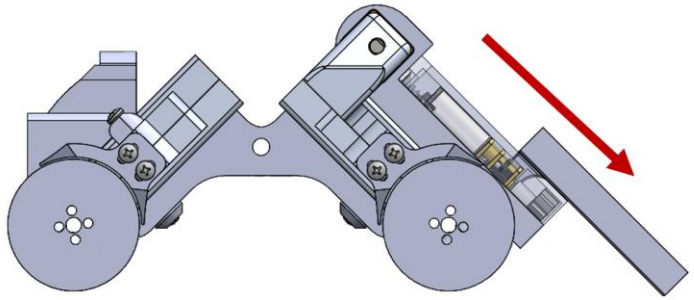
In March 2022, the FIU miniature inspection rover was **deployed at Hanford's AP-105 double-shell tank** by WRPS's site engineers, and the **technology was transferred to DOE**.

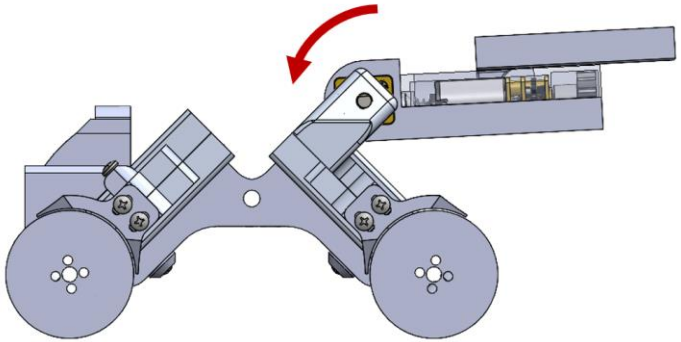
In 2023, WRPS Engineers requested the integration of sampling systems into the FIU Miniature Inspection Rover.



2022 AP-105 double-shell tank deployment





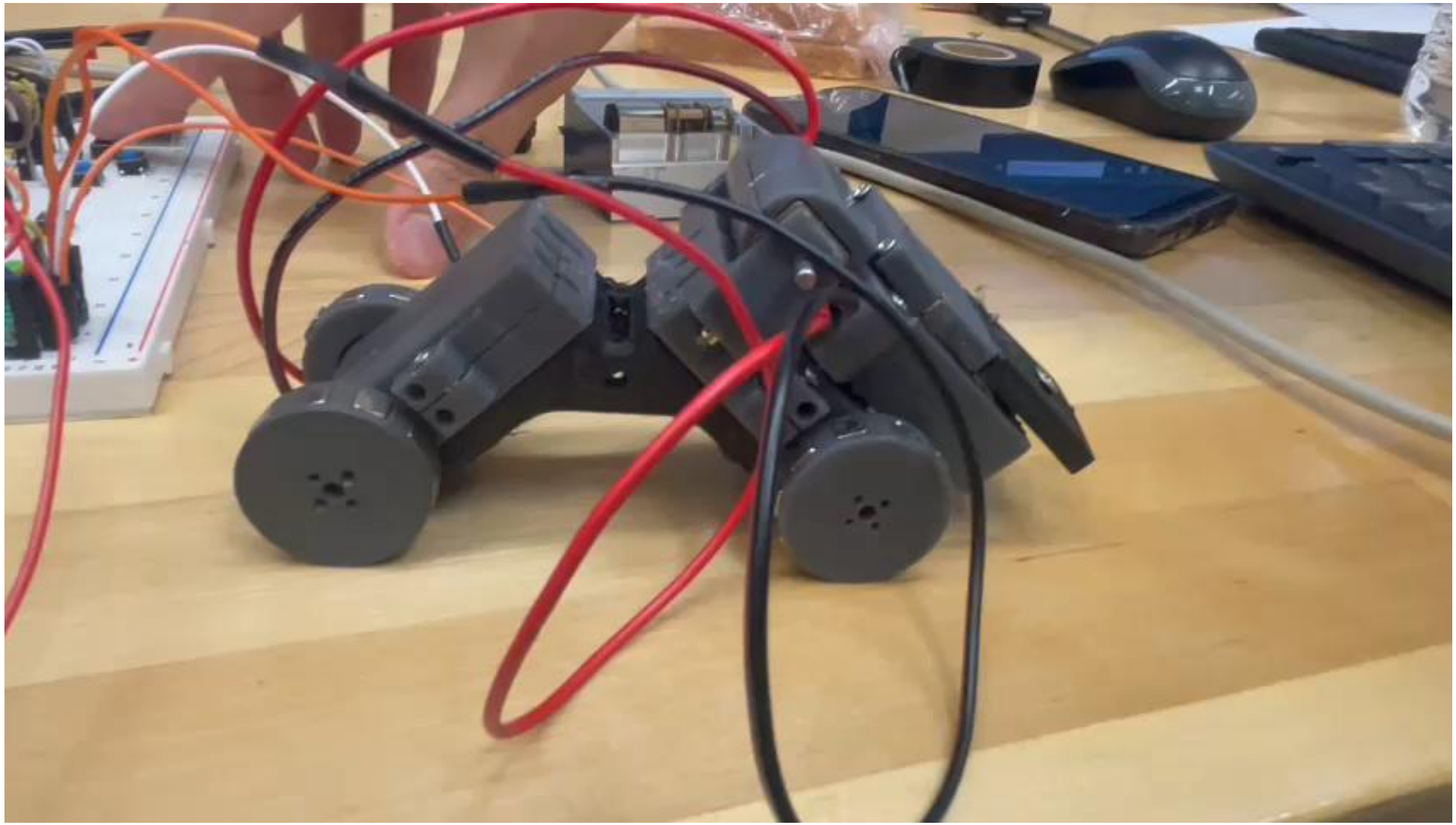


FIU's Minirover Sampling System

FIU Applied Research Center

Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments



FIU's Minirover Sampling System

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Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments

Minirover Chassi CNC

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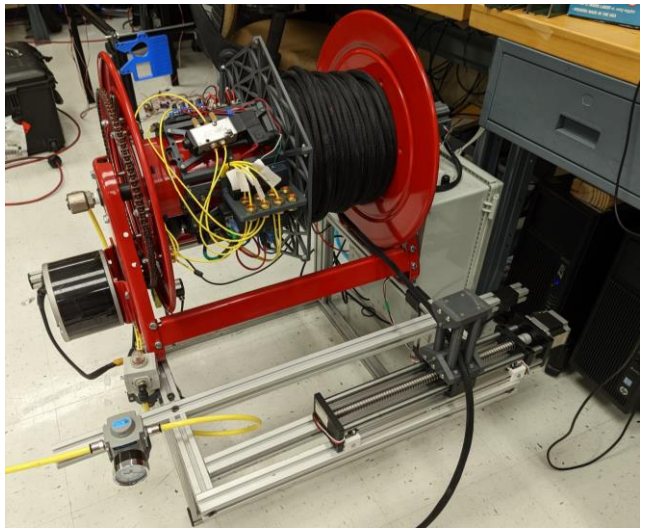
Subtask 18.5: Development of Robotic Systems for DOE Sites

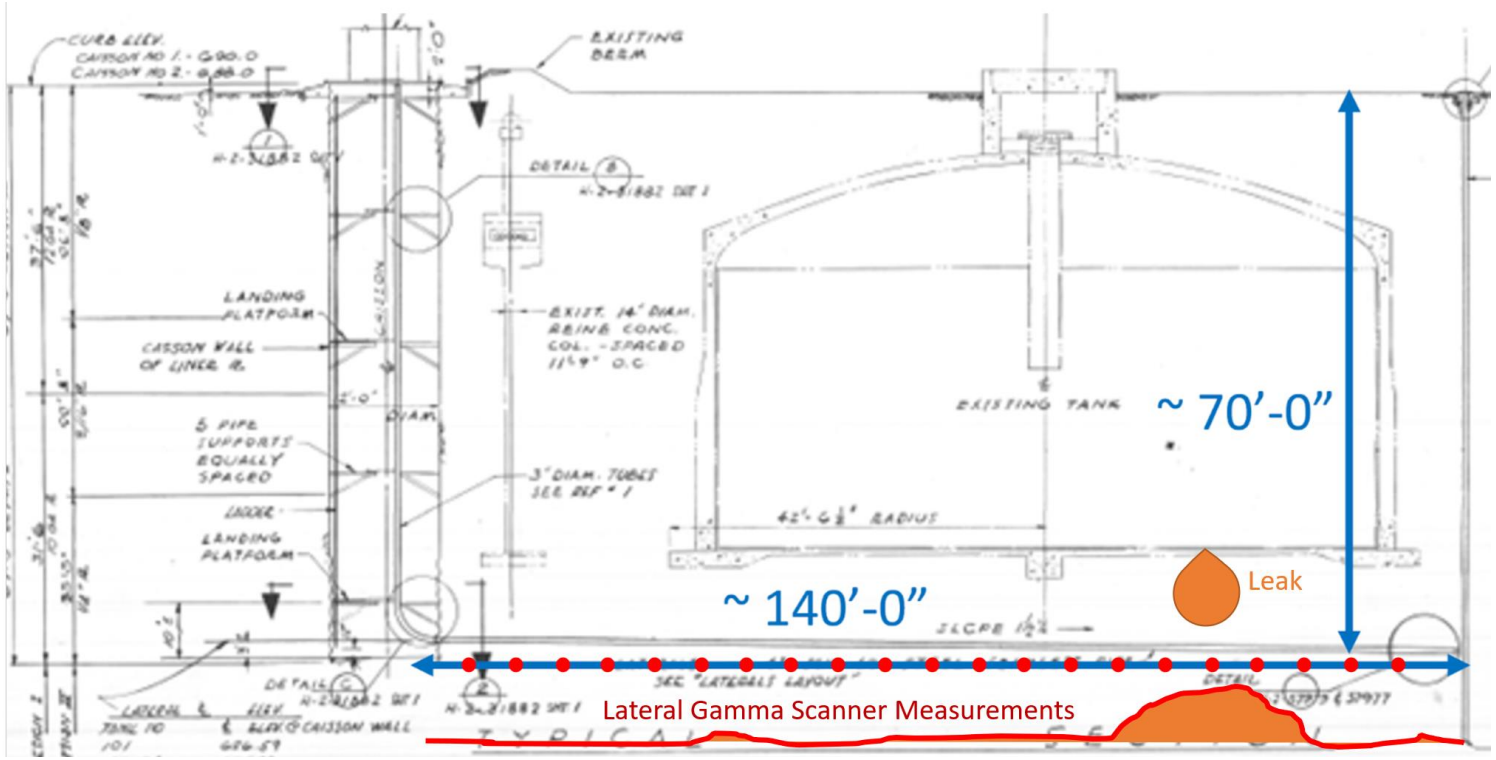
FIU Year 3 Research Highlights and Accomplishments

July 2022 - FIU Lateral Gamma Scanner Crawler **redeployed at WRPS's Cold Test Facility.**

- Unit redeployed in 2023 at Hanford.



Cable Management



Proposed automated inspection

Lateral Gamma Scanner

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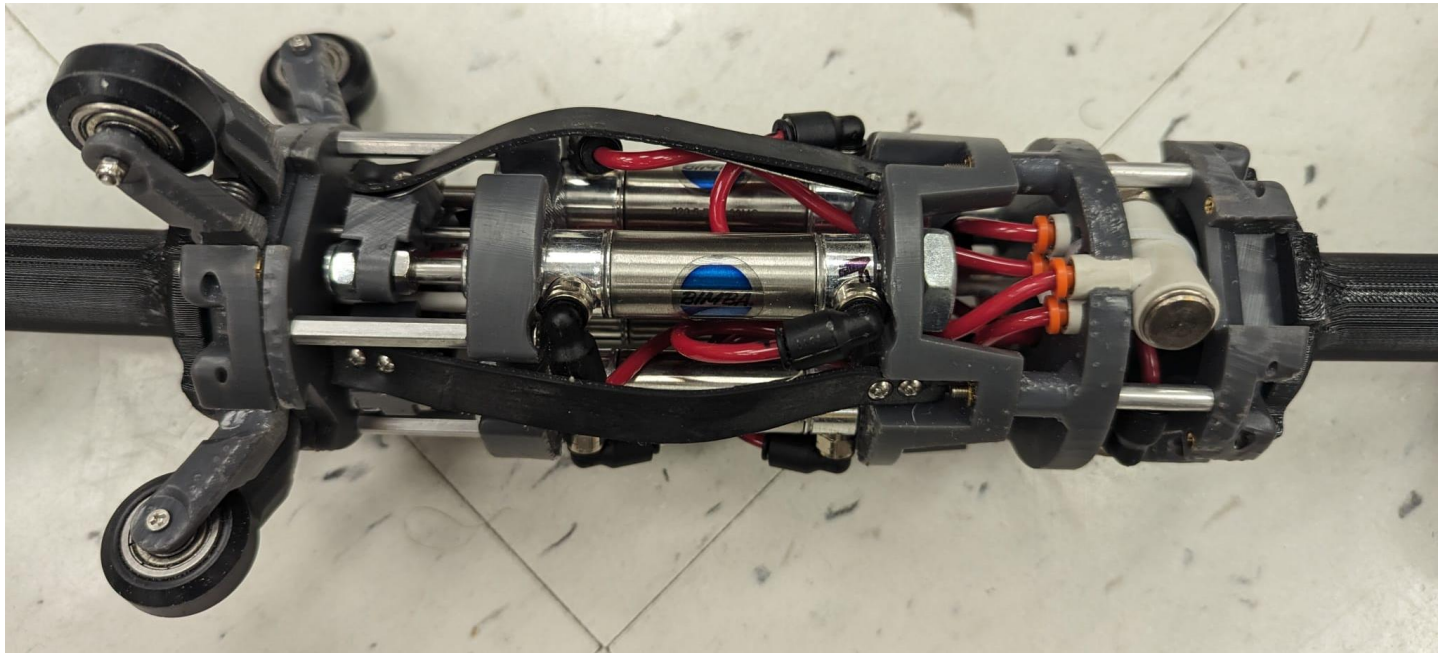
Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments



Streamlined Mechanical Design, Controls, and Operator Interface

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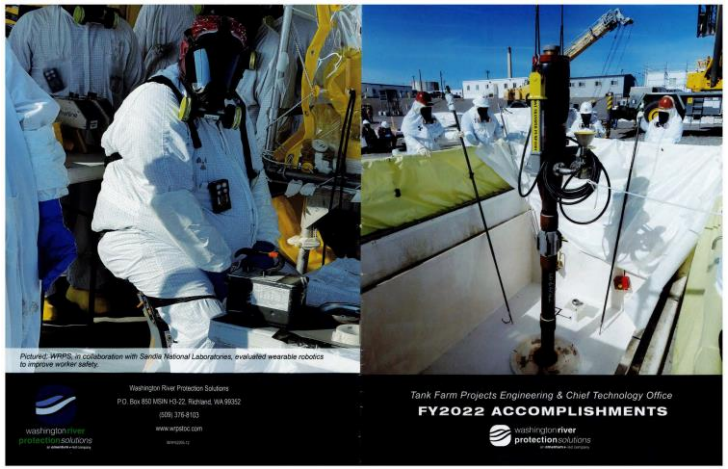
Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments

WPRS' Cold Test Facility Deployment

Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments



TECHNOLOGY MANAGEMENT & FIELD SOLUTIONS

Mission: Providing integrated technology through innovative systems that support tank integrity, waste transfers, and sampling analysis underpinning the Hanford cleanup mission.

Cold spray – one of several tank refurbishment techniques being developed as a tool for maintaining tank integrity – was successfully demonstrated by magnetically adhering to a tank wall replica and depositing a patch on a 12" by 12" area.

Volumetric nondestructive examination (NDE) of double-shell tank (DST) primary tank bottoms will ensure continued tank integrity for the duration of the Hanford mission. Guidedwave Phased Array (GWPA) Sensing is one method in development to execute the inspection. Pictured inside the air-slot replica is the Air-slot Crawler carrying the GWPA sensor.

Together, the Hedgehog III and Shielded Sampler provided Operations an opportunity to retrieve larger samples and transport them with up to 80% reduced worker dose.

17

Pictured: The test setup at Cold Test Facility (CTF) for the lateral gamma scanner that was designed, built, and tested by Florida International University (FIU). The lateral gamma scanner was developed to verify continued integrity in the single-shell tank farms.

18

WRPS collaborates with FIU to design tool for detecting single-shell tank leaks

Engineering and the Chief Technology Office (CTO) are continuing their partnership with Florida International University (FIU) to develop technology that can detect possible leaks under single-shell tanks (SSTs).

The "Lateral Gamma Scanner" project is one of three summer internships currently being sponsored by WRPS. The crawler moves through existing horizontal pipes by using mechanical grabbers that push and pull it along the inside of the pipe, while sensors detect possible leaks by measuring gamma radiation from cesium-137.

Josue Estrada, a WRPS intern and Department of Energy (DOE) Fellow, is part of the team continuing work from last year. He was present to help lead a recent demonstration at the Cold Test Facility (CTF).

"This year, we've furthered development of the system in its reliability, operability, and maintenance," he explained.

The crawler's gripper module has undergone significant design improvements, enhancing the previous gripping force from approximately 20 pounds to 45 pounds per module. The upgrade will allow the tool to crawl through more debris with relative ease. The improvements also include strengthened wheel guides. The guides center the crawler module to minimize friction and potential debris accumulation during inspections.

"We also enhanced operability by adding a more user-friendly interface that shows a video feed of the crawler moving forward and allows the operator to pause and resume the operation with a touchscreen button on a display monitor," said Estrada.

The "Lateral Gamma Scanner" crawler bot is lowered down the pipe and retracted using a reel and cable system.

DOE Fellow and WRPS intern Josue Estrada explains how the design team has improved the crawler bot's ability to navigate debris in pipes during a demonstration at CTF.

The new interface allows an operator to interact with the crawler's automation system more easily.

The crawler bot uses small, mechanical grippers to push and pull itself along the inside of a pipe.

The design team integrated a quick-disconnect attachment into the inspection tools and redesigned the crawler's modules, which previously had wires soldered in place around the crawler's central piston. The new modules have hollow centers that allow cables to be inserted or removed as needed without soldering.

The recent demonstration tested the improved device in front of several WRPS engineers.

"I am impressed by the exceptional talent and unwavering dedication displayed by the students of the DOE Fellowship program at FIU," said Doug Reid, a WRPS mechanical engineer who is Estrada's mentor in CTO. "As a proud corporate sponsor, I have witnessed the remarkable partnership between academia and industry. The students' intelligence, creativity, and technical prowess have benefitted WRPS. Their passion for learning and innovation is a true testament to their potential as future leaders in technology."

"We are honored to have collaborated with these talented individuals and remain committed to supporting their continued success," he added.

In the upcoming fall semester, the robotics team at FIU's Applied Research Center will begin the integration and testing of a preliminary gamma sensor into the crawler system. This development aims to deliver a prototype ready for tank deployment in 2024.

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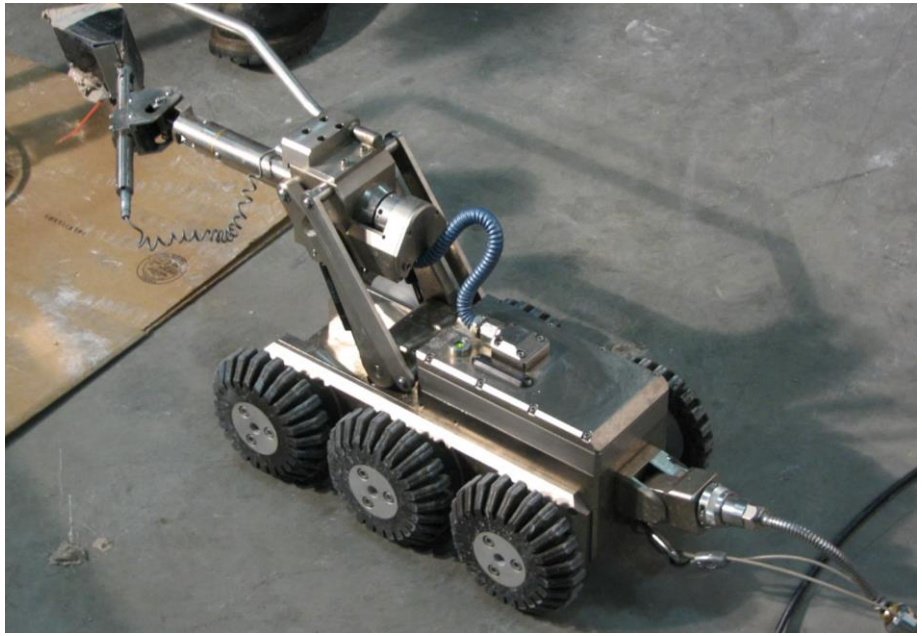
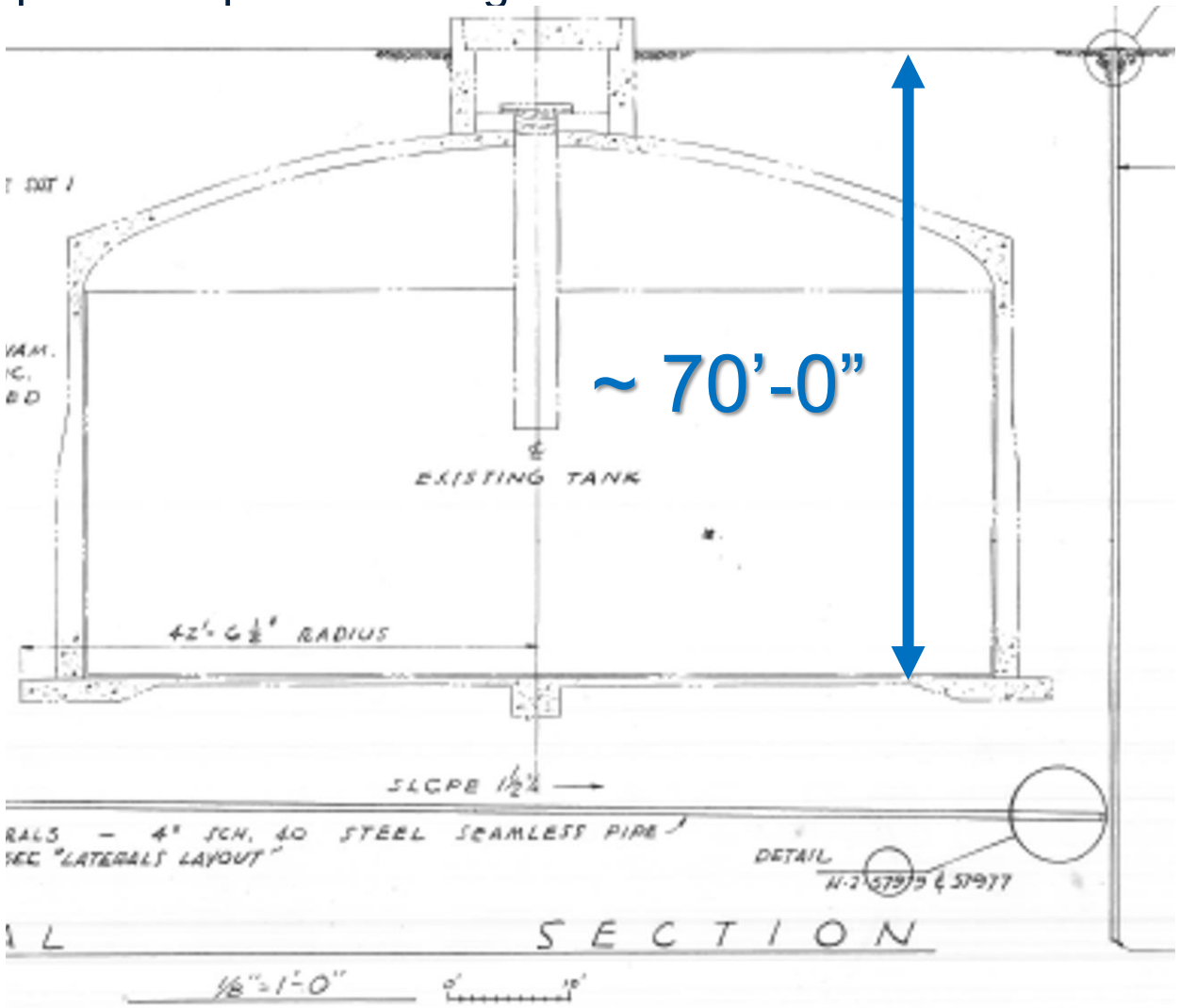
Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments

In Summer 2023, FIU continued the sampler manipulator design at Hanford.





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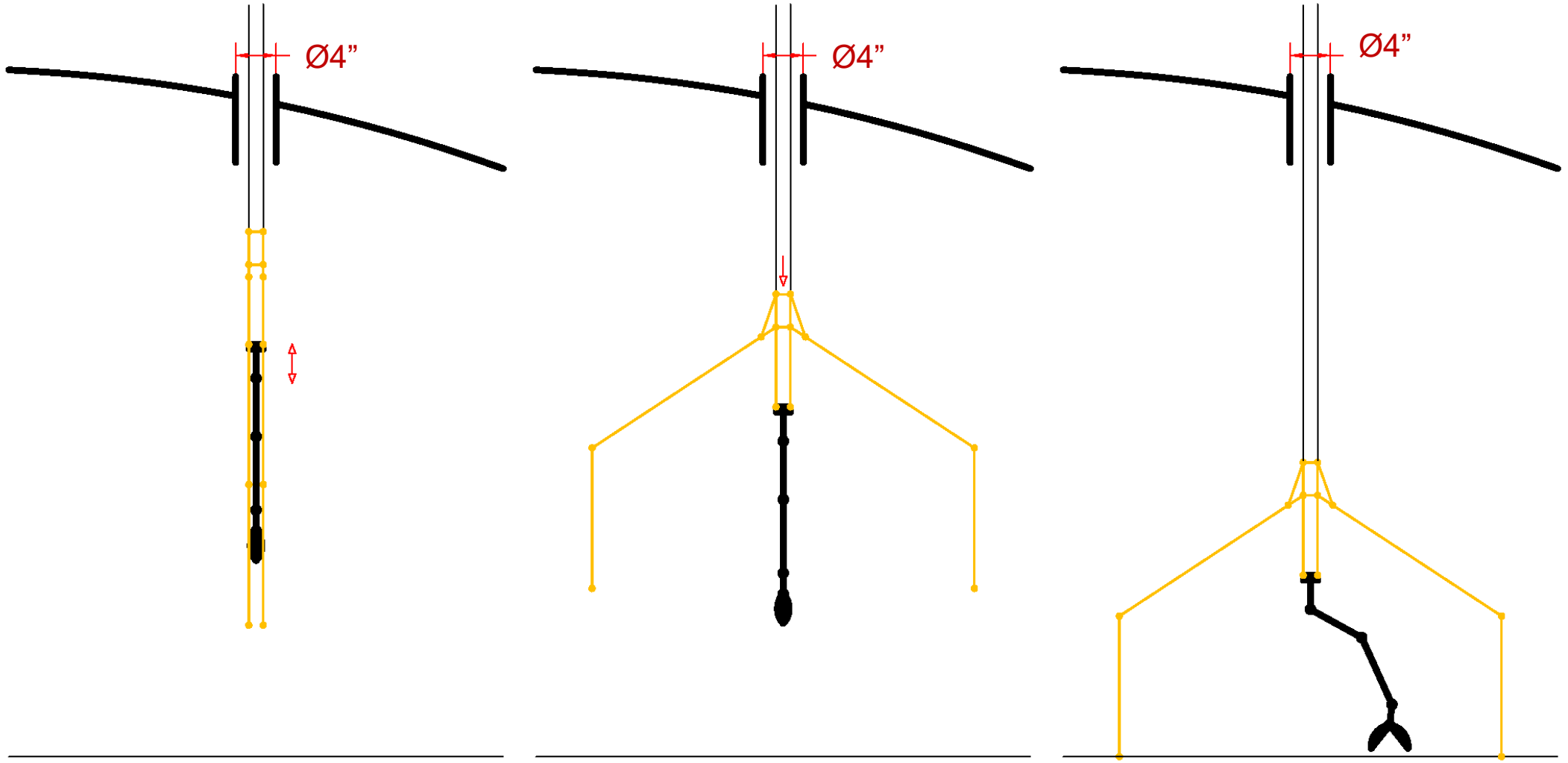
Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments



Off-riser Sampler Conceptual Design

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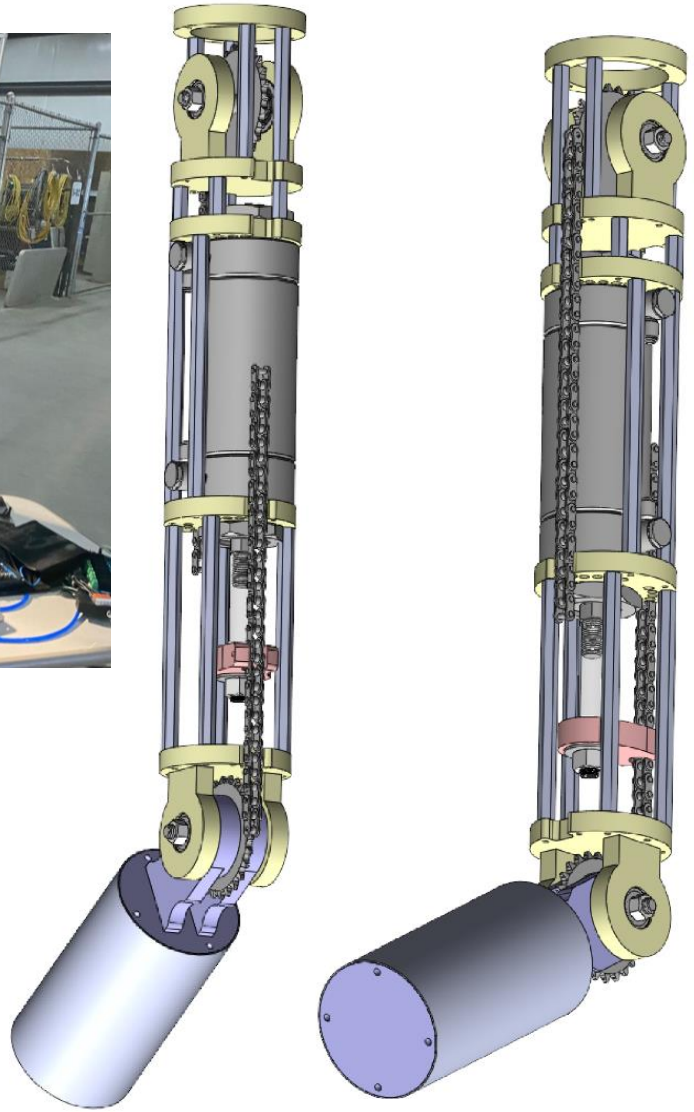
Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 3 Research Highlights and Accomplishments



Off-riser Sampler Development at Hanford

Subtask 18.5: Development of Robotic Systems for DOE Sites

FIU Year 4 Projected Scope

Minirover

- Continue sampling system development and testing for potential summer deployment at Hanford.
- Retrofit the control box to operate the sampling system.
- Implement computer vision techniques to reconstruct refractory channel 3D models.

Lateral Samma Sensor

- Integrate gamma radiation sensor.
- Simulate radiation detection.
- Prepare for potential summer deployment at Hanford.

Off-Riser Sampler

- Complete functional prototype.
- Integrate tool changer.
- Develop innovative end-effector tooling and samplers.
- Create a more natural interface with the operator.
- Deploy for summer deployment at WRPS's Cold Test Facility.

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Task 19

Pipeline Integrity and Analysis

FIU Applied Research Center

Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

Site Needs:

- Structural integrity and life assessment by corrosion and erosion detection in waste tanks and transfer lines.
- Due to uncertainties regarding the structural integrity of pipelines at Hanford, a Fitness-for-Service (FFS) program for the Waste Transfer System has been implemented.
- A direct inspection and assessment of the condition of buried pipelines is required to evaluate the corrosion and erosion wear rates and predict the existing system's remaining useful life.

Objectives:

- Evaluate technologies for real-time thickness changes in pipes and transfer lines.
- Validate flow erosion coupons developed by SRNL for erosion and corrosion detection.
- Model and predict erosion and corrosion using fluid flow dynamics and advanced data analytics.

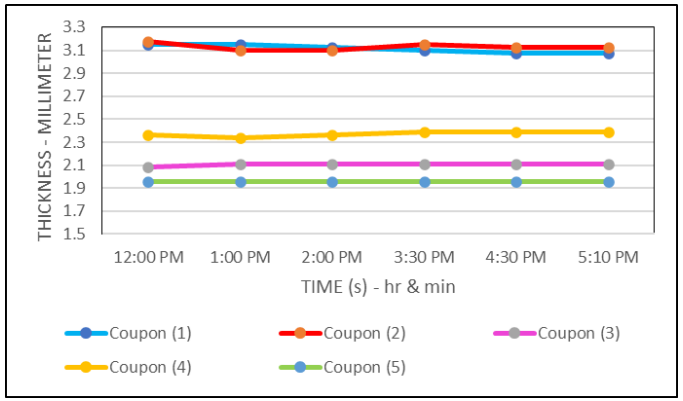
Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

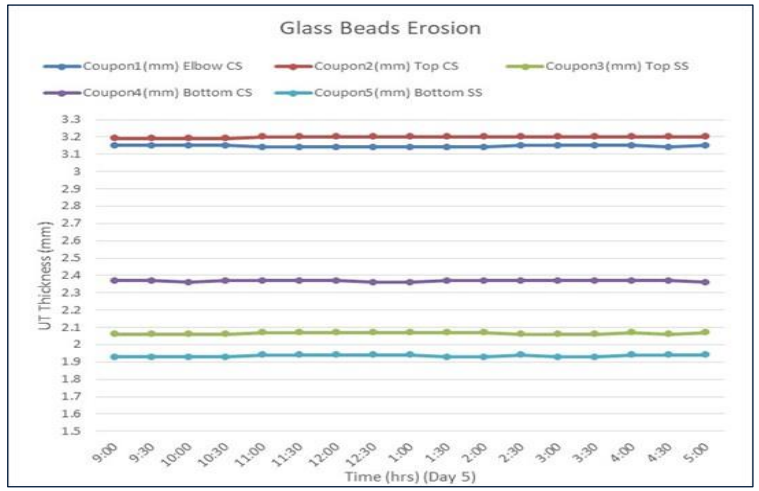
FIU Year 3 Research Highlights & Accomplishments:

Particle Erosion in Pipe Loop Replicating Waste Transfer Encasement Pipes

Sensor Technologies – Ultrasonics and SRNL coupons

Glass and Sand Particle Experimental Test Results

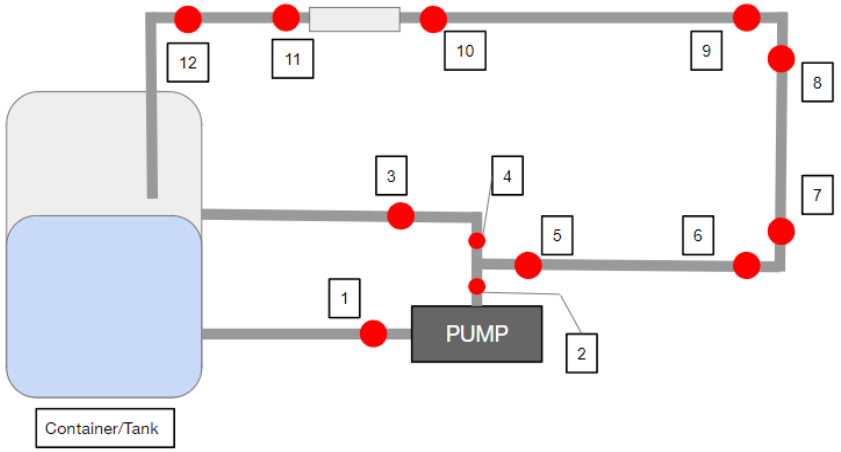


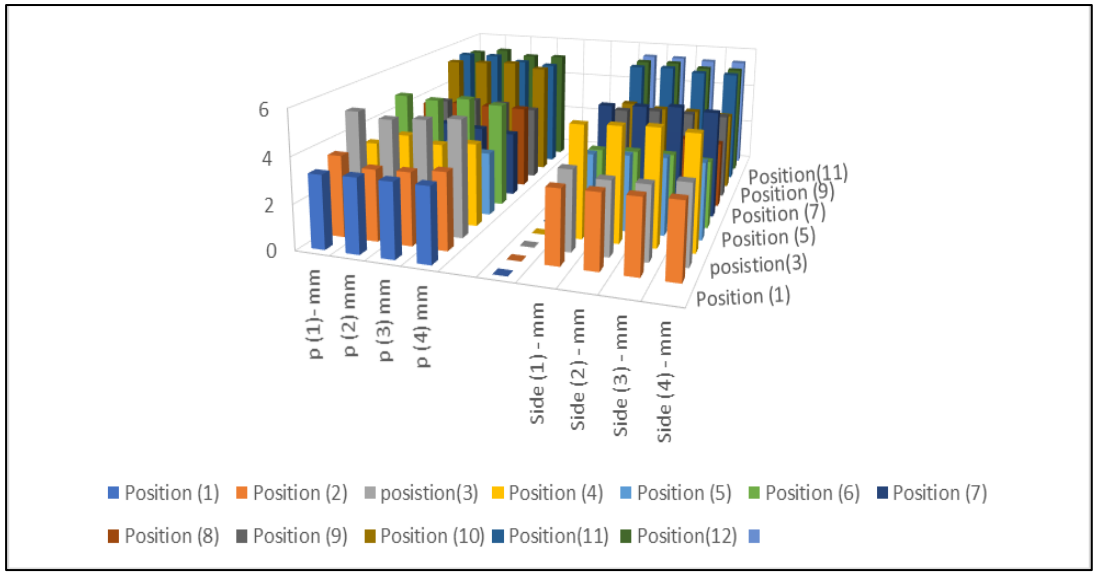


Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

FIU Year 3 Research Highlights & Accomplishments:

Structural Health Assessment of the Pipe Loop



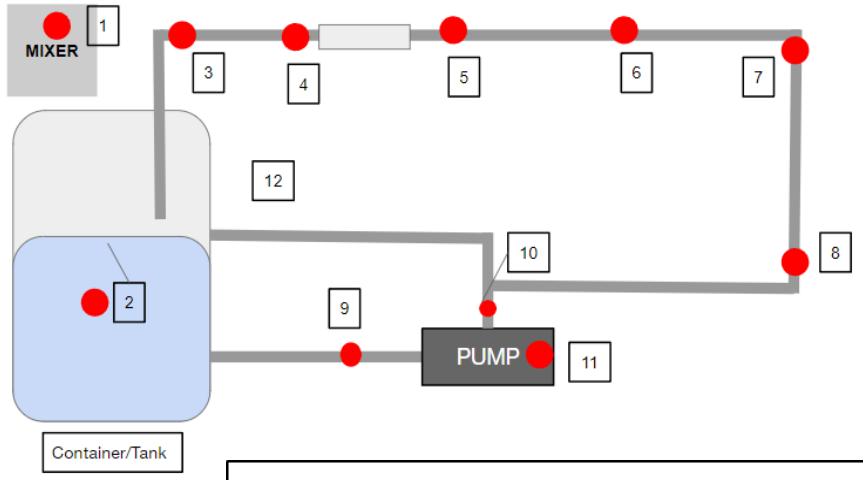


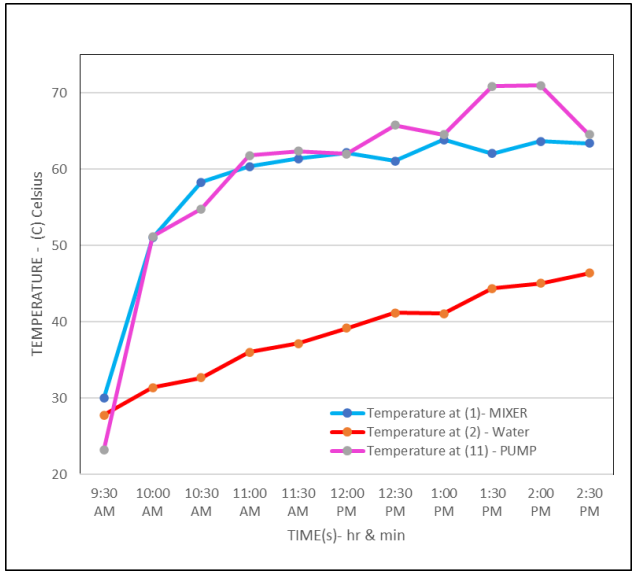
Pipe Degradation Experiment (UT measurements in mm)				
Position (s)	P (1)	P (2)	P (3)	P (4)
Position (1)	3.2258	3.2766	3.2766	3.2766
Position (2)	3.5814	3.1496	3.2004	3.3782
Position (3)	5.1308	4.9022	5.0292	5.1816
Position (4)	3.302	3.81	3.5306	3.7084
Position (5)	2.9718	3.2004	3.2004	2.8702
Position (6)	4.826	4.7244	4.9022	4.7244
Position (7)	2.9464	3.2258	3.0988	2.9718
Position (8)	3.7592	3.8862	3.8608	3.8608
Position (9)	3.556	3.7084	3.6322	3.4544
Position (10)	5.3594	5.4102	5.4864	5.2832
Position (11)	5.4864	5.5118	5.2832	5.1816
Position (12)	5.3594	5.5626	5.334	5.3848

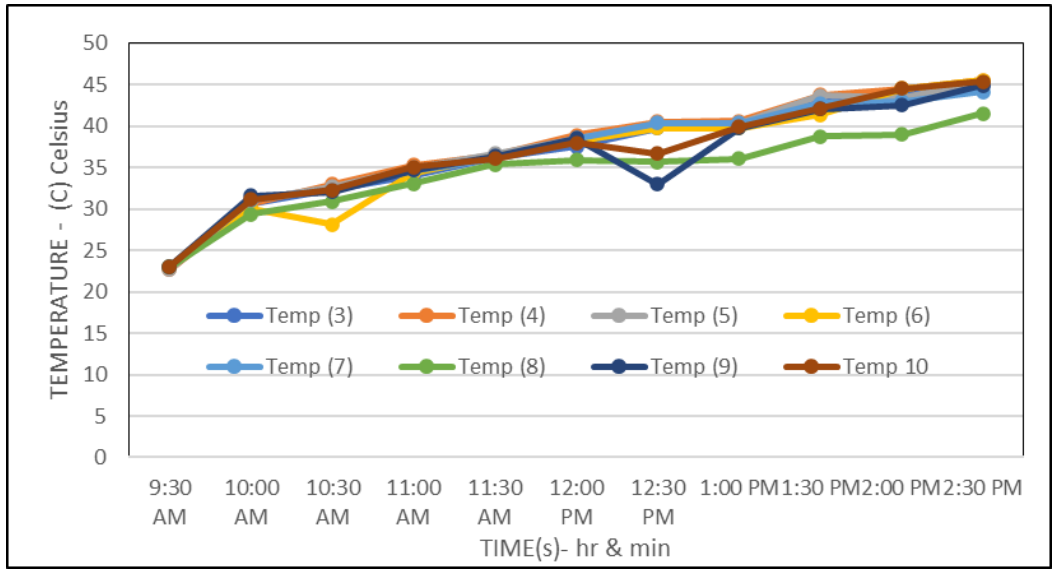
Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

FIU Year 3 Research Highlights & Accomplishments:

Loop Thermal Stability Assessment



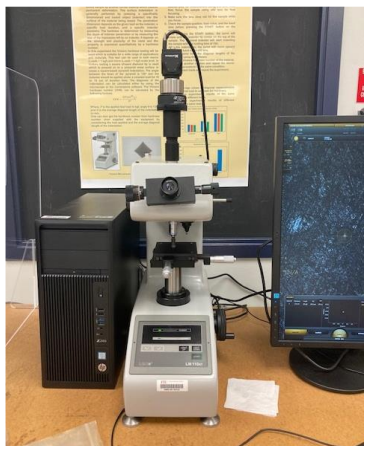




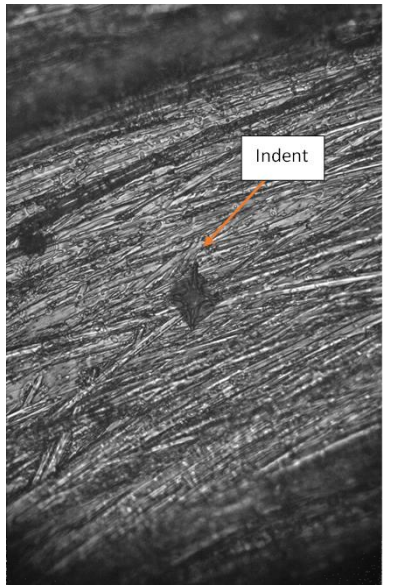
Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

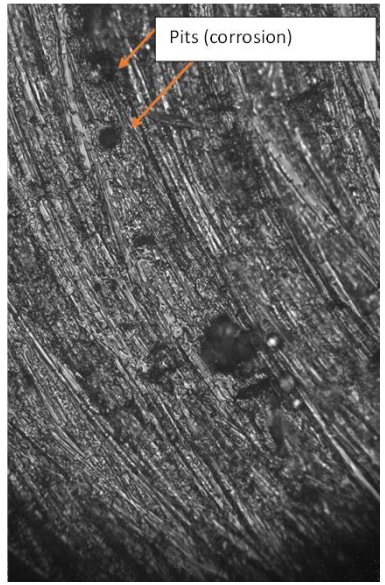
FIU Year 3 Research Highlights & Accomplishments:

Material Hardness Testing



Vickers Hardness Tester with SRNL coupon





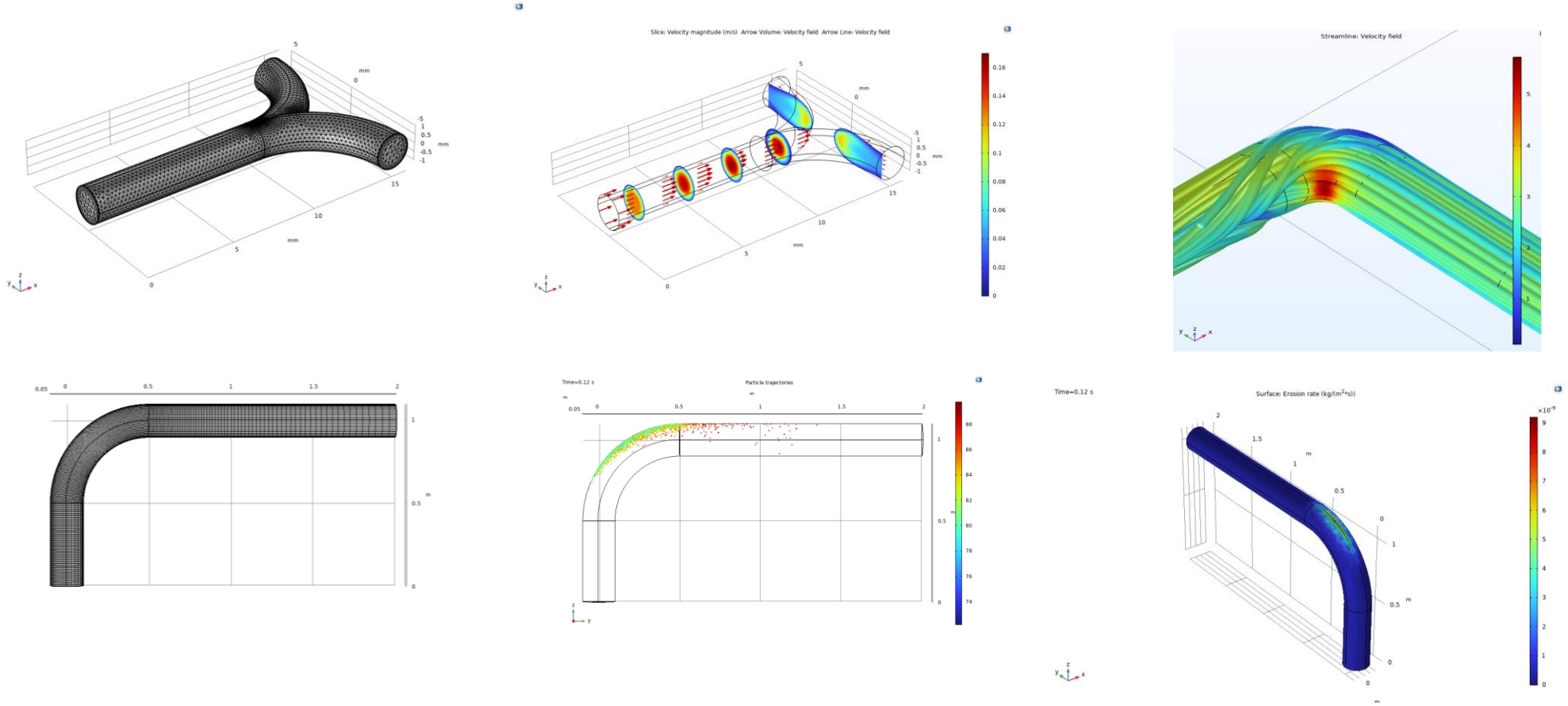
- Average Vickers Hardness Test Results
  - Coupon 1 - 301 HV (105 HRB)
  - Coupon 2 - 329 HV (107 HRB)
- SRNL Provided Data - (104 HRB)

Indent Test #	Hardness (Vickers)	Load	D1	D2
1	302 HV	200 gf	35.0 µm	35.1 µm
2	276 HV	100 gf	26.8 µm	25.0 µm
3	370 HV	100 gf	22.5 µm	22.3 µm
4	267 HV	100 gf	25.8 µm	26.9 µm
5	292 HV	100 gf	24.5 µm	25.9 µm

Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

FIU Year 3 Research Highlights & Accomplishments:

Fluid Flow simulations (CFD) for Particle Erosion



COMSOL simulation results with particle erosion models (DNV, ECRC & Finnie)

FIU Applied Research Center

Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

FIU Year 4 Projected Scope

- Simultaneous experimental evaluation of chemical corrosion and erosion using both SRNL coupons and ultrasonic sensors in the flow loop.
- Continuation of the fluid flow simulations (CFD) using COMSOL Multiphysics software for particle erosion and caustic corrosion in waster transfer pipes.
- Development of sensor data fusion models for pipe erosion and corrosion prediction.
- Integration of experimental and simulation-based results to develop data analytics models using machine learning for pipeline degradation assessment and anomaly detection.

FIU Applied Research Center

Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

Site Needs:

- Nonmetallic materials are used in the US DOE's Hanford Site Tank Farm waste transfer system. These include inner primary hoses in the HIHTLs, Garlock® gaskets, EPDM O-rings, and other nonmetallic materials.
- Nonmetallic materials are exposed to β and γ irradiation, caustic solutions as well as high temperatures and pressure stressors. How they react to each of these stressors individually has been well established, but simultaneous exposure of these stressors is of great concern.

Objectives:

- Provide the Hanford Site with data obtained from experimental testing of the hose-in-hose transfer lines, Garlock® gaskets, EPDM O-rings, and other nonmetallic components under simultaneous stressor exposures.
- Evaluation includes chemical aging and exposure of hose coupons to elevated temperature over time. Radiation is not included.

FIU Applied Research Center

Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Year 3 Research Highlights & Accomplishments:

- Previous year's work included aging HIHTL and EPDM dog-bone specimens in NaOH solutions of 25%, 12.5%, 6.25%, and 0% respectively at 170°F.

- Results showed greatest degradation in material properties occurred at the lowest concentration.

Aging Type	Average Burst Pressure (MPa)	% Change
Baseline (Unaged)	20.71	0.00
Water Only	12.30	-40.61
6.25%	15.29	-26.17
12.50%	16.90	-18.41
25%	19.40	-6.32

Average Hose Burst Pressure

Aging Type	Average Tensile Strength (MPa)	% Change
Baseline (Unaged)	7.70	0.00
Water Only	6.43	-16.49
6.25%	0.95	-87.66
12.50%	1.73	-77.53
25%	1.79	-76.75

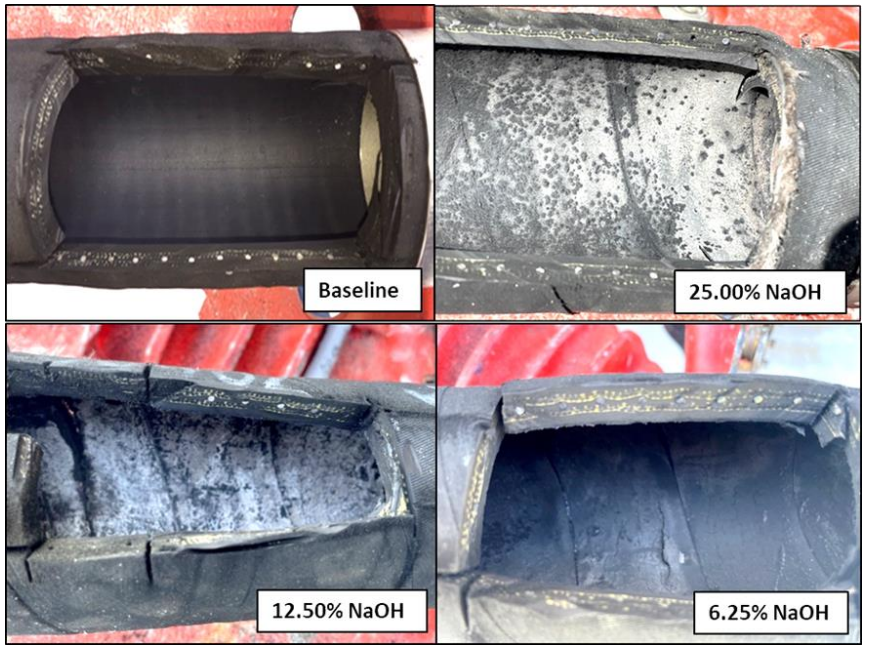
Average Dog-Bone Tensile Strength

FIU Applied Research Center

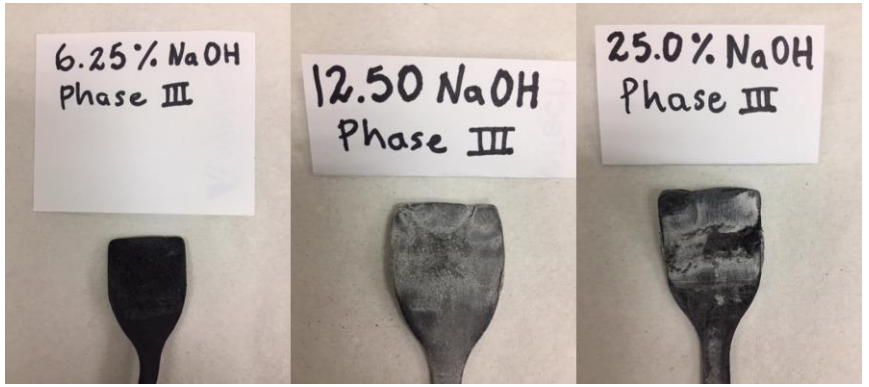
Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Year 3 Research Highlights & Accomplishments:

- After aging, a white crystalline material was observed that coated the inner surface of the HIHTL hoses as well as the dog-bones.
- White coating observed only on specimens aged with higher NaOH concentrations (12.50% and 25.00%).
- No coating observed on specimens aged with 6.25% NaOH solution.



Inside of Hoses



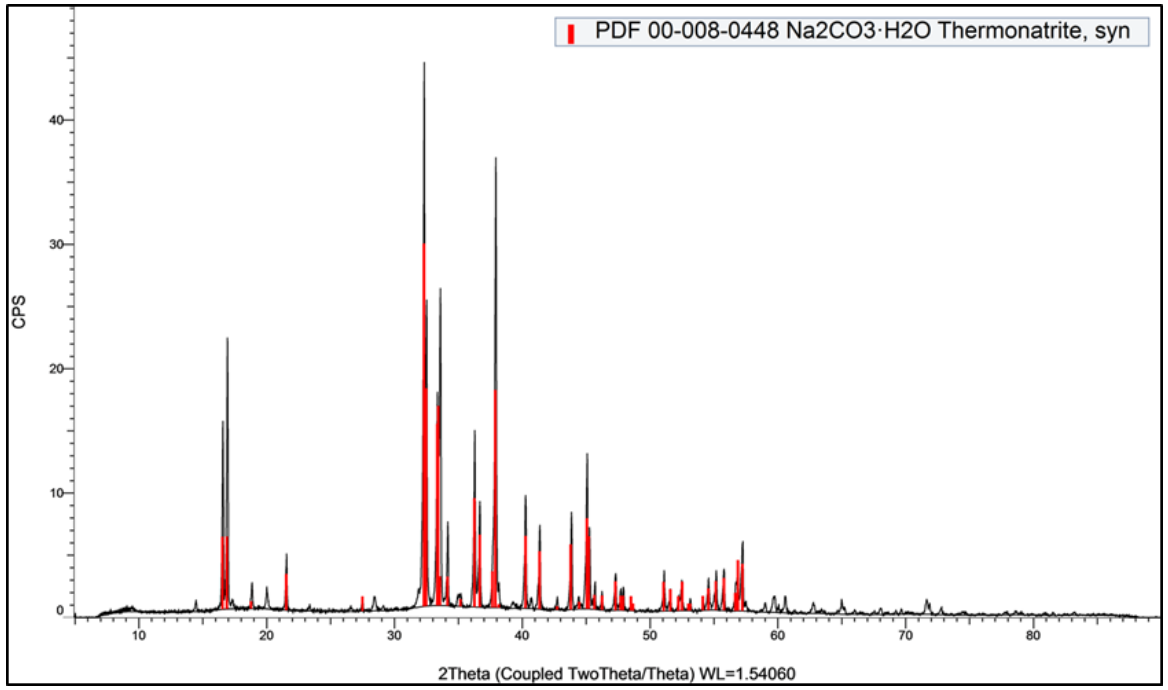
Dog-Bones

FIU Applied Research Center

Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Year 3 Research Highlights & Accomplishments:

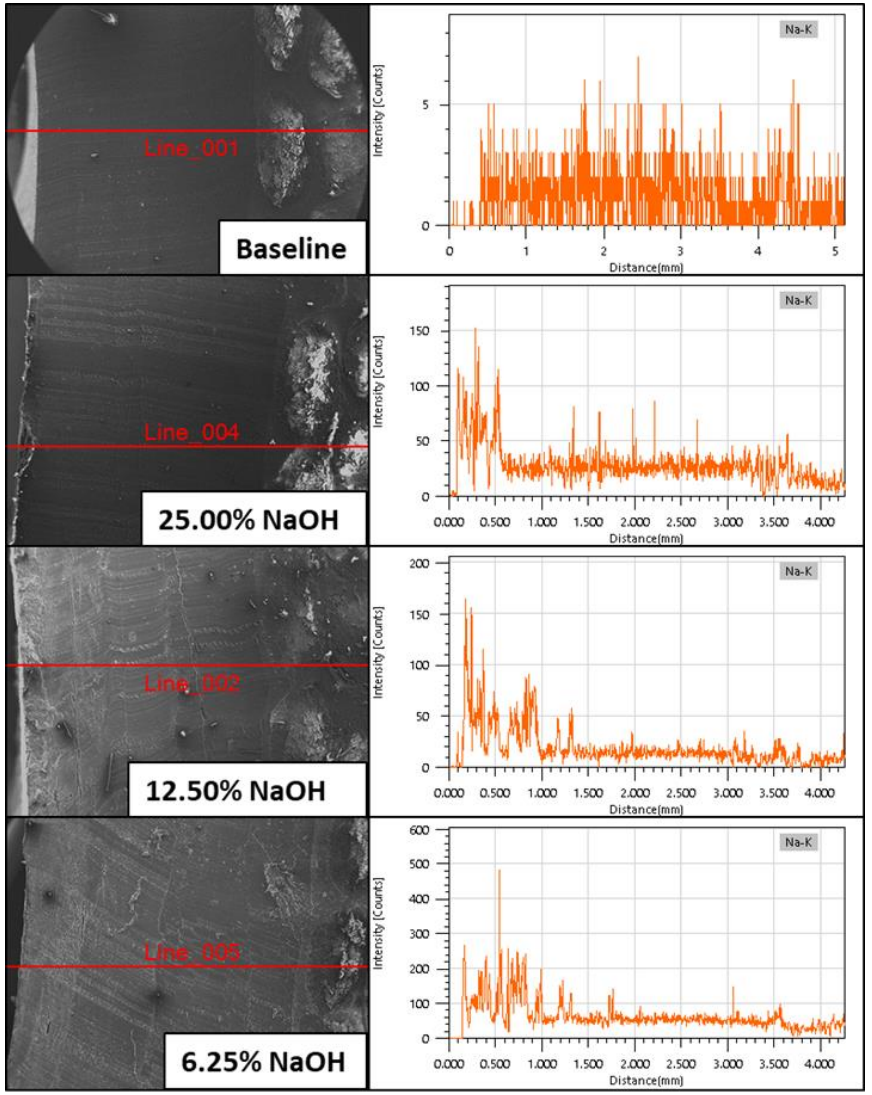
- XRD analysis conducted to identify the crystalline substance using an X-ray diffractometer.
- Determined to be Thermonatrite, a mineral form of sodium carbonate, with chemical formula, $Na_2CO_3 \cdot H_2O$.
- Formation of sodium carbonate due to a reaction between CO_2 in the air of the headspace of the storage tank in each loop and the NaOH solution.



Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Year 3 Research Highlights & Accomplishments:

- SEM-EDX analysis performed on these specimens to determine the level of sodium penetration.
- Average penetration depths in the specimens aged with the 12.50% and 6.25% NaOH solutions observed to be 77% greater than the depth observed in the 25.00% specimen.
- Findings align well with burst pressure measurements of the hoses and deterioration observed in SEM analyses of the corresponding specimens.
- Presence of Thermonatrite appears to have acted as a barrier, restricting further diffusion of NaOH solution into the EPDM material, subsequently reducing the extent of degradation.



SEM-EDX Analysis of Hoses

FIU Applied Research Center

Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Year 3 Research Highlights & Accomplishments:

- To better understand the formation rate of thermonatrite, a test plan was developed where EPDM coupons were exposed to various concentrations of NaOH at 170ºF.
- 1” x 1” coupons were cut from a single sheet of EPDM material that is 3/16” thick.
- A set of 9 coupons were placed in one of three aging containers containing NaOH solution at one of the three concentrations (6.25, 12.50, and 25%) for a total of 27 coupons.
- 1 coupon from each set removed each week and prepped to be analyzed.
- SEM-EDX will be used to determine the rate of thermonatrite buildup on the surface of the coupon and how it effects the sodium ion penetration into the EPDM material.

EPDM Coupons

Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

FIU Year 4 Projected Scope

- SEM-EDX analysis will be completed by the end of FIU Year 3.
- Project will be completed at the end of FIU Year 3.

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Task 20

Corrosion Protection and Characterization of EM Infrastructure

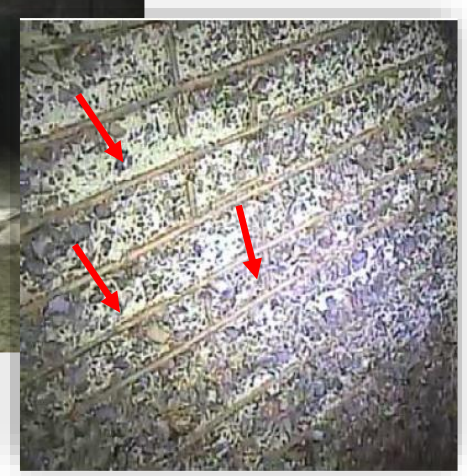
Subtask 20.1: Evaluation of Coatings for the H-Canyon Exhaust Tunnel

Site Needs:

Visual inspections of the H-Canyon exhaust (HCAEX) tunnel showed degradation of the concrete walls. Also, a recent tunnel fragility analysis identified safety issues of the affected concrete regarding their strength.

The identification and evaluation of protective coatings to prevent further degradation of the concrete walls is necessary.

Tunnel view



Degraded concrete exposing the steel rebar (red arrows).

Objectives:

- Develop and evaluate aged concrete surfaces through accelerated aging tests.
- Identify and evaluate potential coatings for future application in the HCAEX tunnel.
- Develop a robotic deployment platform that can navigate on the tunnel walls and apply protective coatings.

FIU Applied Research Center

Subtask 20.1: Evaluation of Coatings for the H-Canyon Exhaust Tunnel

FIU Year 3 Research Highlights & Accomplishments:

Materials and Methods

- Sherwin-Williams (SW) and Belzona (B) coated samples prepared
- Accelerated aging conditions:
  0.5 M HNO_3 solution and erosion
- Durability measurements (Visual inspection, thickness, impedance, pH)

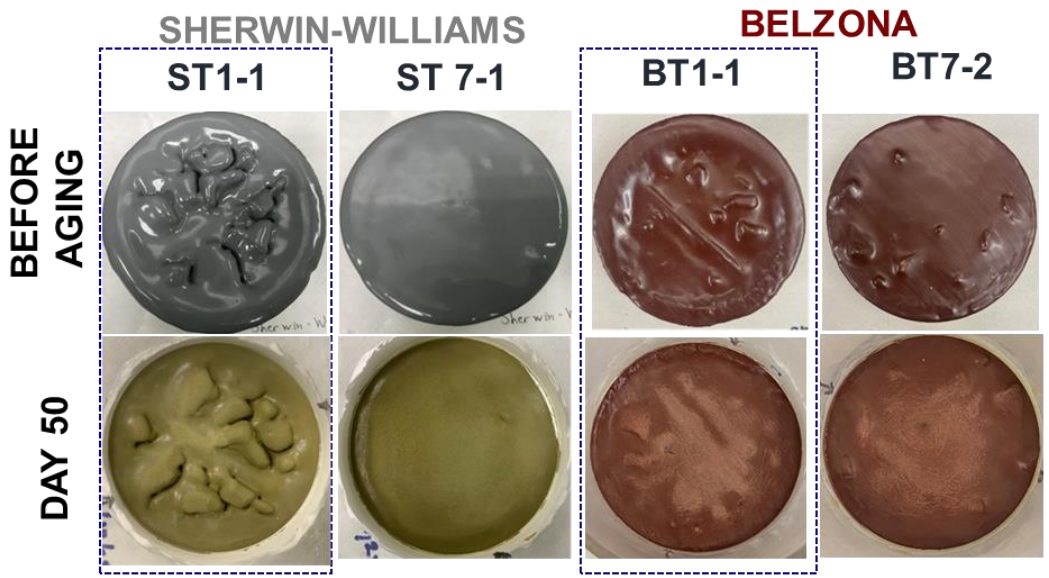
Results of Accelerated Aging Tests

1. Thickness:

Thickness loss (%), Day 35	Sherwin-W samples	Belzona samples
With surface preparation	10 - 11	7.4 - 20
No surface preparation	10 - 14	15 - 23

2. Visual Inspection:

Greatest degradation for aged concrete samples.



Highlighted in blue: samples with surface preparation

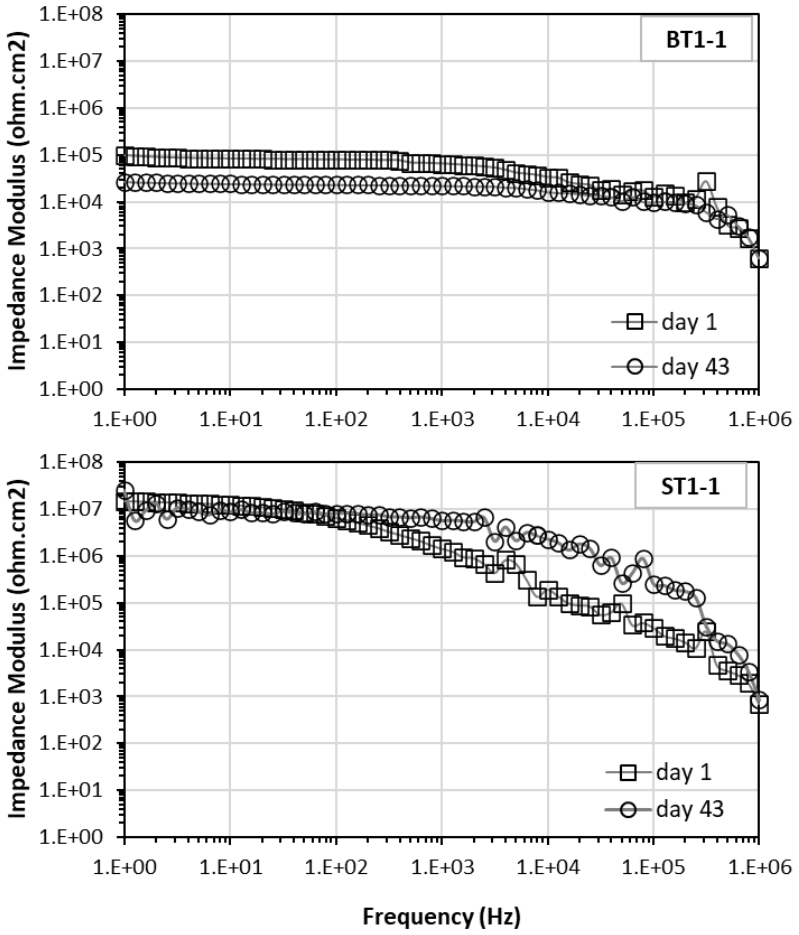
- In general, samples with surface preparation depicted less thickness loss.
- Belzona coating, with and without surface prep, showed the greatest thickness loss.

Subtask 20.1: Evaluation of Coatings for the H-Canyon Exhaust Tunnel

FIU Year 3 Research Highlights & Accomplishments:

3. Impedance measurements:

Greatest degradation observed on Belzona's coated samples. Lowest impedance values.



Accomplishments

- Two potential coatings (coating systems and single coats) for the protection of the tunnel concrete walls were evaluated.
- Sherwin-Williams coated samples completed the accelerated aging process and evaluation.
- Preliminary evaluation of Belzona coated samples with rebar.
- Impedance measurements supported the evaluation of the coating's protective properties by using the new potentiostat.

FIU Applied Research Center

Subtask 20.1: Evaluation of Coatings for the H-Canyon Exhaust Tunnel

FIU Year 4 Projected Scope

- Continue the evaluation of potential coatings trough accelerated aging tests.
- Initiate the evaluation of Framatome coated samples.
- Study the effect of key variables on the coating’s performance.
- Perform surface characterization on selected coated samples.
- Establish a ranking based on the coating's behavior to the aging condition.

FIU Applied Research Center

Subtask 20.2: Corrosion Evaluation of Steel Canisters for Hanford Integrated Disposal Facility (IDF) (NEW)

Site Needs:

- A technical gap for DOE is to understand the site-specific durability of steel canisters/containers containing waste forms at the Hanford IDF. The canisters are an additional barrier to environmental exposure that are not considered in long-term models.
- Currently, electrochemical corrosion data of steels in site specific conditions of the IDF is very limited.
- The main goal is to evaluate the corrosion behavior of canister/container materials in simulated Hanford IDF groundwaters using electrochemical techniques

Objectives:

Evaluate material behavior of the canisters in environments similar to IDF conditions and obtain site-specific corrosion data through electrochemical measurements.

Containers for the storage of waste.
Left: Carbon steel B-25 box for possible placement of cementitious waste forms,
Right: Steel canister for LAW glass waste forms.

Subtask 20.2: Corrosion Evaluation of Steel Canisters for Hanford Integrated Disposal Facility (IDF) (NEW)

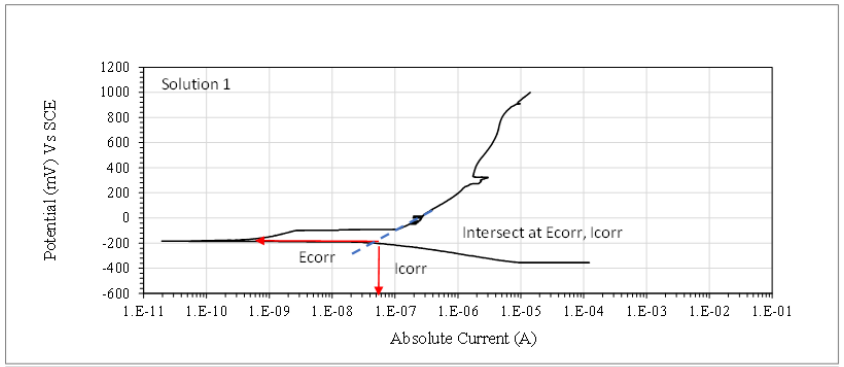
FIU Year 3 Research Highlights & Accomplishments:

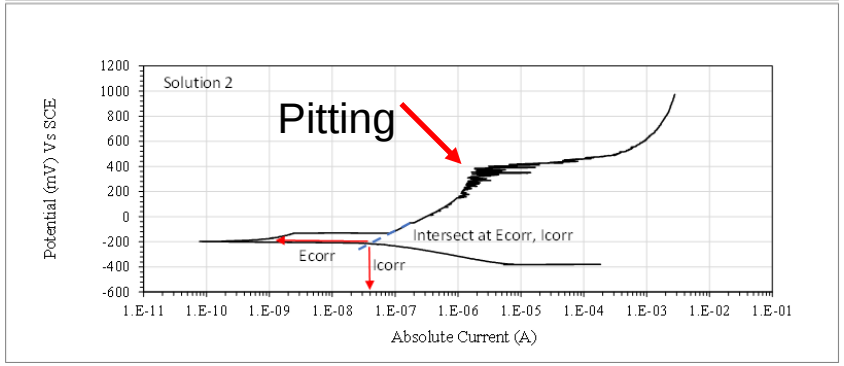
Materials and Methods

- 304 and 316 stainless steel samples
- Hanford simulated groundwater solutions
- Electrochemical measurements: Corrosion potential (OCP), impedance (EIS) and potentiodynamic polarization (PDP)

View of the potentiostat, Faraday Cage and computer used for electrochemical measurements.

Potentiodynamic graphs for 316 SS in Hanford groundwater Solutions 1 and 2





Potentiodynamic Polarization Results Corrosion parameters in Solution 1

Canister Material	Icorr, A	Ecorr, mV Vs SCE	icorr, A/cm2
304 SS	1.8E-5	-187.39	1.12E-5
316 SS	5.89 E-8	-202.46	3.65 E-8

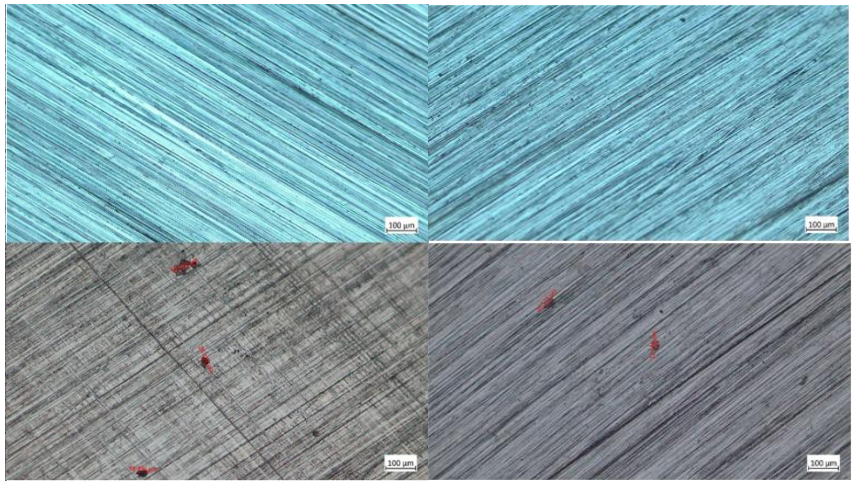
- Corrosion data obtained from Tafel slopes.
- Effect of chloride ions on pitting formation on 316SS in Solution 2 (only chloride ions).
- Similar behavior on 304SS in Solution 2.

FIU Applied Research Center

Subtask 20.2: Corrosion Evaluation of Steel Canisters for Hanford Integrated Disposal Facility (IDF) (NEW)

FIU Year 3 Research Highlights & Accomplishments:

Surface characterization of the 304SS and 316 SS samples before/after PDP tests



Images of 304 (left) and 316 (right) stainless steels before (reference) and after potentiodynamic test in Solution 2 at different magnifications. Top images: reference sample; Bottom: images for the sample after test.

Pitting corrosion identified on both samples exposed to Solution 2, only with chloride ions, after the PDP tests.

The pitting length for both canister materials was in the range between 26 µm and 38 µm.

Accomplishments

- Completed evaluation of 304SS & 316SS exposed to simulated Hanford groundwater Solutions 1 and 2 through electrochemical measurements.
- Corrosion parameters (Ecorr, Icorr, icorr) obtained from Tafel slopes and calculations.
- Completed preliminary surface characterization of tested surfaces using optical microscopy.
- Evaluated effect of chloride ions in a simulated Hanford groundwater solution on corrosion behavior of 304SS & 316SS canister materials.

FIU Applied Research Center

Subtask 20.2: Corrosion Evaluation of Steel Canisters for Hanford Integrated Disposal Facility (NEW)

FIU Year 4 Projected Scope

- Continue the evaluation of potential canister materials when exposed to simulated Hanford groundwater solutions.
- Electrochemical testing of potential canister materials in contact with different cement waste forms:
- Evaluate the corrosion performance of various canister materials, 304SS, 316SS, etc., exposed to cement waste forms.
- Get corrosion data of different low alloy carbon steel (reference material) and compare to corrosion data of 304SS and 316SS.
- Study the effect of the waste form concentration on the corrosion performance of canisters materials.
- Get and analyze the corrosion data obtained using specific software's

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FIU Year 3 Overall Accomplishments

Conference Papers

- J. Adams, A. Abrahao, D. Reid, D. McDaniel, L. Lagos, “Development of Semi-Autonomous Robotic Manipulator for Off-Riser Sampling of Tank Waste”, Proceedings of the Waste Management Symposia 2023, Phoenix, AZ, February 26 – March 2, 2023.
- B. Cintas, D. McDaniel, A. Aravelli, D. Sinnott, M. Poirier, “Engineering-Scale Evaluation of Flushing Requirements for High-Level Liquid Waste at Savannah River and Hanford Sites”, Proceedings of the Waste Management Symposia 2023, Phoenix, AZ, February 26 – March 2, 2023.
- M. Boan, N. Espinal, S. Tashakori, L. Lagos, D. McDaniel, “Evaluation of Coatings for the Protection of the HCAEX tunnel Concrete Walls at Savannah River”, Proceedings of the Waste Management Symposia 2023, Phoenix, AZ, February 26 – March 2, 2023.
- M. Telusma, D. McDaniel, L. Lagos, R. Velasquez, N. Espinal, “Prototyping and Testing of a Wall Crawling Mobile Platform for Damage Mitigation of H-Canyon’s Concrete Walls”, Proceedings of the Waste Management Symposia 2023, Phoenix, AZ, February 26 – March 2, 2023.
- A. Aravelli, D. Sinnott, R. Piloto, D. McDaniel, L. Lagos, B. Wiersma, “Simulant Based Particle Erosion and Chemical Corrosion in HLW Pipe Components”, Proceedings of the Waste Management Symposia 2023, Phoenix, AZ, February 26 – March 2, 2023.
- A Abrahao, L. Lagos, D. McDaniel, M. Telusma, "New Technologies to Reduce the 3Ds (dangerous, dull, dirty) in Decommissioning Projects", International Conference on Nuclear Decommissioning: Addressing the Past and Ensuring the Future, Vienna, Austria, May 15-19, 2023.

FIU Year 3 Overall Accomplishments

Journal Papers

- A. Awwad, D. McDaniel, L. Lagos, J. Rivera, B. Tansel, “Effect of solution concentration on ethylene propylene diene monomer (EPDM) nonmetallic components used in caustic liquid waste transfer lines”, *Engineering Failure Analysis*, (2023) https://doi.org/10.1016/j.engfailanal.2022.107007.
- A. Awwad, D. McDaniel, L. Lagos, J. Rivera, B. Tansel, “Effect of ion penetration on the aging of EPDM components used in caustic liquid transfer lines by microscopic analysis”, *Polymer Degradation and Stability*, (Submitted 6/12/23).

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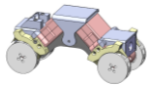
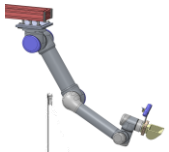
Technology Roadmap

		2020	2021	2022	2023	2024
Tank Farm Hanford	 Minirover	In-house Deployment	Site Deployment	Site Deployment	Technology Transferred ✓	
	 Lateral Gamma		Integration	Cold Test Facility Deployment ✓	Cold Test Facility Deployment ✓	Site Deployment
	 Off-Riser Sampler			Design	Integration	Cold Test Facility Deployment
	 Long-Term Surveillance	Conceptual Design	Sensor Integration	Evaluation	Cold Test Facility Demostration ✓	Site Deployment
H Canyon SRNL	 Wall Crawler	Conceptual Design	Sensor Integration	Evaluation	In-house Deployment	Site Deployment
WIPP MSIPP	 Salt Closure Inspection	Evaluation	Integration	In-house Deployment	Site Deployment ←	
Rifle Cell LM	 Aerial Lidar	Evaluation	Site Deployment ✓			
	 Ground Radar		Evaluation	Integration	Site Deployment ✓	
Wearable SANDIA	 Exoskeleton		Conceptual Design	Integration	Integration	Site Deployment

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DOE-FIU Cooperative Agreement

Upcoming Events Announcement

DOE Fellows Poster Exhibition

DOE Fellows Induction Ceremony


Thank You. Questions?