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# Inspection Tools for Hanford Tanks and Waste Transport Systems

**Dwayne McDaniel**

Florida International University

Tank Closure Forum

Drone and Robotics Seminar

September 10, 2019

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## Florida International University

- Top 10 largest U.S. public university
- Top-tier research institution (Carnegie R1 Doctoral Universities - Highest Research Activity)
- ABET accreditation
- Minority Serving Institution (MSI)
- Top in U.S. for awarding bachelor's and master's degrees to Hispanic students

**57,000 enrolled**

**10,000 employees**

**11 colleges and schools**

**201 bachelors, master's & doctoral programs**

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# OUTLINE

Overview of systems being developed at FIU aimed to assist engineers in understanding the integrity of Hanford tanks and waste transport system.

- Magnetic Miniature Rover
  - Motivation, Challenges
  - Testing
- Peristaltic Pipe Crawler
  - Motivation, Challenges
  - Testing
- Marsupial Crawler
  - Motivation, Challenges
  - Testing
- 2 inch Pipe Crawler
  - Motivation, Challenges
  - Testing

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# TEAM MEMBERS

**Principle Investigators:** Dwayne McDaniel, Ph.D., P.E.
Leonel Lagos, Ph.D., PmP

**Research Scientists:** Anthony Abrahao
Aparna Aravelli, Ph.D.

**Post Docs:** Shervin Tashakori, Ph.D.
Sebastian Zanlongo, Ph.D.

**Students:** Michael DiBono
Jason Soto
Patrick Uriarte
Christopher Excellent
Jeff Natividad
Dan Martin

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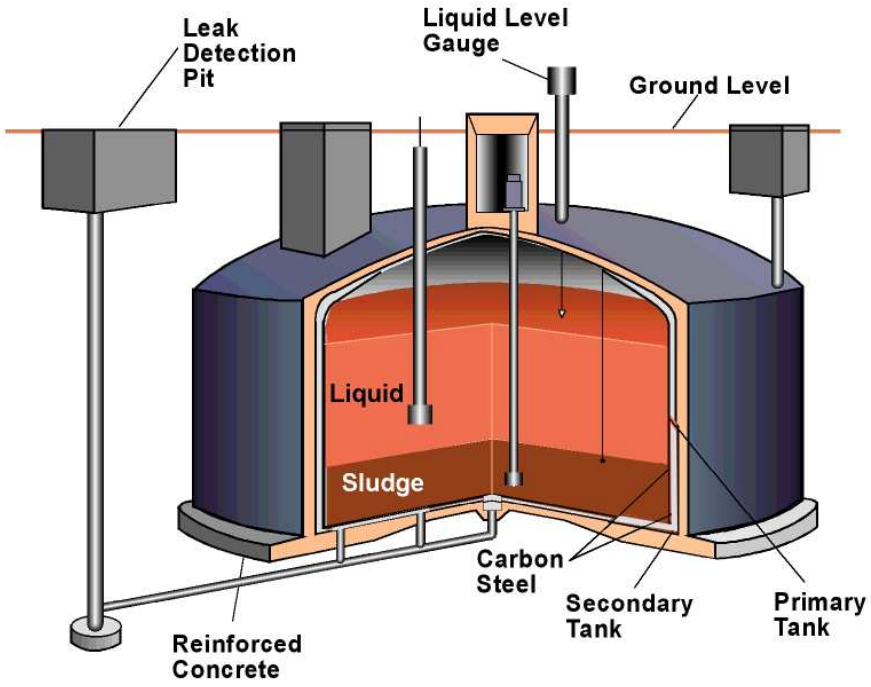
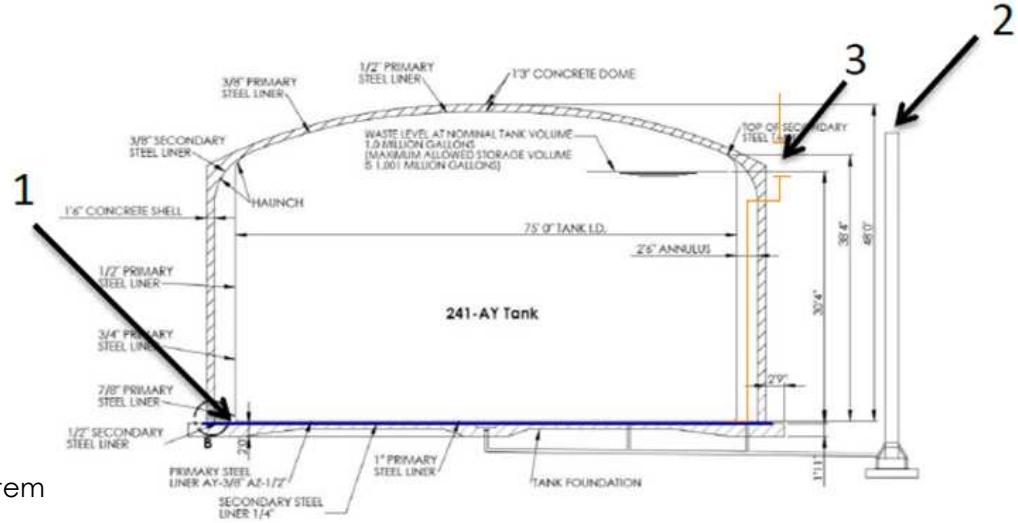
# DOUBLE-SHELL WASTE TANK

TANK FARM




**(1)** Annulus

**(2)** Leak Detection Pit

**(3)** Ventilation Pipe System

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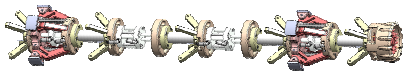
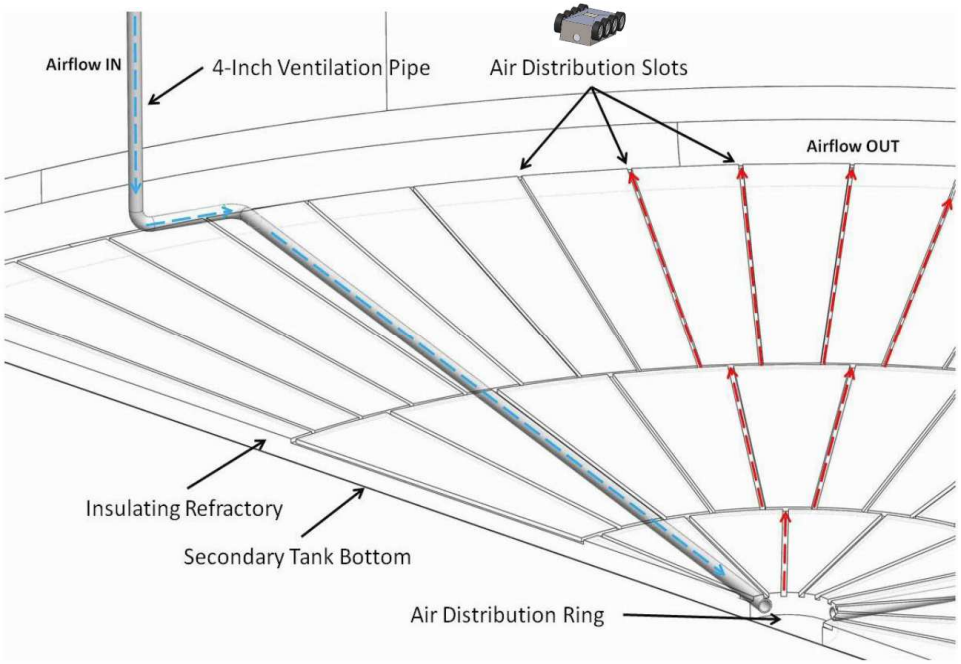
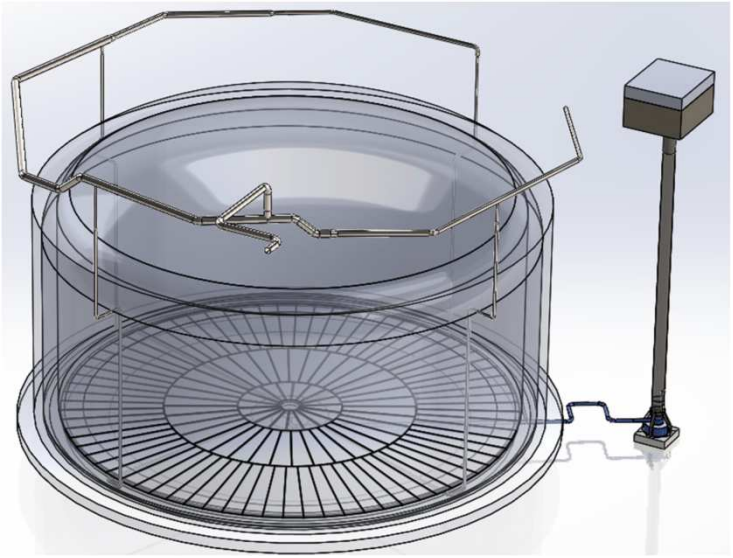
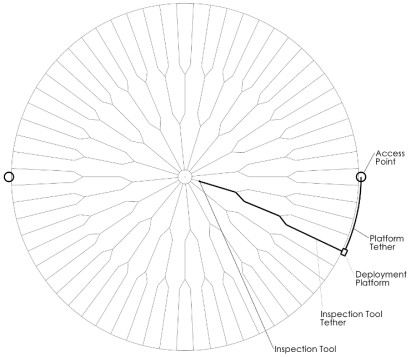
# DOUBLE-SHELL WASTE TANK

## VENTILATION SYSTEM







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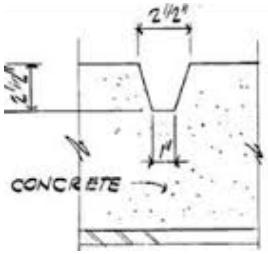
# MAGNETIC MINIATURE ROVER

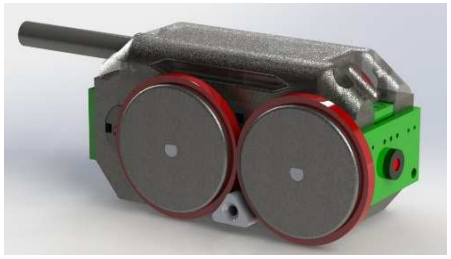
INSPECTION TOOL

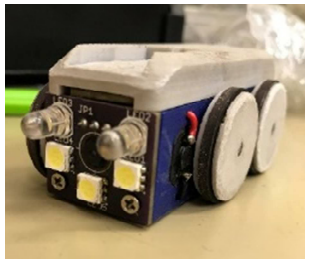
## Challenges

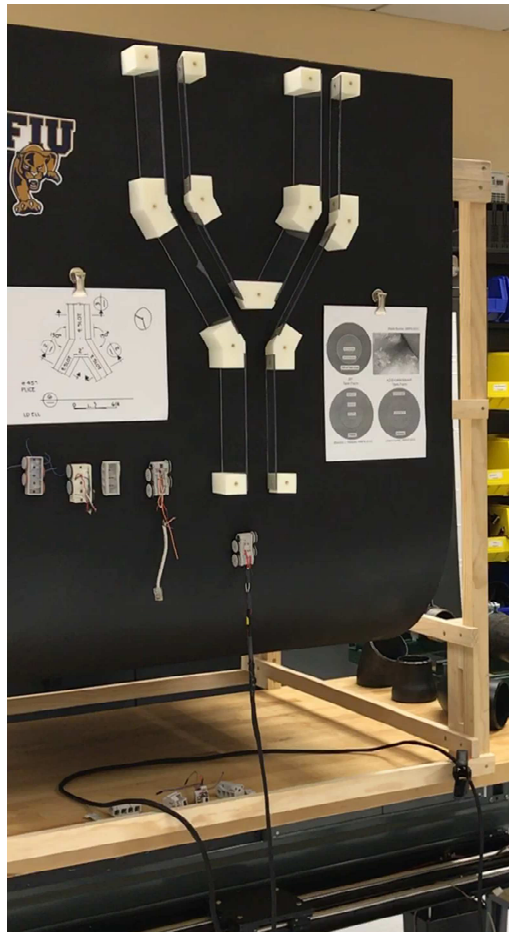



## Prototypes

- Remotely controlled
- Independently driven wheels
- Modular sensor hoods
- Front and back cameras
- 5 lbs of pull force







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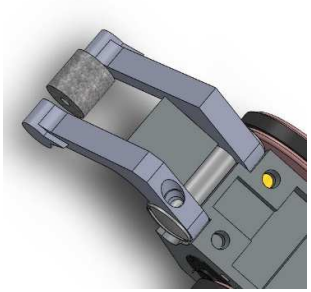
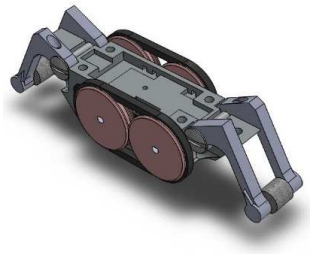
# MAGNETIC MINIATURE ROVER

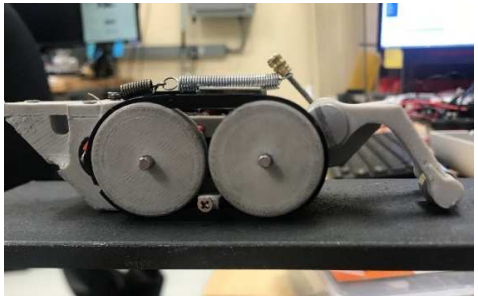
INSPECTION TOOL

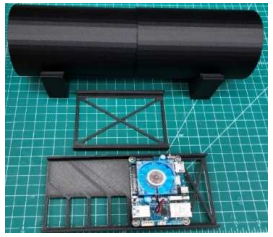
## Recent Modifications

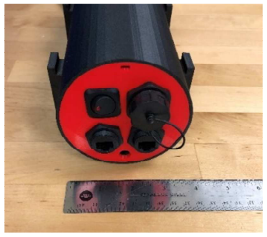
- A magnetic arm was added to assist the rover in traversing over weld seams. The arm is spring loaded and allows the unit to navigate over 3/8 inch radius weld seams.
- To address issues related to significant voltage drop and video signal transmission over long cable lengths, a control capsule was designed that will stay within the tank annulus.
- The capsule houses an Odroid XU4, an Adafruit Featherwing motor controller, an Adafruit Feather M4 microcontroller, a 5V voltage regulator, a 12V voltage regulator, and 2 analog to digital video converters.











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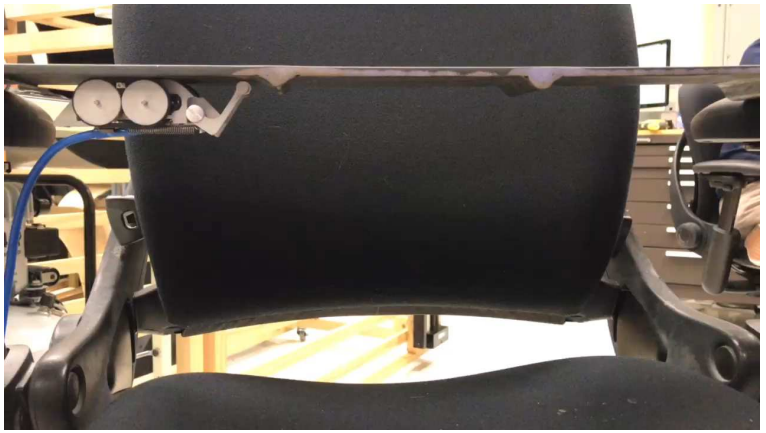
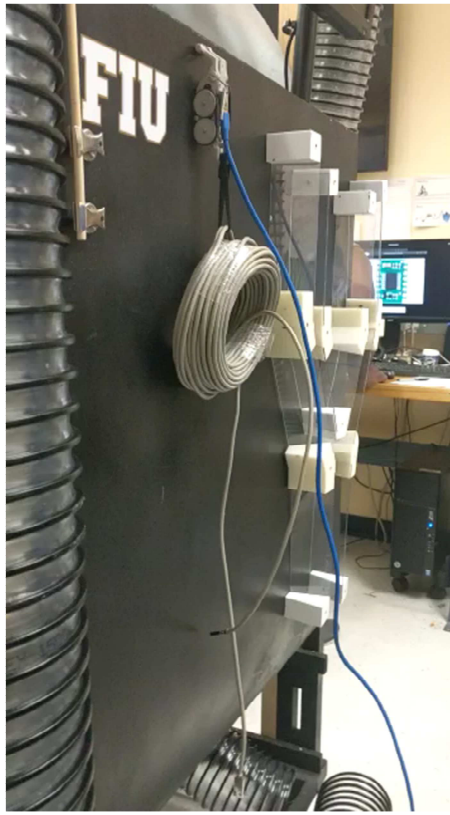
# MAGNETIC MINIATURE ROVER

INSPECTION TOOL

## Engineering Scale Testing

## Magnetic Arm





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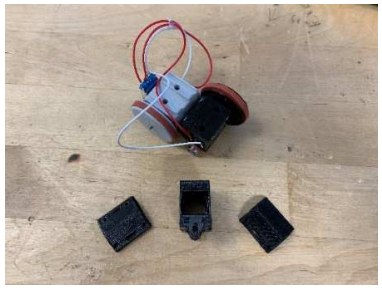
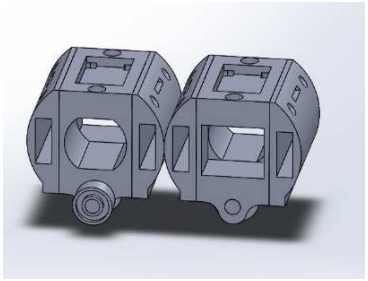
# MAGNETIC MINIATURE ROVER

INSPECTION TOOL

## New Caterpillar Design

- Utilizes magnets in articulating joints
- Can include any of number of modules needed
- One motor/wheel combination per modules
- Traverses up to one inch weld seam
- Can be used in the design for the inspection tool for AY101 – capable of 90 degree turns





## Caterpillar Testing

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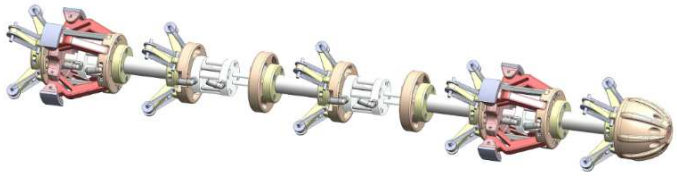
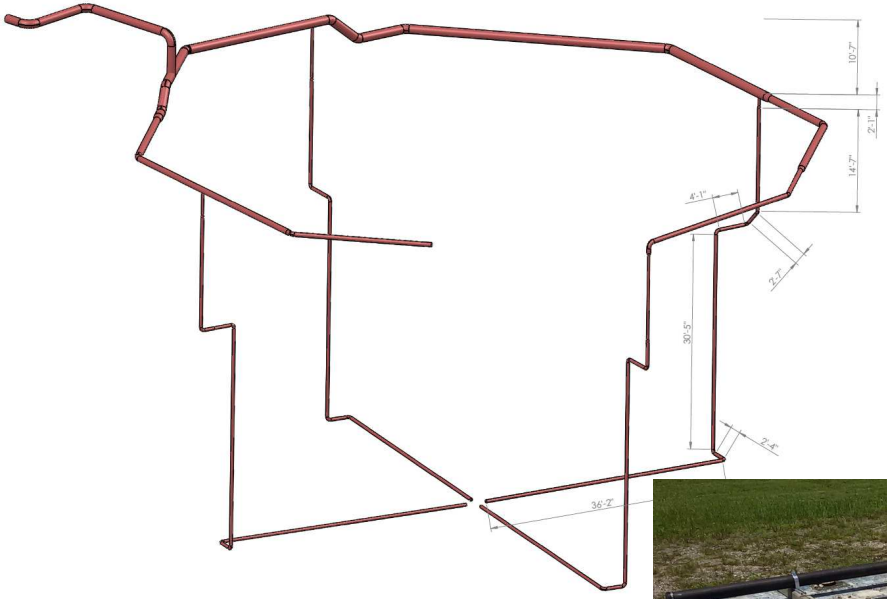
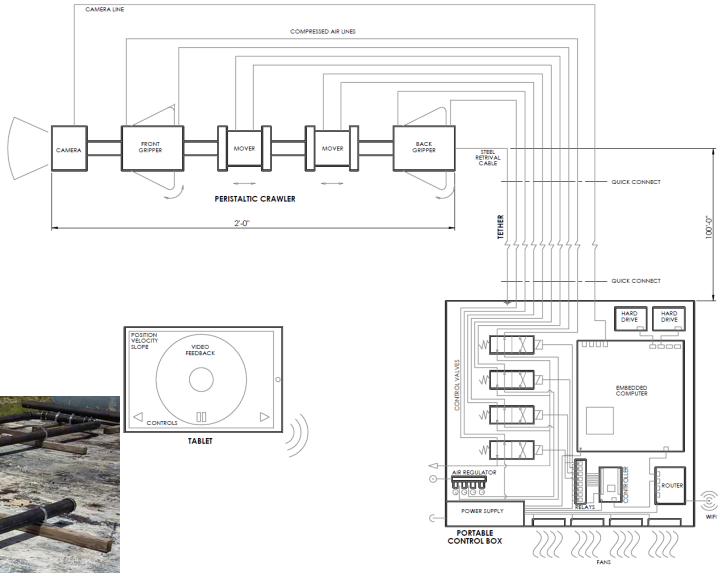
# PERISTALTIC PIPE CRAWLER

## PROPOSED INSPECTION

*Develop an inspection tool that crawls through the air supply pipe that leads to the central plenum of the primary tank of the DSTs at Hanford and provides video feedback*





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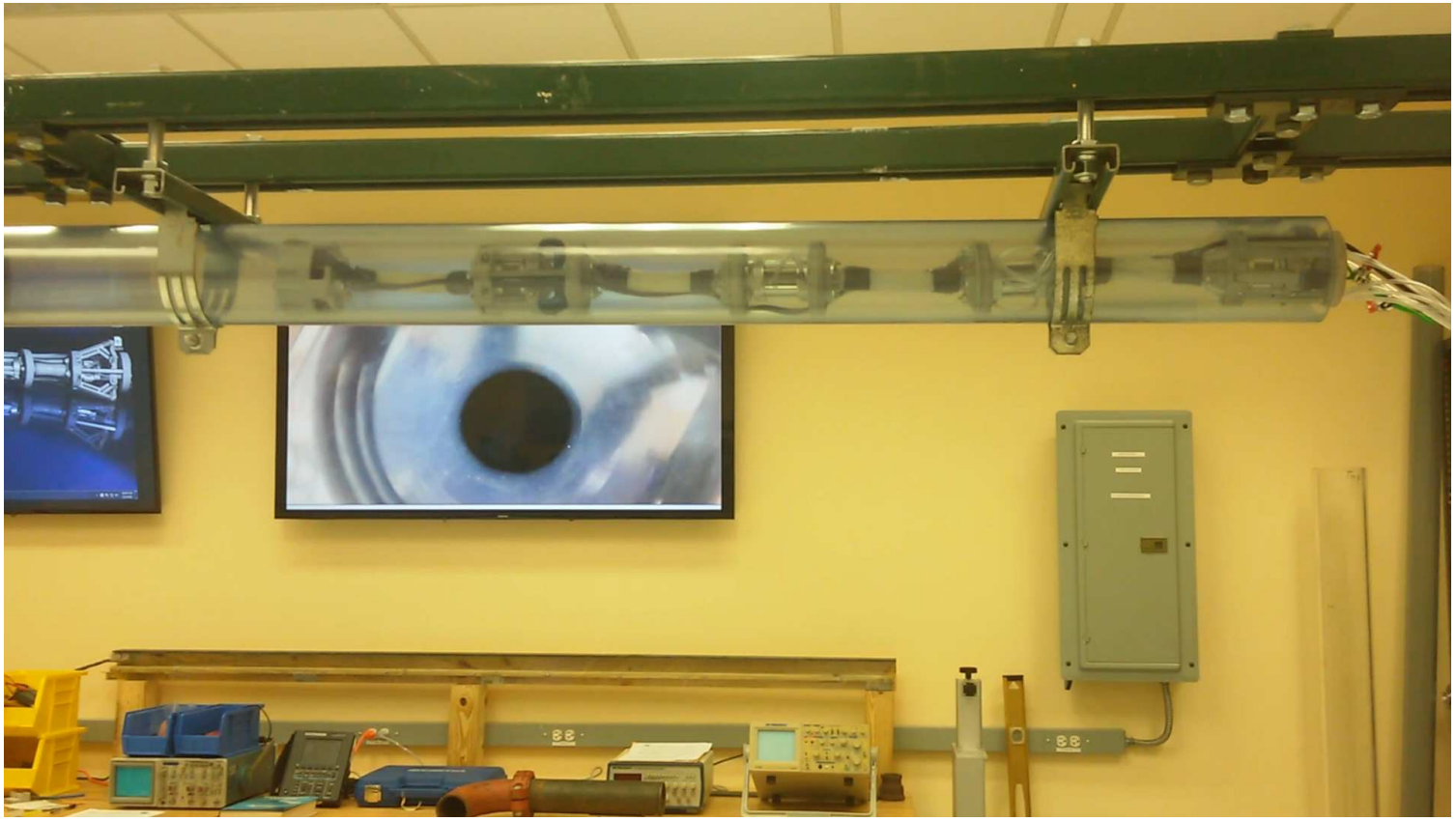
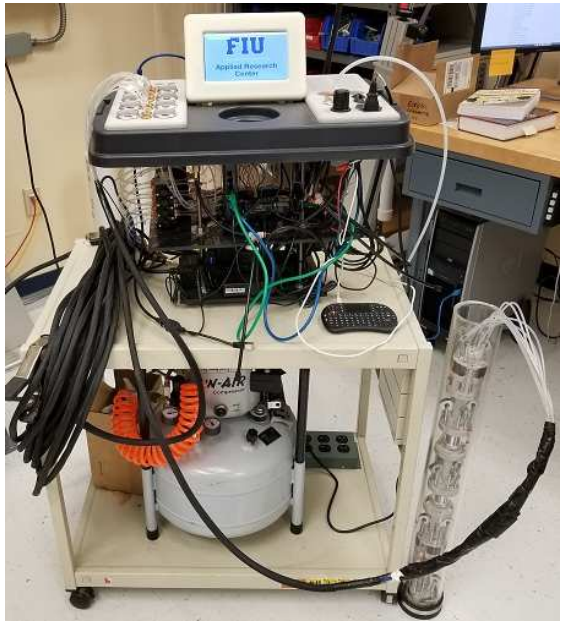
# PERISTALTIC PIPE CRAWLER

INSPECTION TOOL





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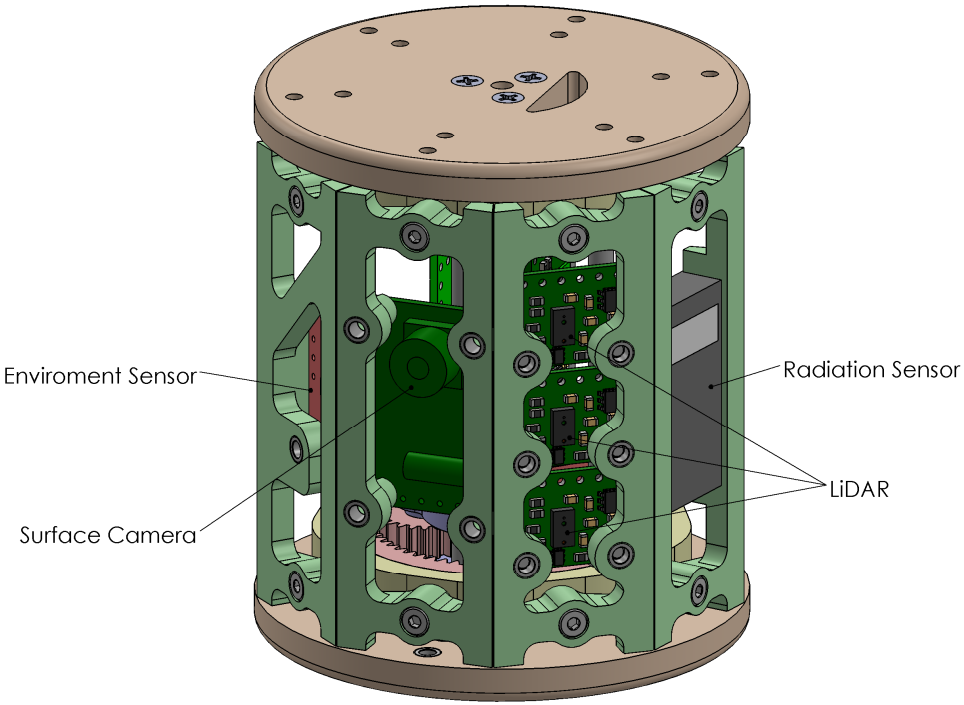
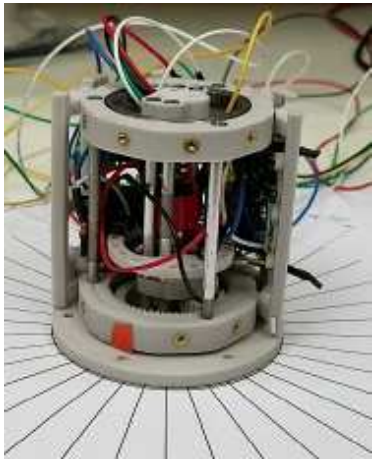
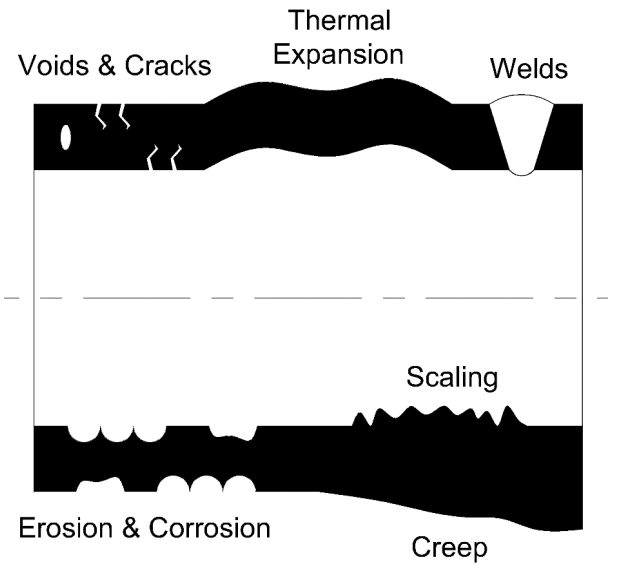
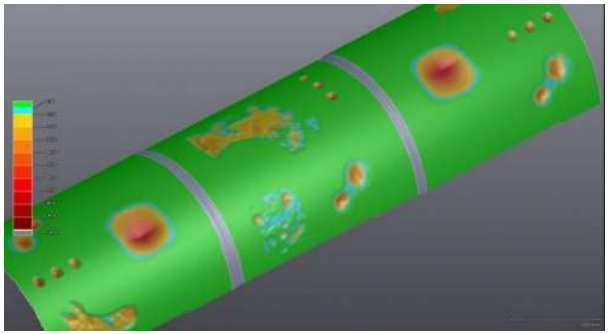
# PERISTALTIC PIPE CRAWLER

## PIPELINE INTEGRITY AND SURVEYING TOOL





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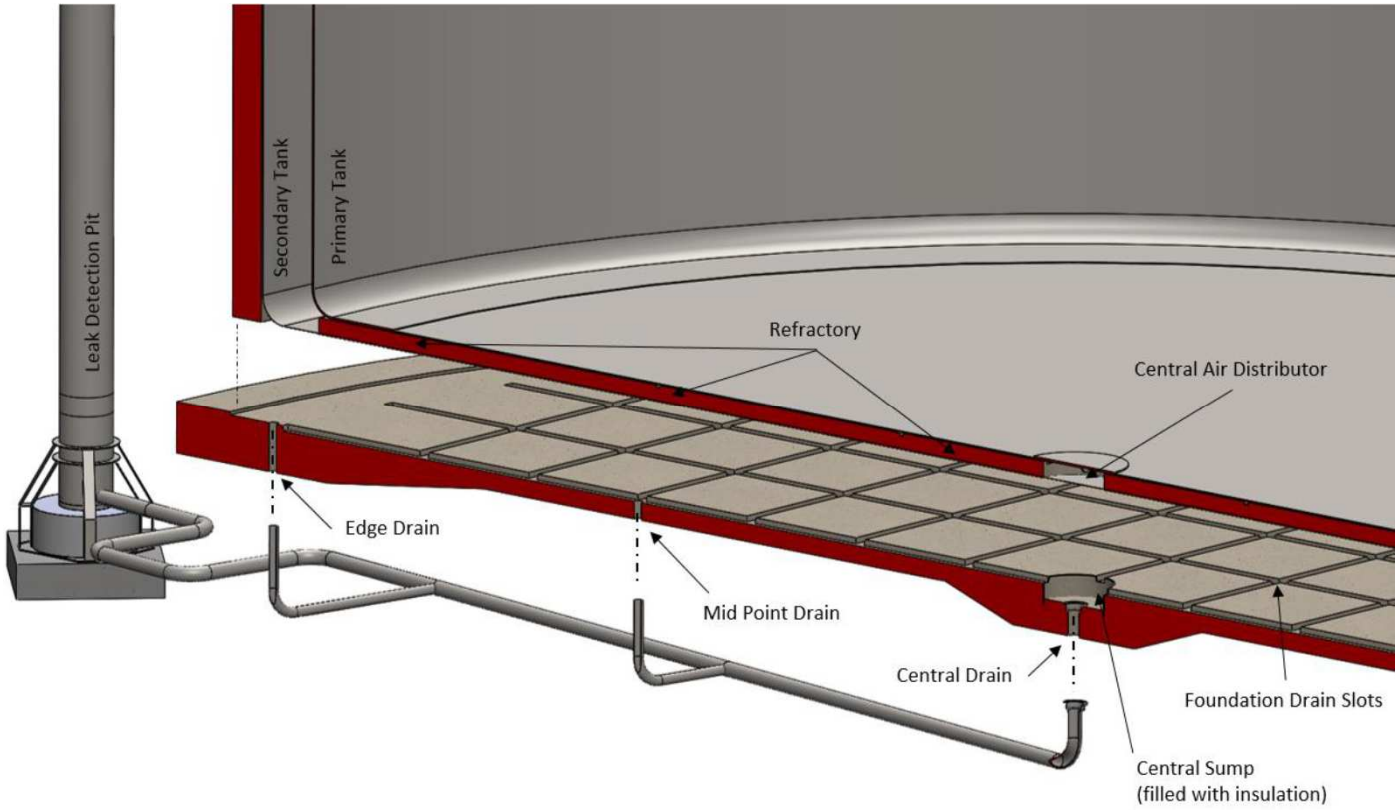
# SECONDARY LINER

## PROPOSED INSPECTION

*Develop an inspection tool that navigates through the foundation drain slots under the secondary liners of the DST's at Hanford while providing live video feedback*





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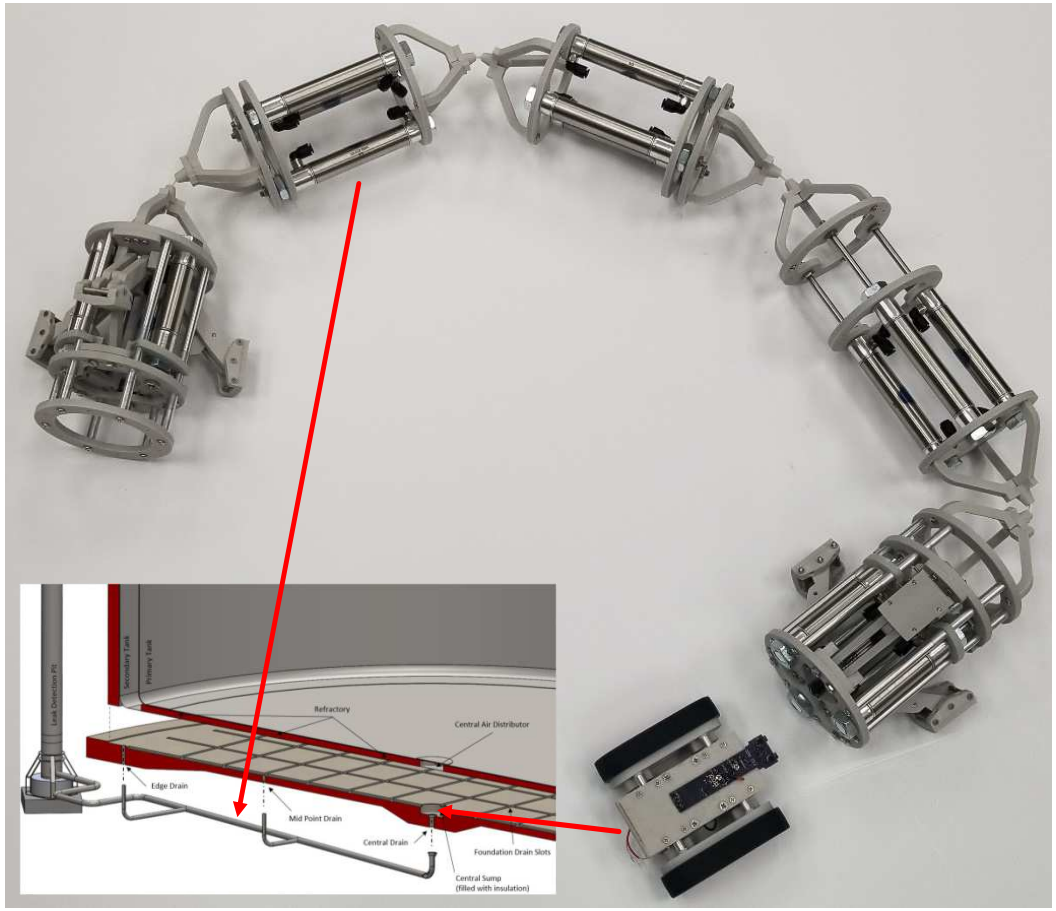
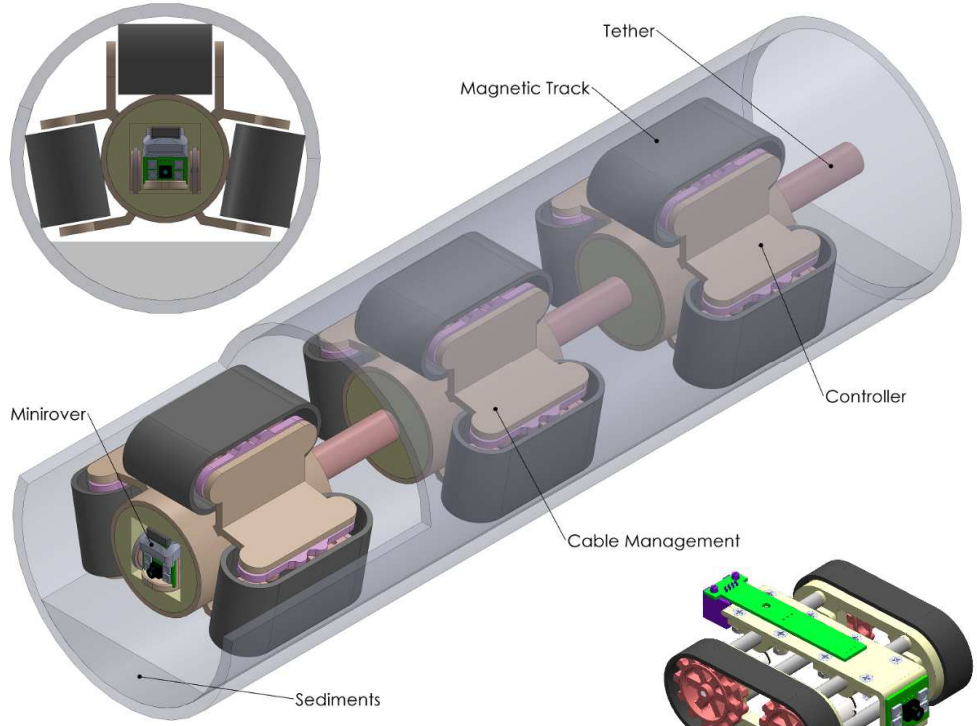
# MARSUPIAL CRAWLER

## INSPECTION TOOL



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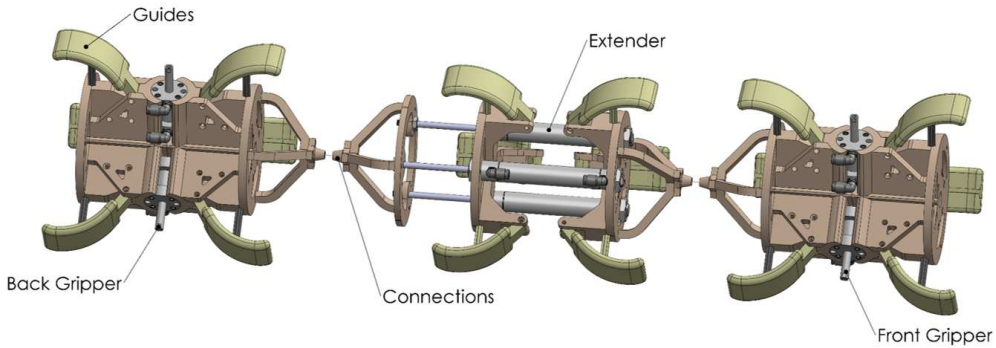
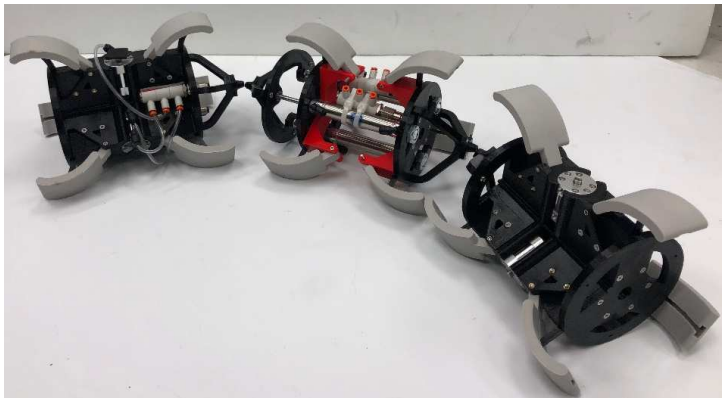
# MARSUPIAL CRAWLER

INSPECTION TOOL

## New Prototype Description

- Pneumatic system for gripping and linear motion in 6 inch diameter pipes
- Can increase the number of modules as needed
- Spring loaded guides are used to keep the system centered in the pipeline and avoid scaling on the pipe walls
- With additional pipeline space, the grippers are aligned perpendicular to the motion to maximize pull force



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# MARSUPIAL CRAWLER

INSPECTION TOOL


## Path Forward

- Engineering scale testing – validate navigation in FIU mock-up
- Tether design
- Incorporate the front module to deploy rover
  - Cable management
  - UT sensors

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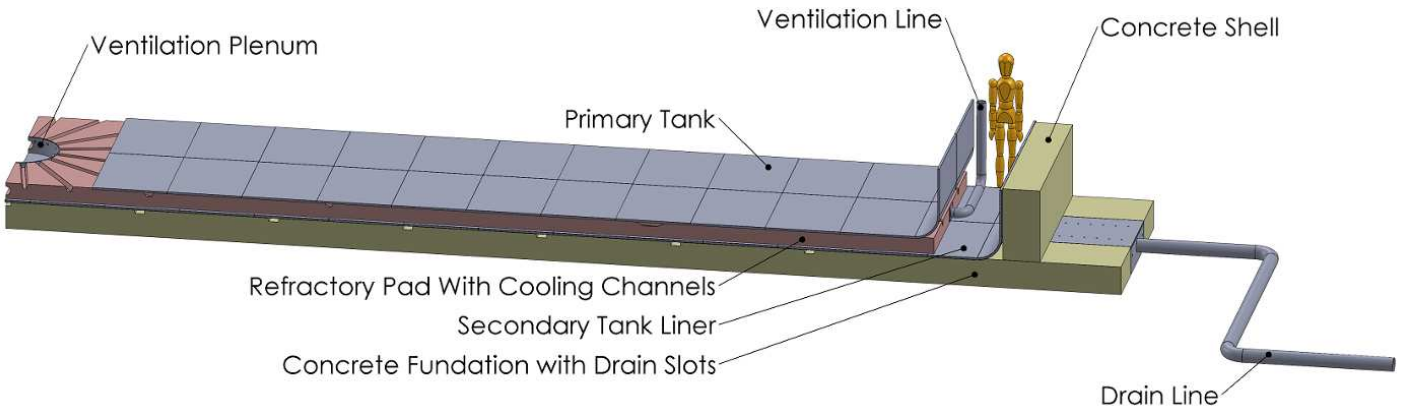
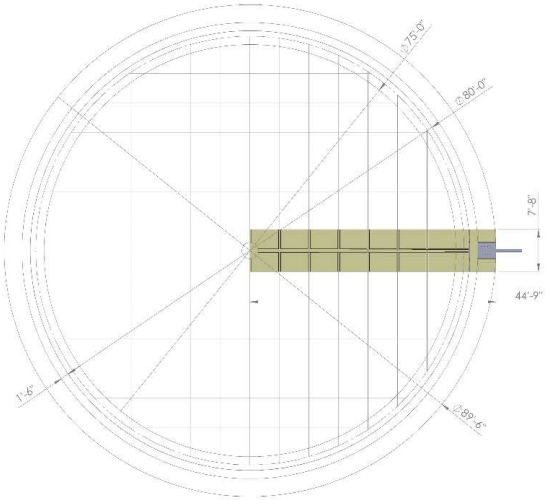
# FULL-SCALE SECTIONAL MOCKUP

## MODULAR TEST BED



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# 2 INCH PIPE CRAWLER

INSPECTION TOOL

Power plant inspections:

- Challenging and time consuming
- Typically manual and external
- Difficult/impossible to access areas

Present work:

- Robotic inspection to monitor the structural health of plant components
  - reaching hard to access places
  - conditions sometimes unsafe for humans
- Improves capabilities of the fossil energy community to better understand the health of critical components in their infrastructure
- Reduces plant down time, increasing efficiency and cost

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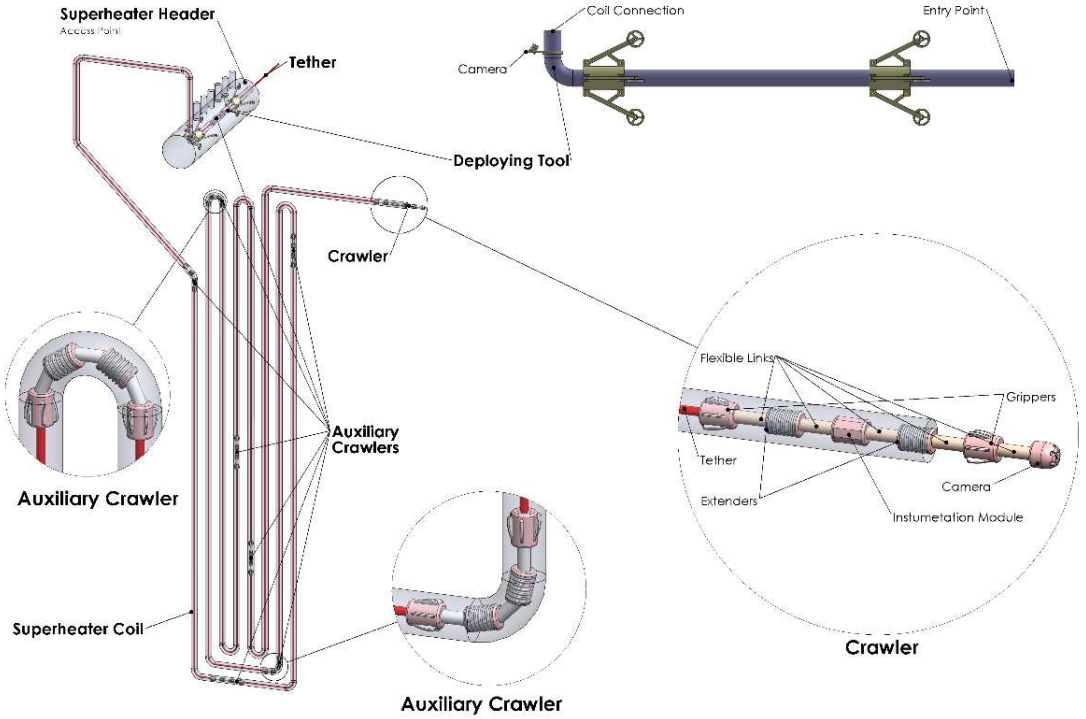
# 2 INCH PIPE CRAWLER

## INSPECTION TOOL

- Utilize lessons learned from previous pipe crawler and inspection tools
- System will navigate through 180 degree bends
- Multiple systems will be likely be coupled together to distribute tether load
- Deploying mechanism through the header
- Cable management system

Superheater header and tubes




Inspection tool operation

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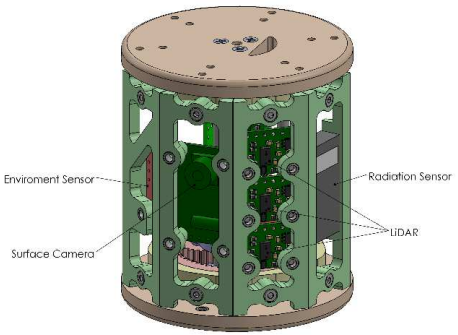
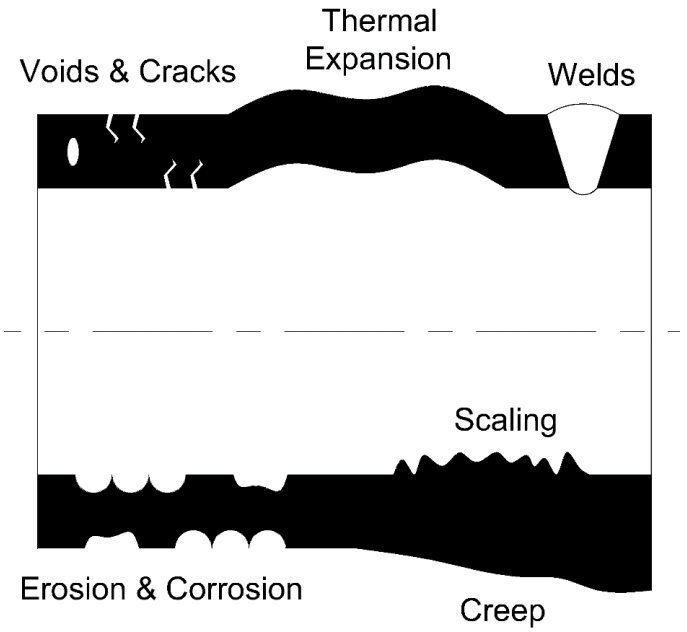
# 2 INCH PIPE CRAWLER

INSPECTION TOOL

- Sensors will be incorporated into a sensor module
- The module is customizable and will include an optical camera, IMU, range finder (LiDAR)
- Visual inspection of interior surface – anomalies in pipe, scaling, wear, weld seams




Sensor module concept

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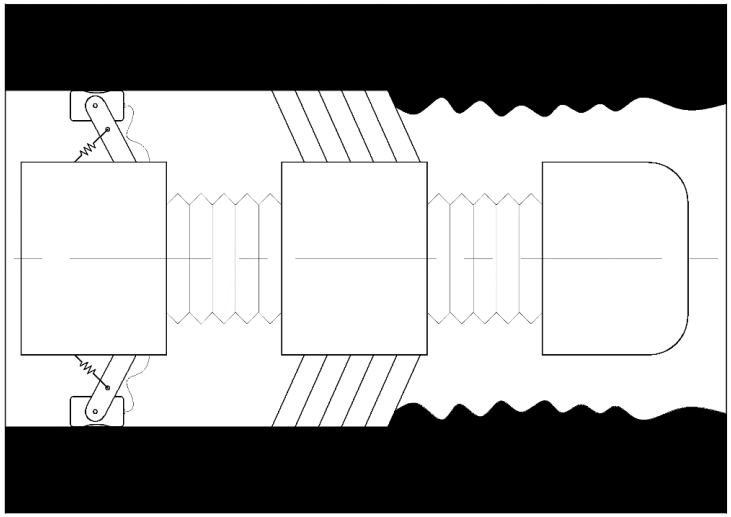
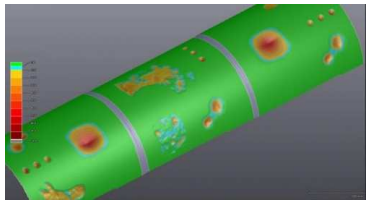
# 2 INCH PIPE CRAWLER

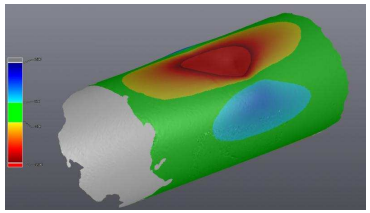
## INSPECTION TOOL

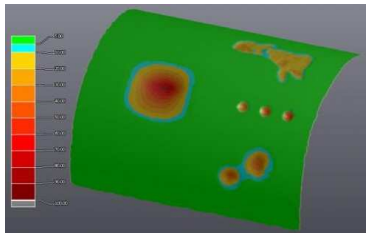
- Additional modules will be used to prepare surfaces – remove scaling via rotating wire brush
- Rotating module will be used to deploy a sensor to measure thickness from any point around the circumference
- LiDAR mapping can provide additional information on the various anomalies



Surface preparation and measurement







Surface mapping

https://www.creaform3d.com/en/ndt-solutions/ndt-pipeline-inspection-oil-and-gas-industry

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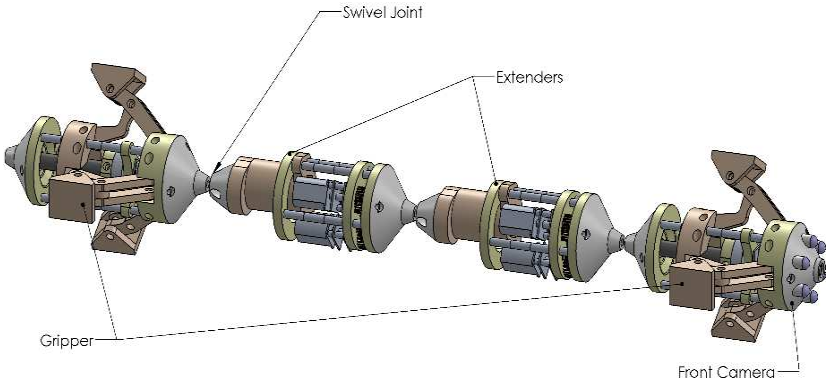
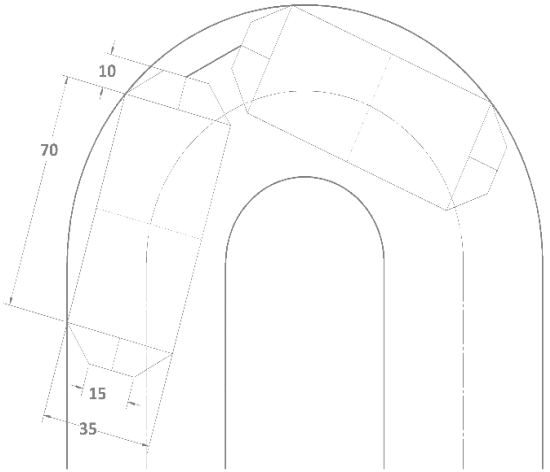
# 2 INCH PIPE CRAWLER

## INSPECTION TOOL

- Previous crawler was required to traverse through 90 degree bends up to ~100 ft in a 3 inch diameter pipe with a radioactive environment.
- Issues to condsider with longer pipe lengths and tighter bends
  - Motor selection
  - Mechanism for actuation
  - Power over long pipe lengths
  - Kinematic analysis
  - Joint connections
  - Number of units – distribution of tether load
  - Control of multiple systems



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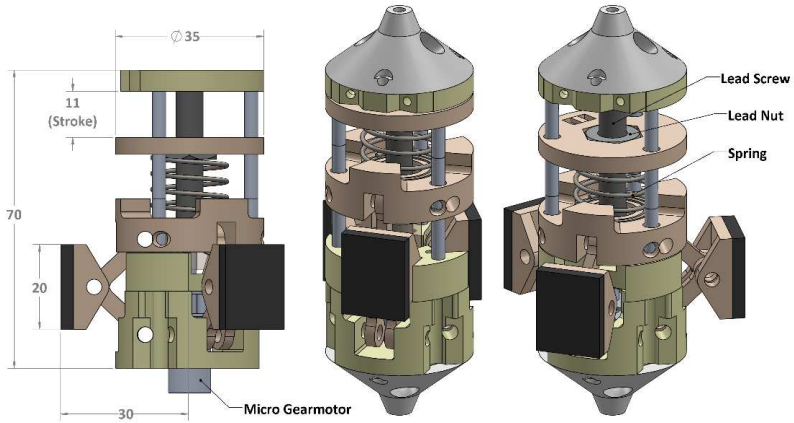
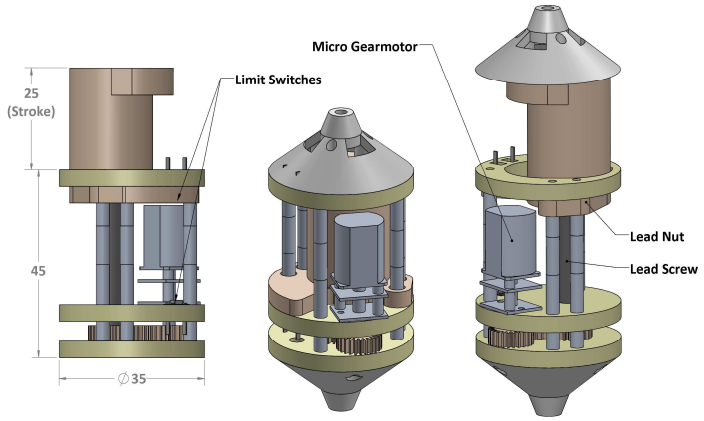
# 2 INCH PIPE CRAWLER

INSPECTION TOOL

## Gripper and Extender Module Designs

- A lead screw and nut design was selected as a means to actuate three arms of the gripper and extend the length of the extender module. A 12V micro gearmotor is used to drive the system.
- Other options included pneumatic actuation or a belt driven system.
- Each extender has an extension of 2.5 cm – total translation per cycle is 5 cm (~ 2 ins).
- Limit switches are used to define the range of extension. The speed of the screw is also controllable.
- Spring connecting lead nut and hinges of gripping arms maintains force against pipe walls when motor is off.
- Gears (1:1) are used to mount the motor vertically. A second motor can be added, if needed.



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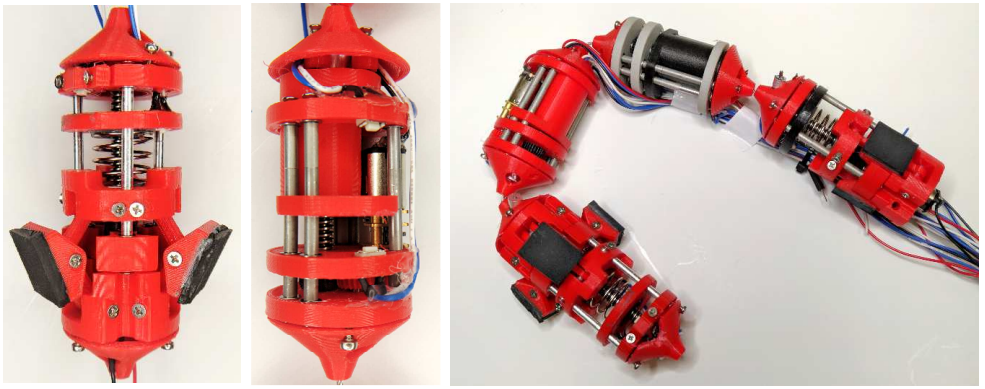
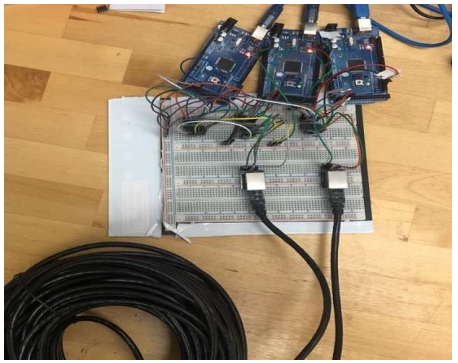
# 2 INCH PIPE CRAWLER

INSPECTION TOOL

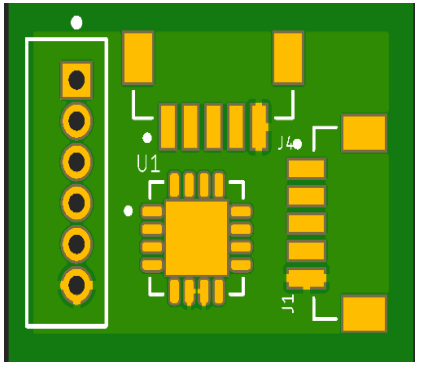
## Prototype Development

- The frame and arms are 3D printed with Ultimaker Tough PLA (red) which makes the unit is easy to manufacture and assemble. Bench scale testing will verify the strength of the material is satisfactory.
- The joints are short linear flexible cables that may need to redesigned after initial testing.
- A digital communication network was developed using a full duplex serial bus (RS-485 standards). The bus will network microcontrollers used for motor controls, video and sensors. Recent upgrades, include 3 Arduino Megas, 3 TI instruments transceiver chips and hardware flow compatibility.
- Each unit will contain at least one microcontroller but others may be added for integrity sensors, IMUs and other sensors.
- Must evaluate power/sensor integration over long tether lengths.





Breadboard Testing




PCB Layout

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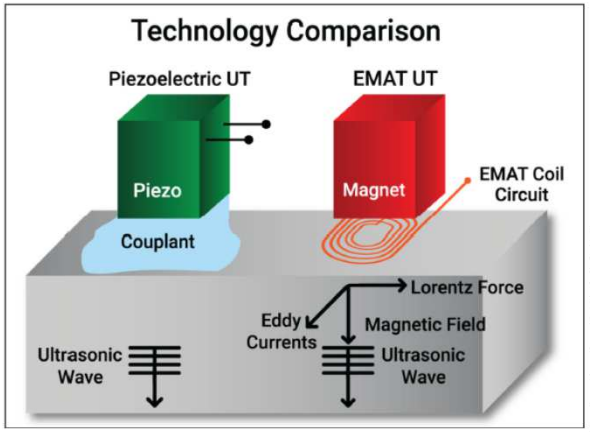
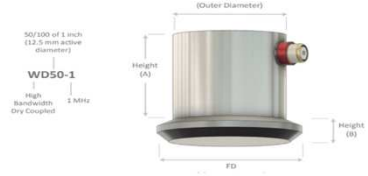
# 2 INCH PIPE CRAWLER

## INSPECTION TOOL

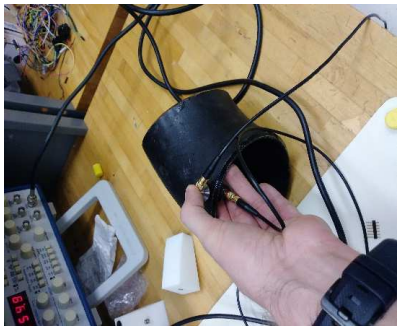
- Sensor must be compatible with geometric constraints and be capable of mating with a 2 inch radius of curvature.
- Must be sensitive enough to detect some level of thinning.
- Investigating the EMAT and piezoelectric UT sensors.
- Evaluated the Ultran dry couplant UT sensors (single element) on carbon steel pipe sections and plates
- Feasibility of the UT sensor for physical size on 2 inch clear pipe.
- Determine deployment mechanism and level of surface preparation required.




| Frequency | Active Diameter | | | | | |
|---|---|---|---|---|---|---|
| | 3.2 mm | 6.3 mm | 9.5 mm | 12.5 mm | 19.0 mm | 25.0 mm |
| 500 kHz | | | | WD50-0.5 | WD75-0.5 | WD100-0.5 |
| 1 MHz | WD12-1 | WD25-1 | WD37-1 | WD50-1 | WD75-1 | WD100-1 |
| 2 MHz | WD12-2 | WD25-2 | WD37-2 | WD50-2 | WD75-2 | WD100-2 |
| 5 MHz | WD12-5 | WD25-5 | WD37-5 | WD50-5 | WD75-5 | WD100-5 |
| 10 MHz | WD12-10 | WD25-10 | WD37-10 | WD50-10 | | |
| Height (A) | 10 | 11 | 13 | 16 | 17 | 17 |
| Height (B) | 3 | 6 | 7 | 8 | 8 | 8 |
| OD | 6 | 6 | 13 | 17 | 25 | 32 |
| FD | 10 | 10 | 22 | 25 | 32 | 38 |




| | | |
|---|---|---|
| Part Number | | 274A0334-SPIRAL |
| Sensor Type | | SH Lorentz Permanent Magnet |
| Temperature Ranges | | -30°C - 80°C |
| Connector | | 2 Pin Lemo 0B |
| Coil Geometry | | Spiral |
| Tuning Module[1] | | See Below |
| Coil Width | Inch | 0.250 |
| | mm | 6.25 |
| Coil Length | Inch | 0.730 |
| | mm | 18.25 |
| Sensor | Inch | 1.5 D x 0.63 H |
| | mm | 38.1 x 15.9 |
| Anchor Points | | Thread |



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# 2 INCH PIPE CRAWLER

INSPECTION TOOL

## Working Prototype

## Next Steps - Improvements

- Increase speed – customize motors, add additional extender modules
- Automate and optimize controls
- Add improved wiring scheme
- Add an additional motor for each module to improve pull force
- Incorporate sensor module and surface preparation module
- Test ability to navigate 180° turns
- Test durability of components for significant operations
- Incorporate a second system to distribute the tether load

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# H-CANYON EXHAUST TUNNEL

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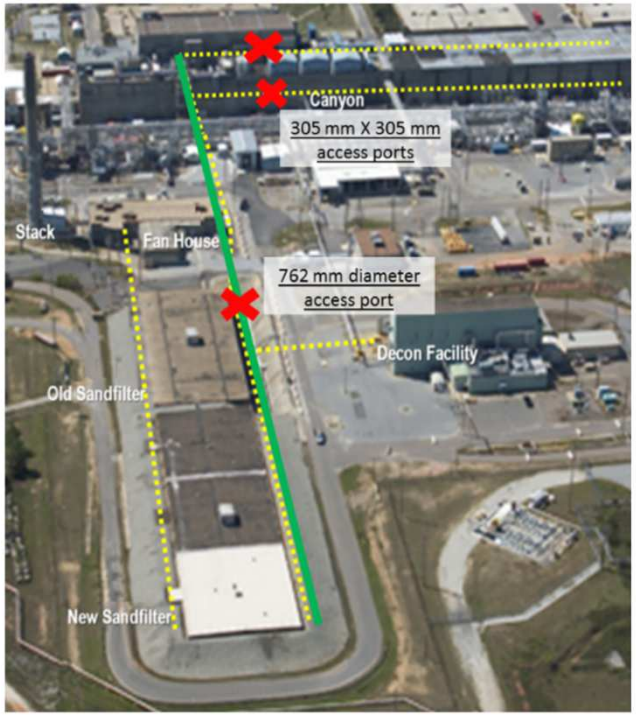
PROPOSED INSPECTION




At the Savannah River Site is the **only remaining plutonium/HEU reprocessing facility in the USA** constructed in early 1950's.

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UF UNIVERSITY of FLORIDA

SRNL SAVANNAH RIVER NATIONAL LABORATORY

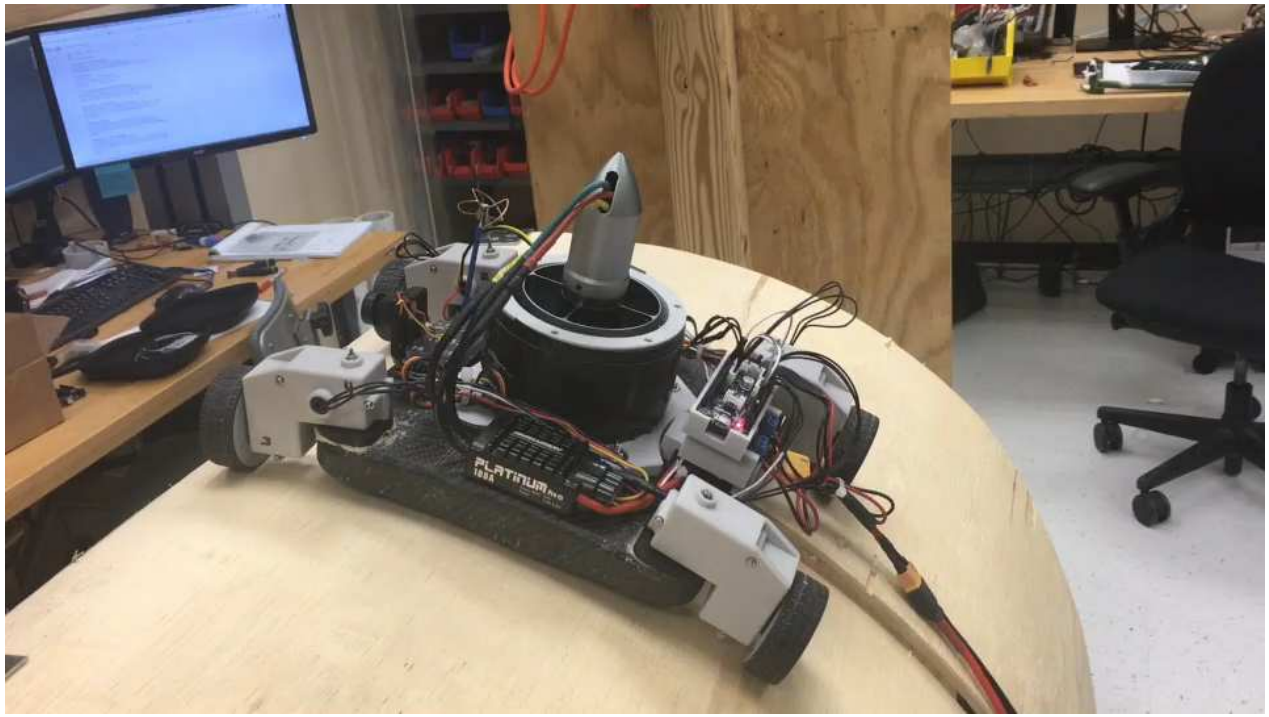
TEXAS The University of Texas at Austin

# WALL CLIMBER
## INSPECTION TOOL

*Objective: Develop an inspection tool that can navigate around the exterior of a 3 ft diameter pipe and provide video feedback*

Obtain information regarding walls that are hidden behind a 3 ft diameter aluminum pipe within the tunnel (acidic environment with a minimum of 30 mph winds).

Collaborative effort with UF and UT at Austin.



- Inertial Measurement Unit (IMU) – used to measure the pitch, roll and yaw of the unit
- Force Sensitive Resistors (FSR) – used to measure reaction force at each motor mount location
- Radio Receiver and Transmitter
- Motor controllers: OpenCM9.04C and L298N
- Arduino Uno R3 and Arduino Nano

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# Radiation Mapping and Quantification

Radiation quantification is crucial in nuclear facility Deactivation and Decommissioning (D&D).

Accurate quantification of the radionuclides and the associated actinide activity ensures the D&D personnel work within the safe exposure limits.

**Conventional methods** of taking radiation measurements by hand within or around the containment areas, and analyzing the collected data to obtain the result are:

- **ineffective** and
- **puts scientists to the risk** of radiation exposure.

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# AUTONOMOUS RADIATION MAPPING AND QUANTIFICATION

DEACTIVATION AND DECOMMISSIONING

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**Stereo Camera**

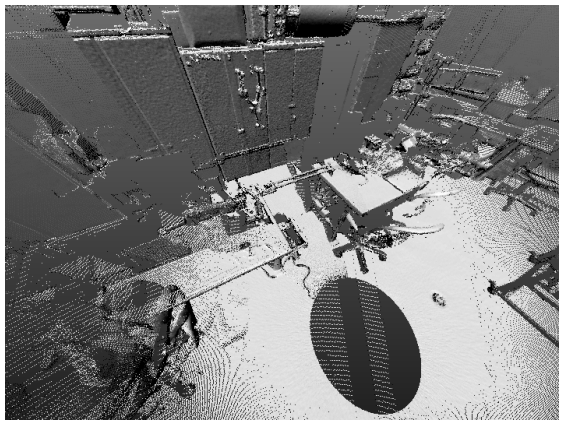
+


**3D LiDAR**

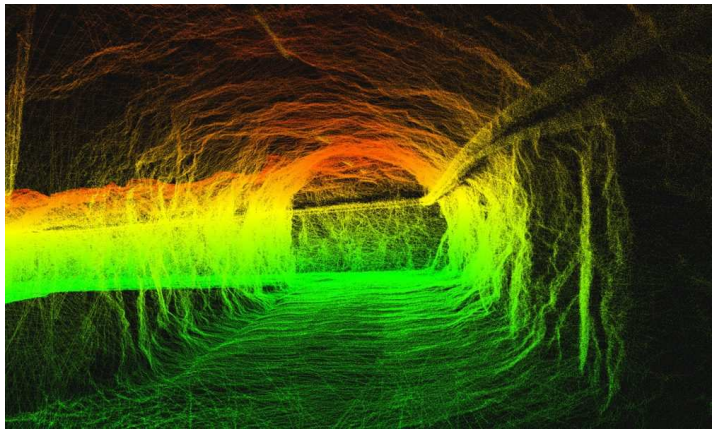
+

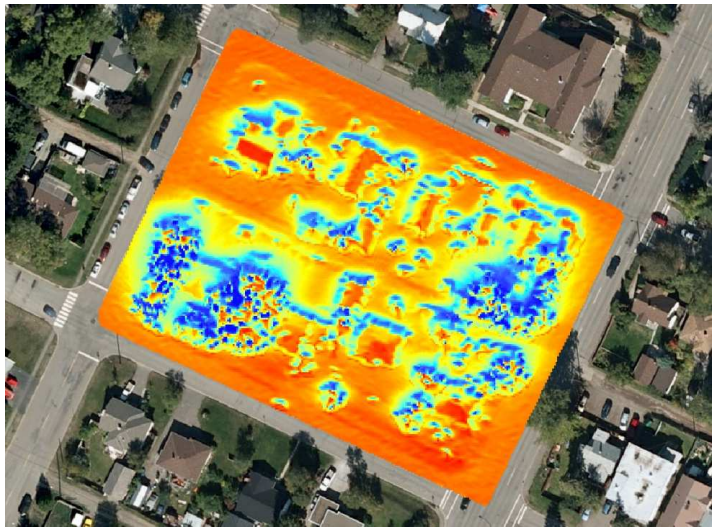

**Radiation Detector**

- Three-Dimensional Mapping
- Radiation Detection and modeling into a continuous stochastic distribution model
- Rapid Radiation Source Localization via Adaptive Sampling



**FIU Applied Robotics Lab**





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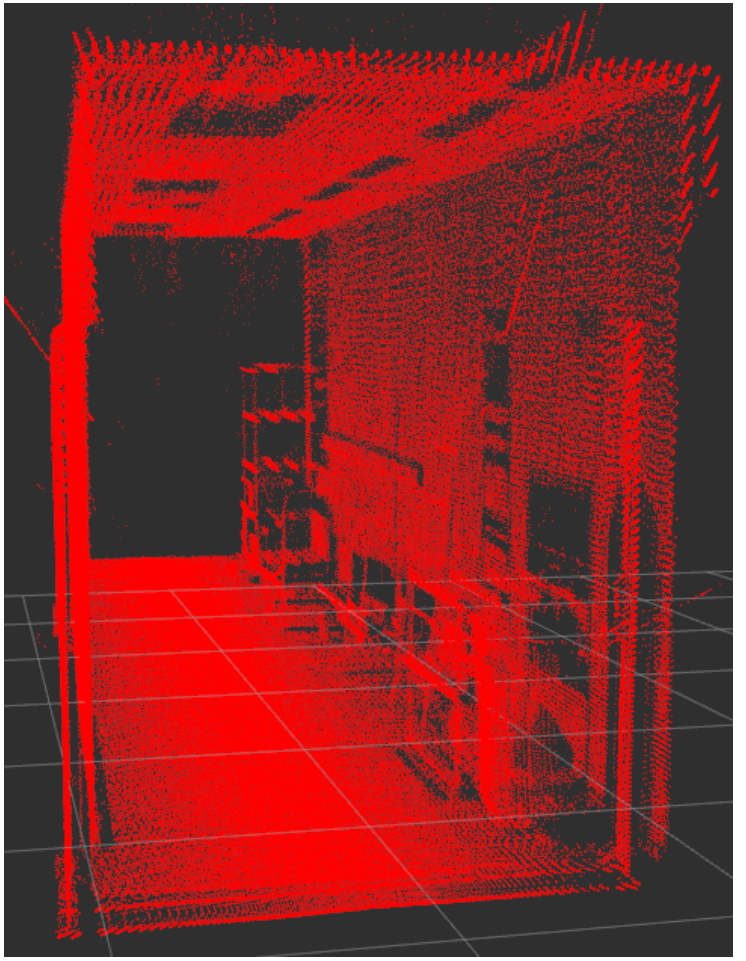
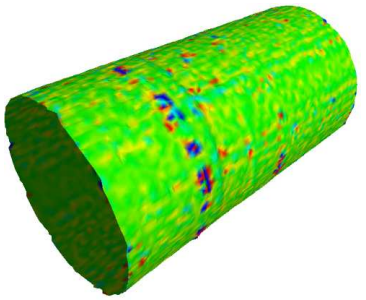
NSF

IRSC Indian River State College

# INFRASTRUCTURE MAPPING

## AUTONOMOUS SURVEILLANCE



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**Thank You**

**Questions?**