

# DOE, FIU, WRPS, and SRNL Technology Development Collaboration Meeting

Innovating investing in the future...

## Applied Robotics Laboratory

Applied Research Center  
Florida International University  
Miami, Florida  
February 7 and 8, 2022



# Florida International University

A vibrant, 58,000 student-centered public research university located in Miami, Florida.

**Among the largest Hispanic-serving institutions in the U.S. and is designated a Minority-Serving Institution.**

As a top-tier research institution, research is a major component in FIU mission.



# Applied Robotics Laboratory

**Principal Investigator:** Leonel Lagos, Ph.D., PMP®

**Project Manager:** Dwayne McDaniel, Ph.D., P.E.

**Research Scientist:** **Anthony Abrahao, M.S. [lab manager]**  
Aparna Aravelli, Ph.D.  
Mackenson Telusma, M.S.  
Manuel Escobar, M.S.  
Rodrigo Ramon, Ph.D.

**DOE-EM Fellows:** Sebastian Story (MS)      Gabriel Cerioni (MS)  
Joel Adams (PhD)      Rafael Velasquez (BS)  
Josue Estrada (MS)      Philip Moore (MS)  
Nicholas Espinal (BS)      Brendon Cintas (MS)

**DOE-LM Fellows:** Shawn Cameron (MS)

**Research Assistants:** Maria Sotolongo (PhD)      Sharif A. Sarker (PhD)  
Nicolas Issa      Munim Rayhan (PhD)  
Hiba Khalil (BS)      Abdiel Hernandez (BS)  
Daniel Estrada (BS)      Daniel Picado (BS)  
Carlos Hernandez (BS)



*“Support DOE-EM and DOE-LM collaborating with National Laboratories actively training STEM students to enter DOE’s workforce.”*

## Personnel

- 7 Fulltime Researchers
- 18 Research Assistants

## Technology Roadmap

2020

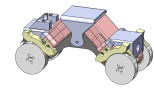
2021

2022

2023

2024

Tank Farm  
Hanford



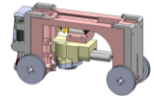
Minirover

In-house Deployment

Site Deployment

Site Deployment

Technology Transferred



UT Rover

Conceptual Design

Evaluation

In-house Deployment

Site Deployment

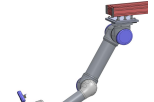


Lateral Gamma

Integration

Cold Test Facility Deployment

Site Deployment



Off-Riser Sampler

Conceptual Design/Integration

Cold Test Facility Deployment

Site Deployment



Long-Term Surveillance

Conceptual Design

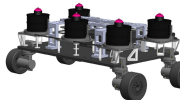
Sensor Integration

Evaluation

In-house Deployment

Site Deployment

H Canyon  
SRNL



Wall Crawler

Conceptual Design

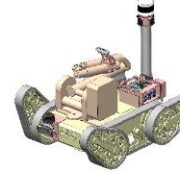
Sensor Integration

Evaluation

In-house Deployment

Site Deployment

WIPP  
MSIPP



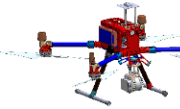
Salt Closure Inspection

Evaluation

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

In-house Deployment

Site Deployment



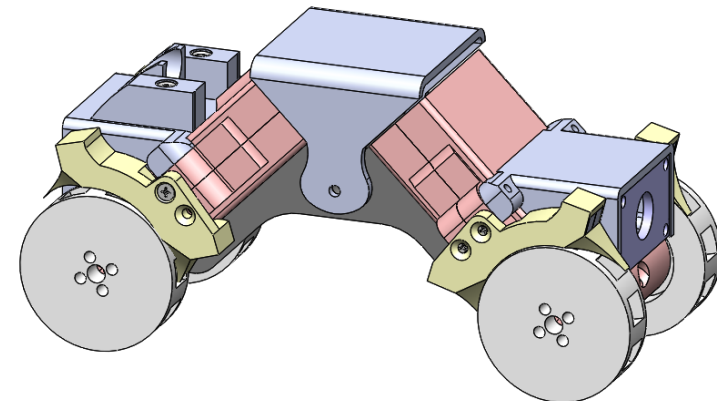
# Presentation

- **DOE-EM Mini-rover Sampling Mechanisms and Other Plug-and-Play Accessories for Hanford's Double Shell Tanks**  
Sebastian Story, M.S. Mechanical Engineering
- **DOE-EM Off-Riser Sampler for Hanford's Single Shell Tanks**  
Philip Moore, M.S. Mechanical Engineering
- **DOE-EM Lateral Gamma Scanner Deployment for Hanford's Single-Shell Tanks**  
Josue Estrada, M.S. Mechanical Engineering
- **DOE-EM Wallcrawler Development for Savannah River's H-Tunnel Repair**  
Nicholas Espinal, B. S. Mechanical Engineering
- **DOE-EM Long-Term Surveillance using Mobile Platforms**  
Part I – Nuclear Facilities, Joel Adams, Ph.D. Mechanical Engineering  
Part II – Nuclear Repositories, Shawn Cameron, M.S. Mechanical Engineering
- **DOE-EM Exoskeleton for Glovebox Applications**  
Rodrigo Ramon, Post-Doctoral Associate
- **Discussions and Final Remarks**

# Mini-rover Sampling Mechanisms and Other Plug-and-Play Accessories for Hanford's Double Shell Tanks

Sebastian Story, M.S. Mechanical Engineering

DOE-EM



# Hanford's Tank Farm



**177** TOTAL  
TANKS

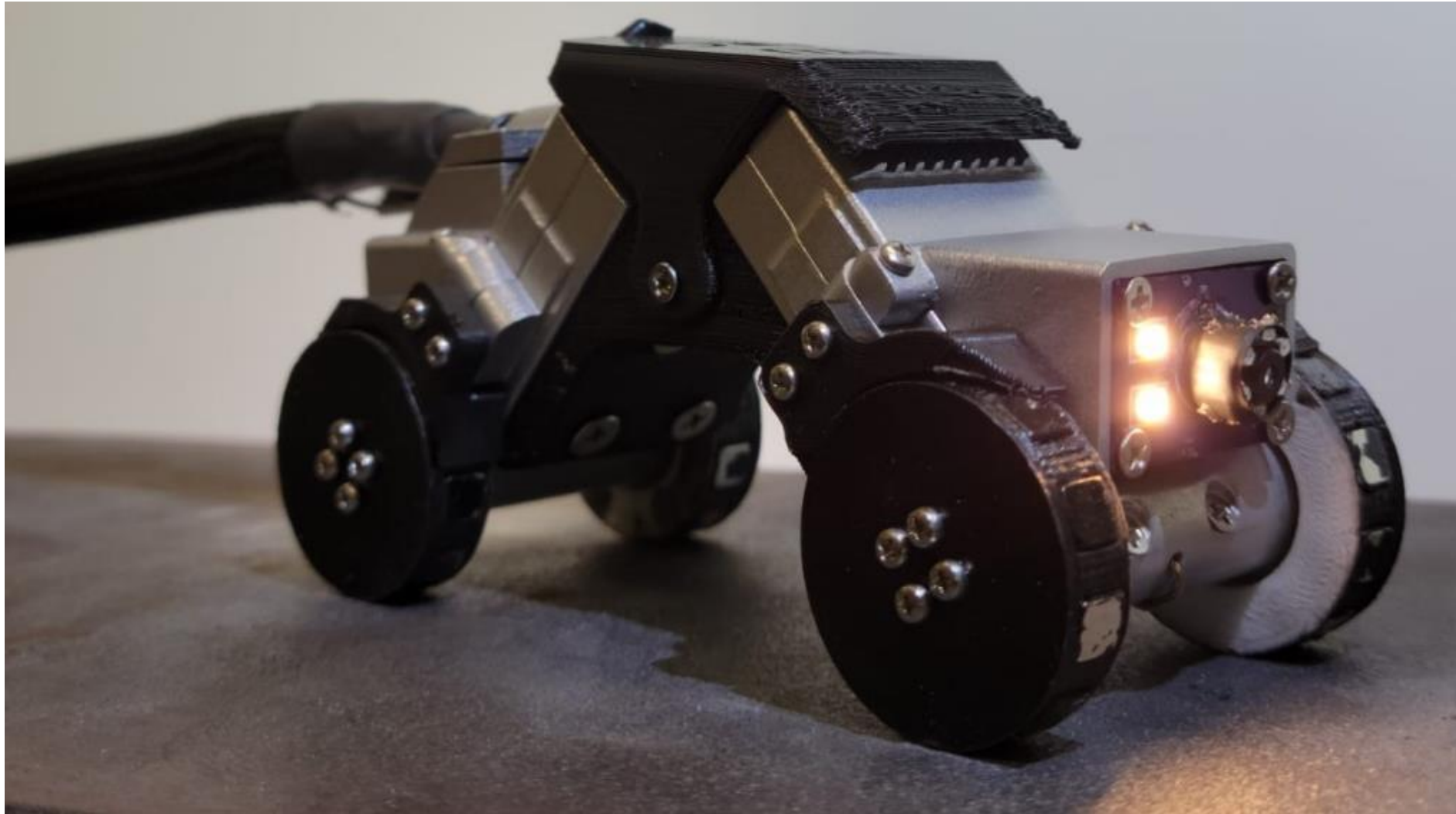
**149** SINGLE-SHELL TANKS  
Constructed 1943-1964

**28** DOUBLE-SHELL TANKS  
Constructed 1968-1986

**Hanford site has 56 million gallons of radioactive waste**

left from the past production of nuclear weapons being stored in underground tanks.

# Miniature Inspection Rover



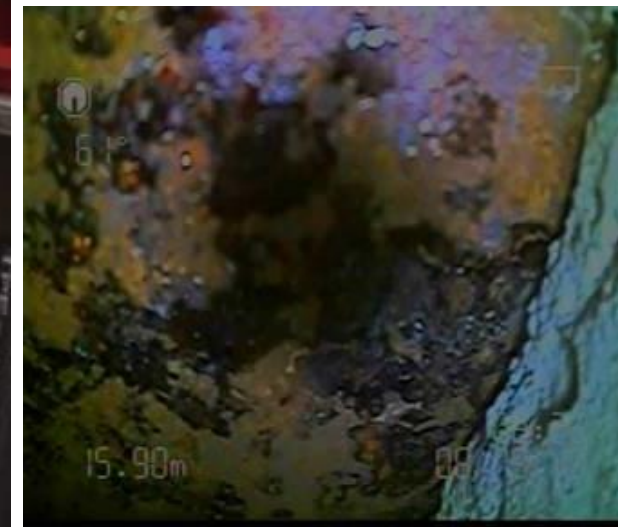
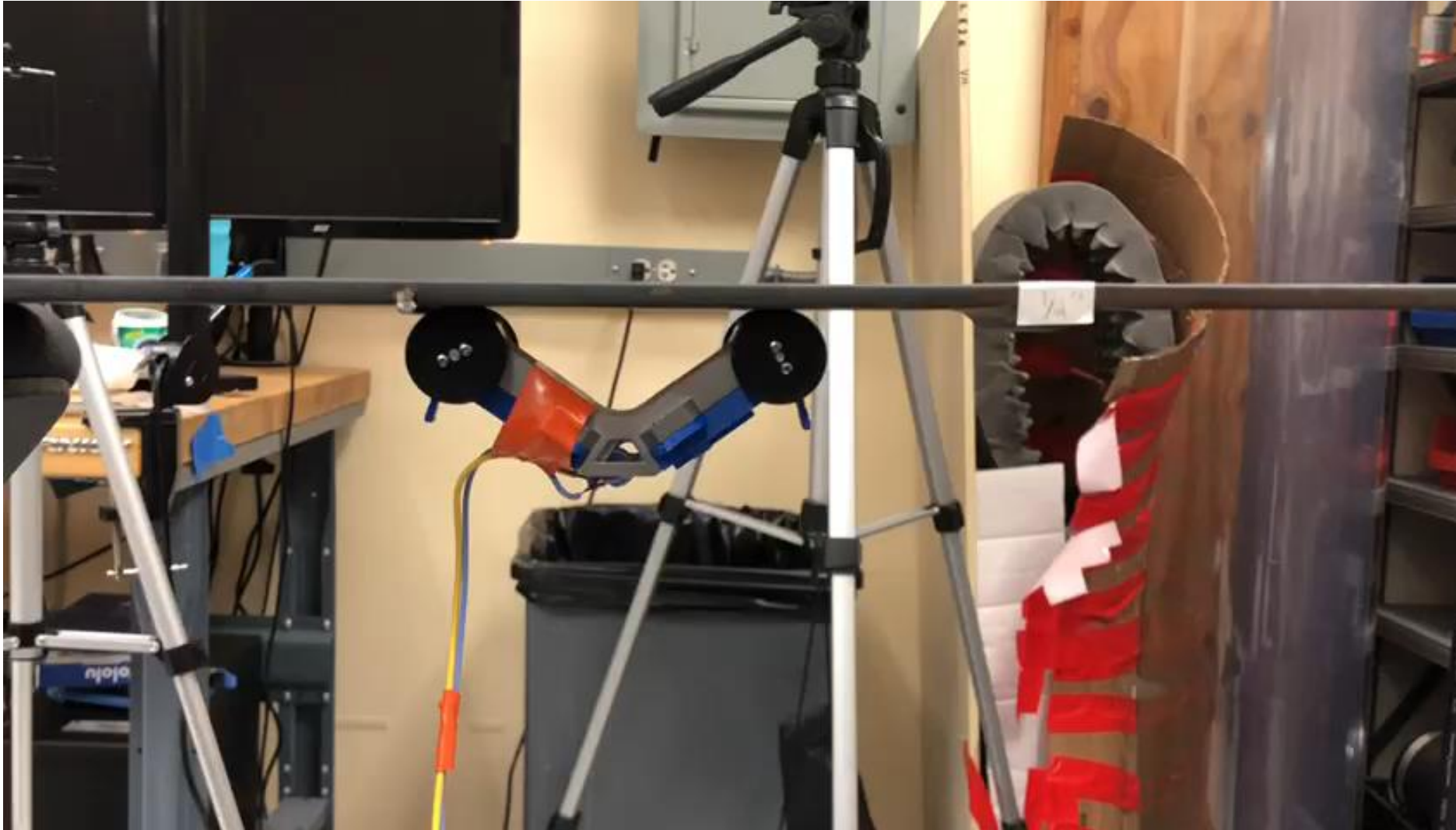
Aluminum 3D Printed Body  
Patented Flexible Chassis



Control Box  
Game Controller

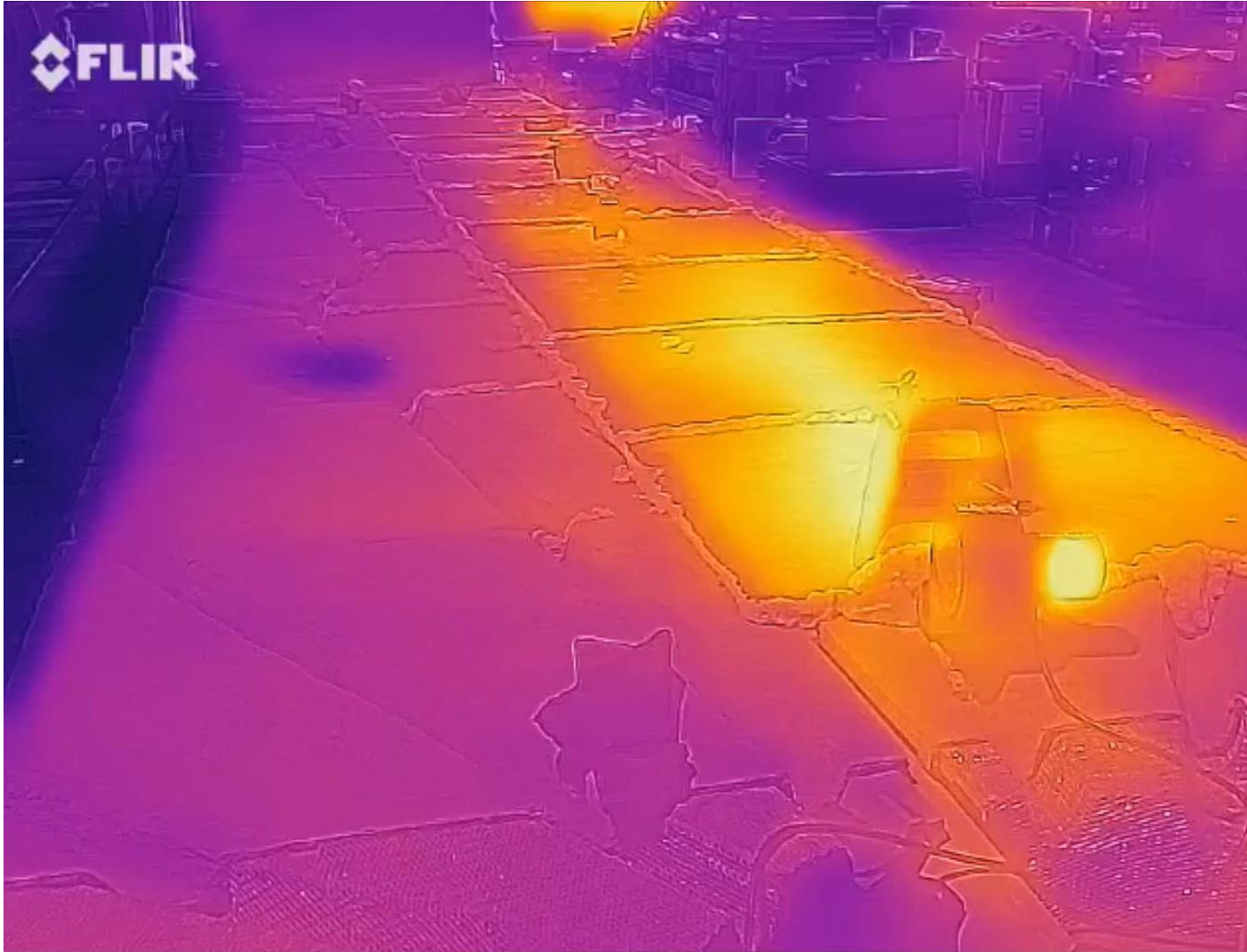


# Miniature Inspection Rover



Traversing weld seams + Corroded Surfaces + Elevated Temperatures!

# In-house Deployment



Traversing weld seams  
Elevated Temperatures  
Corroded Surfaces

Extensive in-house testing duplicating DOE site conditions

# WRPS's Field Operator Training



# AP-105 Double Shell Tank Deployment



# AP-105 Double Shell Tank Deployment



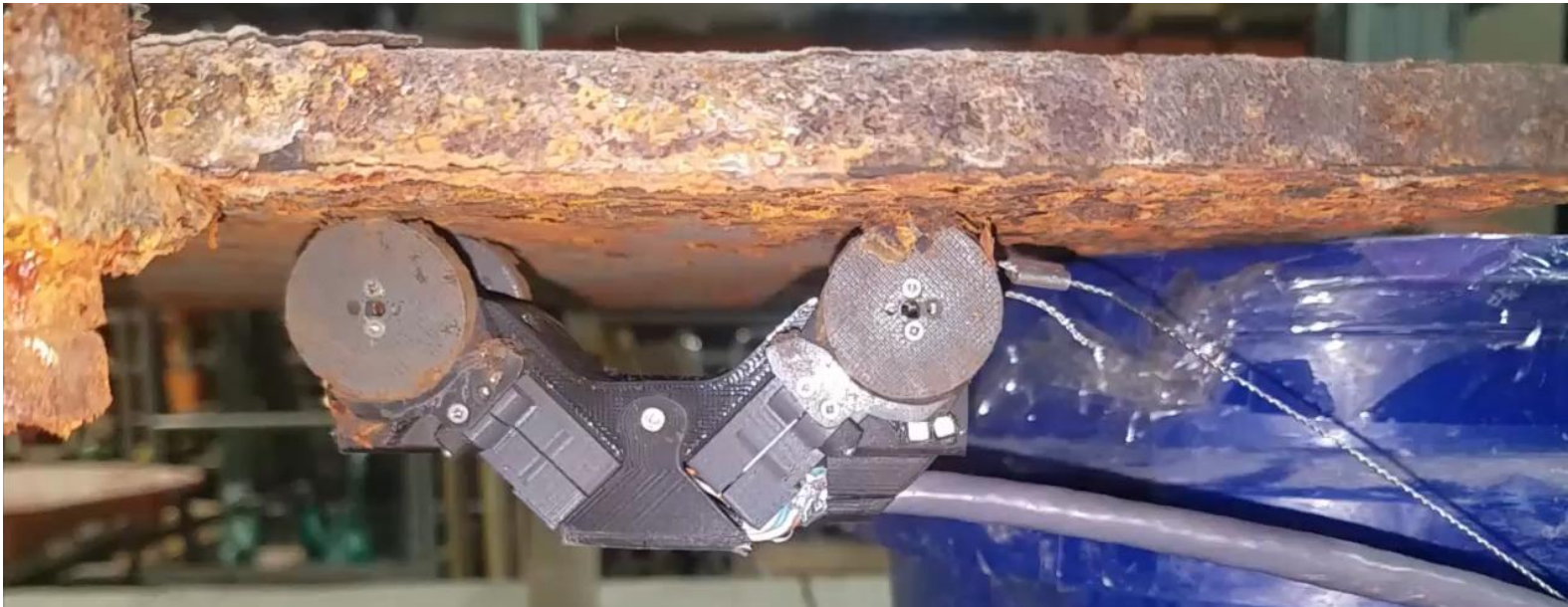
washington river  
protection solutions

FIU

Applied  
Research  
Center



AP-105 double-shell tank deployment



FIU mockup rust removal simulation

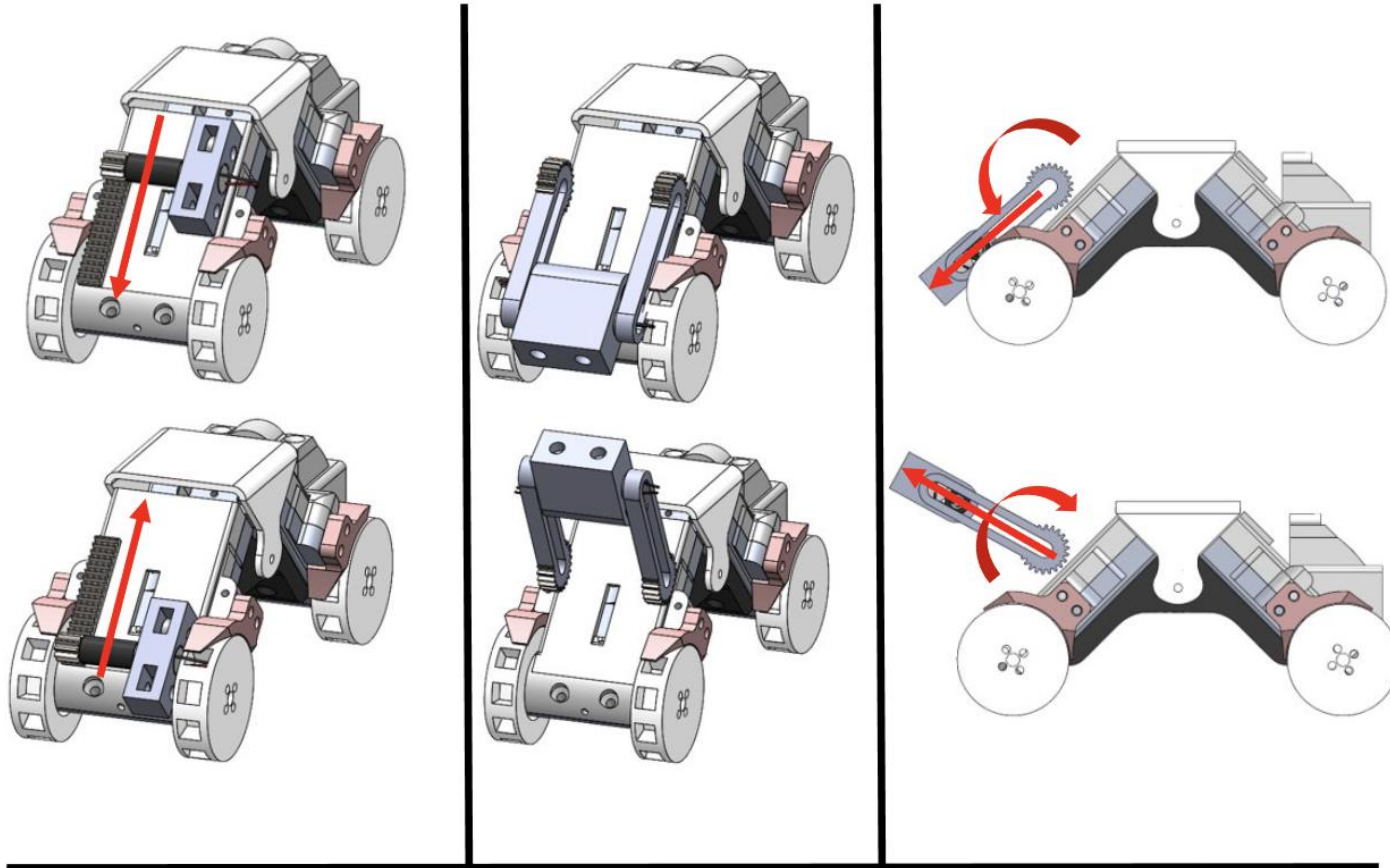


After deployment

# Ultrasound Sensor Integration

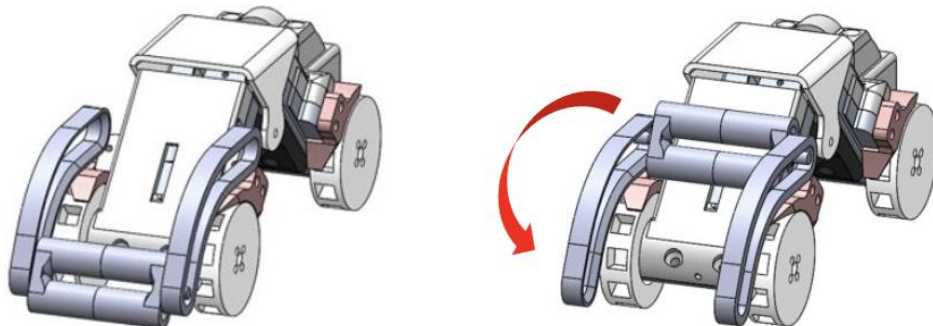
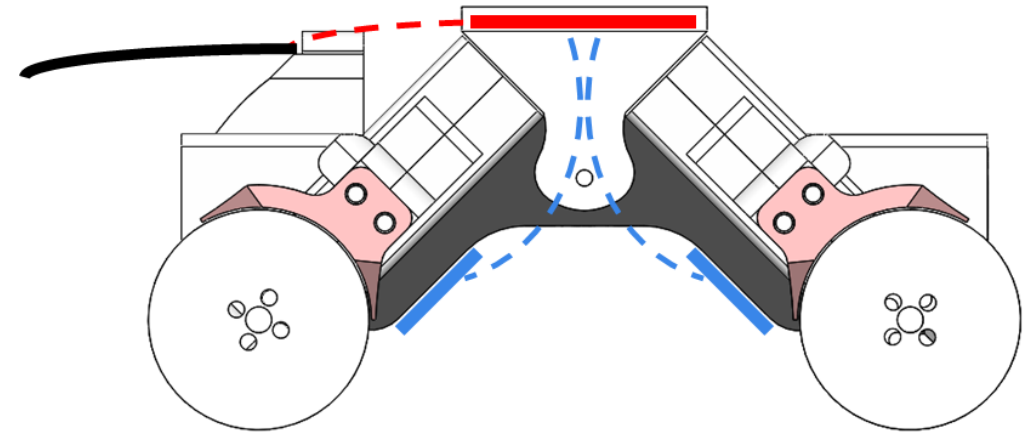


# Sampler Mechanism



Adapted to existing miniature rover:

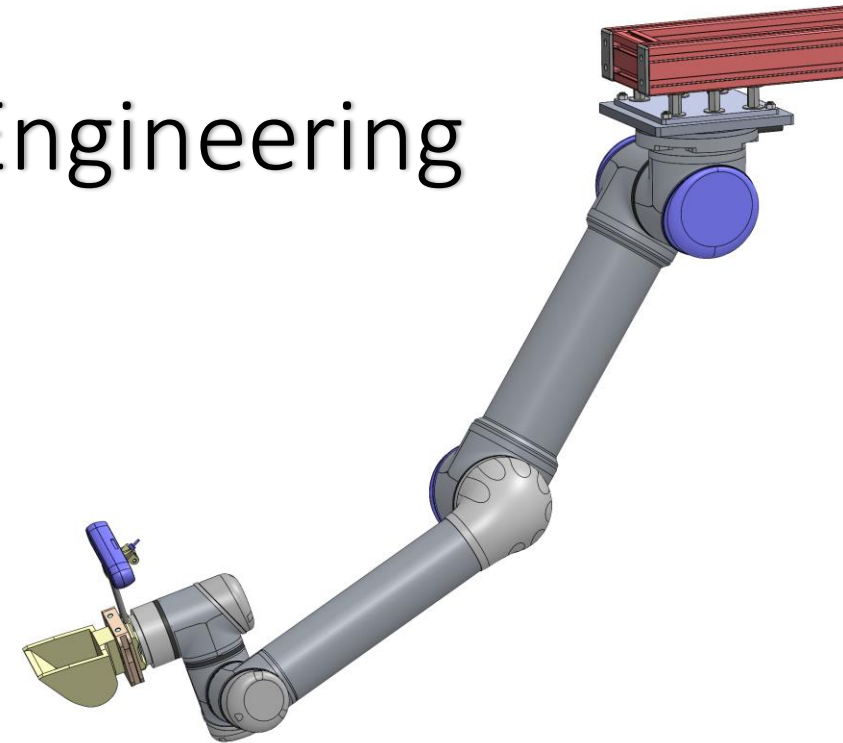
- Vacuum
- Scraping
- Gripping



- Tether
- Motor controllers
- Microcontroller & communication

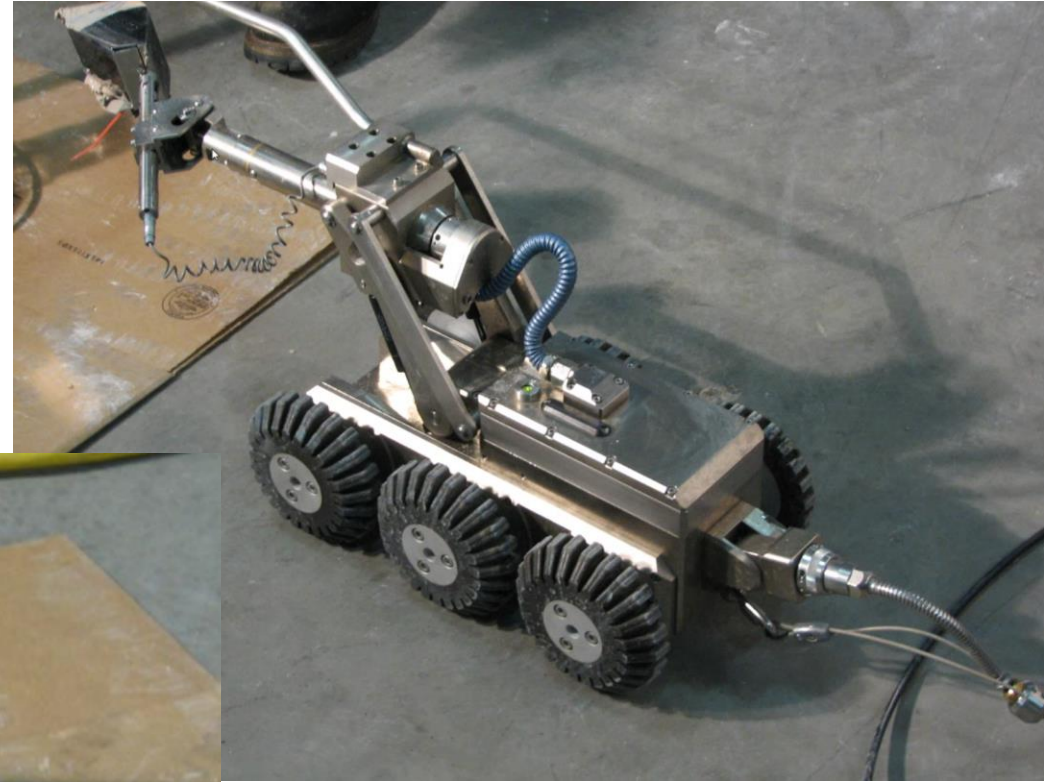
# Off-Riser Sampler for Hanford's Single Shell Tanks

Philip Moore, M.S. Mechanical Engineering  
DOE-EM

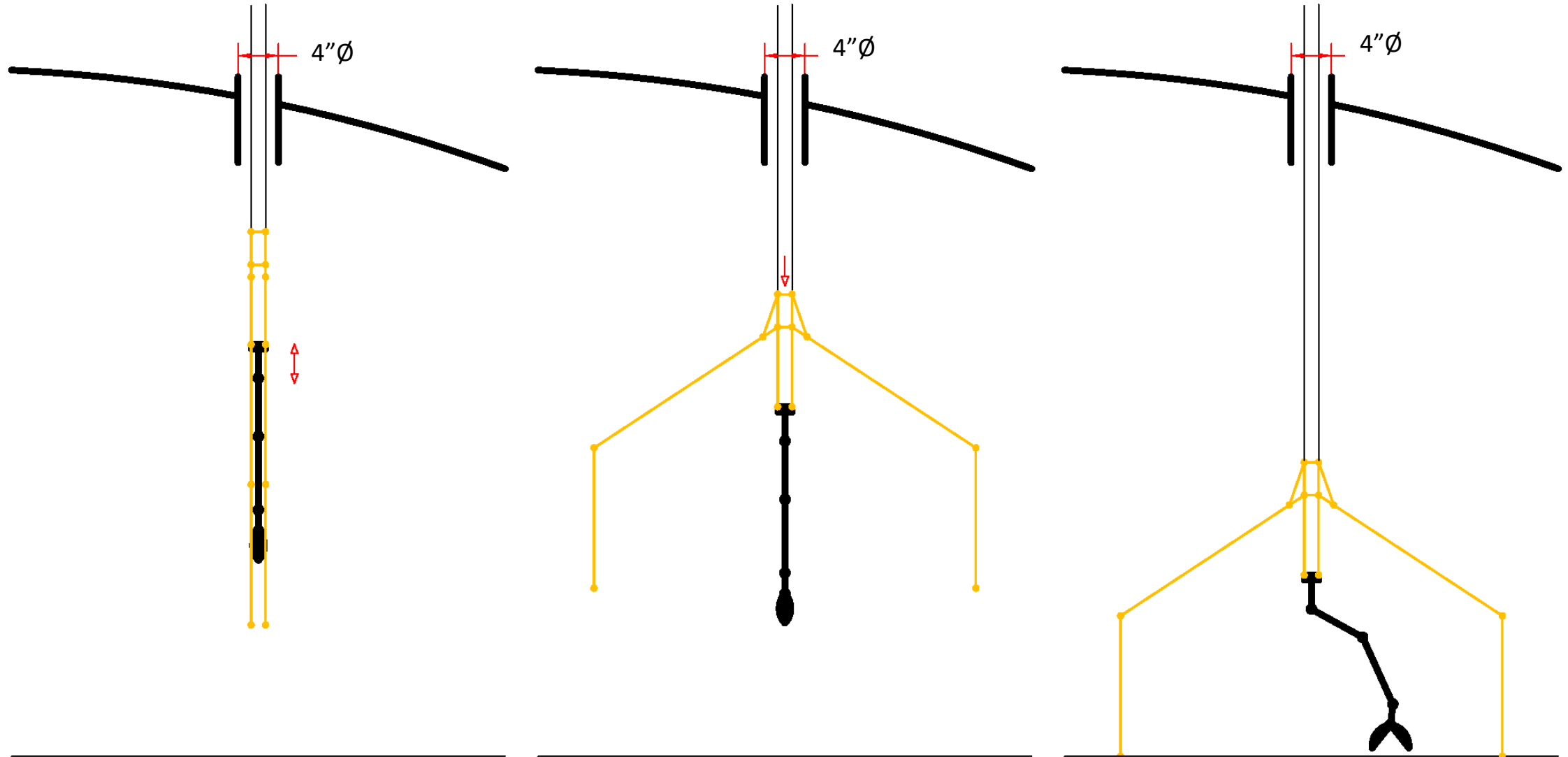




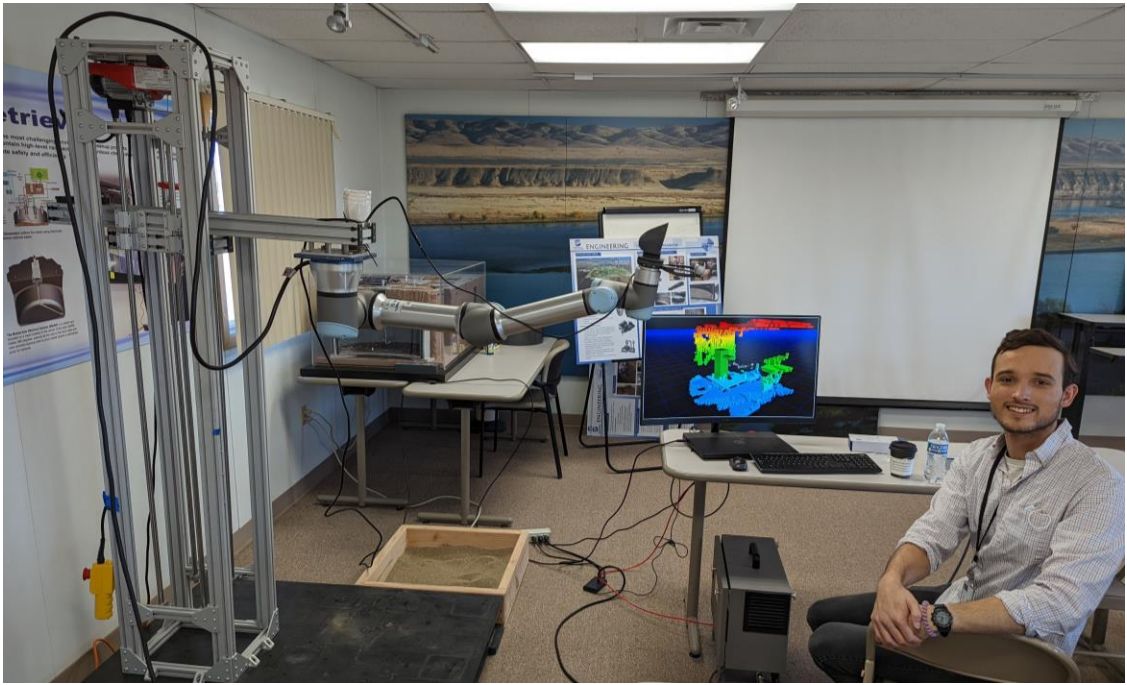
# Current Sampling Devices



# Off-Riser Sampling Conceptual Design

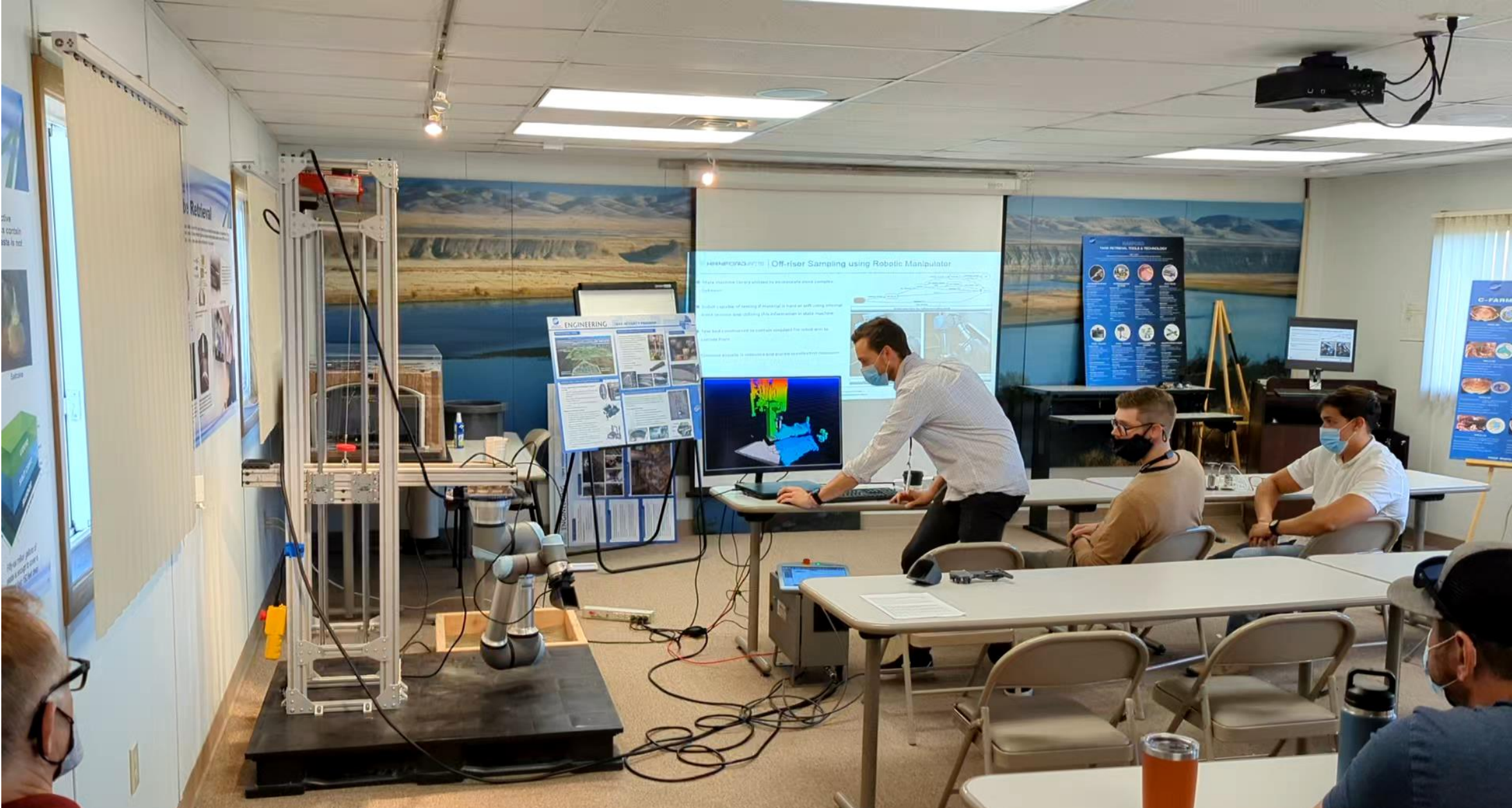


# 2022 Demonstration

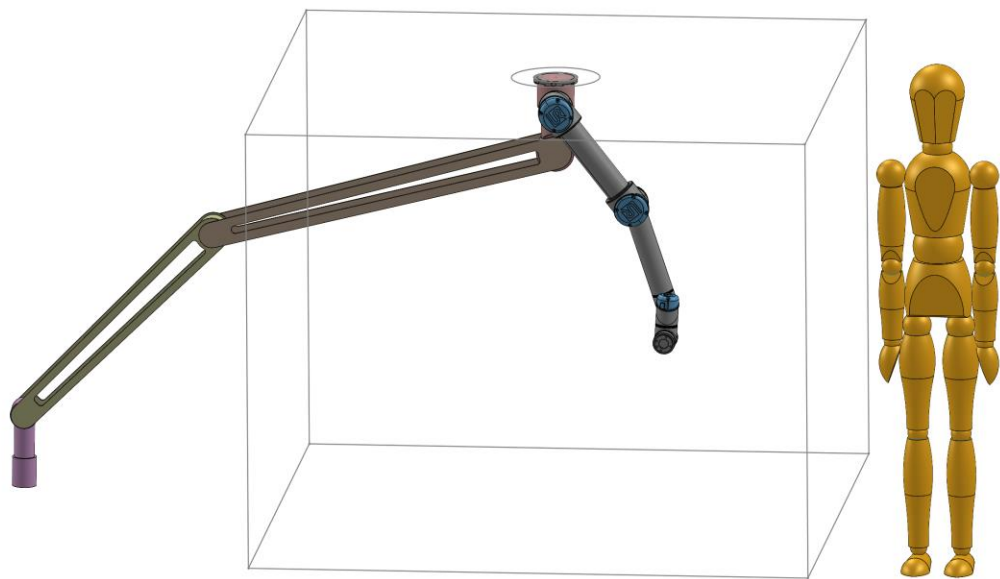
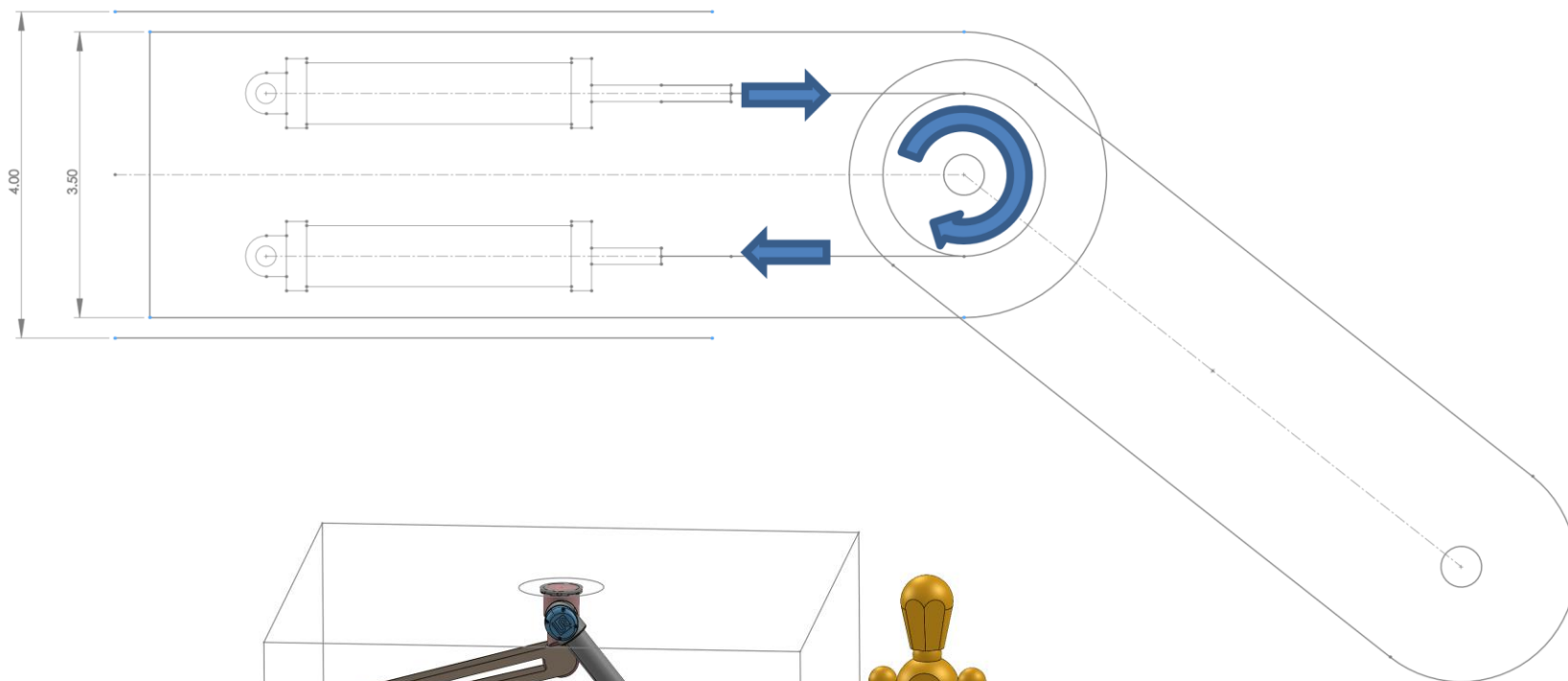


In the Summer of 2022, FIU in collaboration with WRPS, demonstrated at Hanford the potential of using robotic manipulators to perform off-riser sampling in high-level waste tanks.

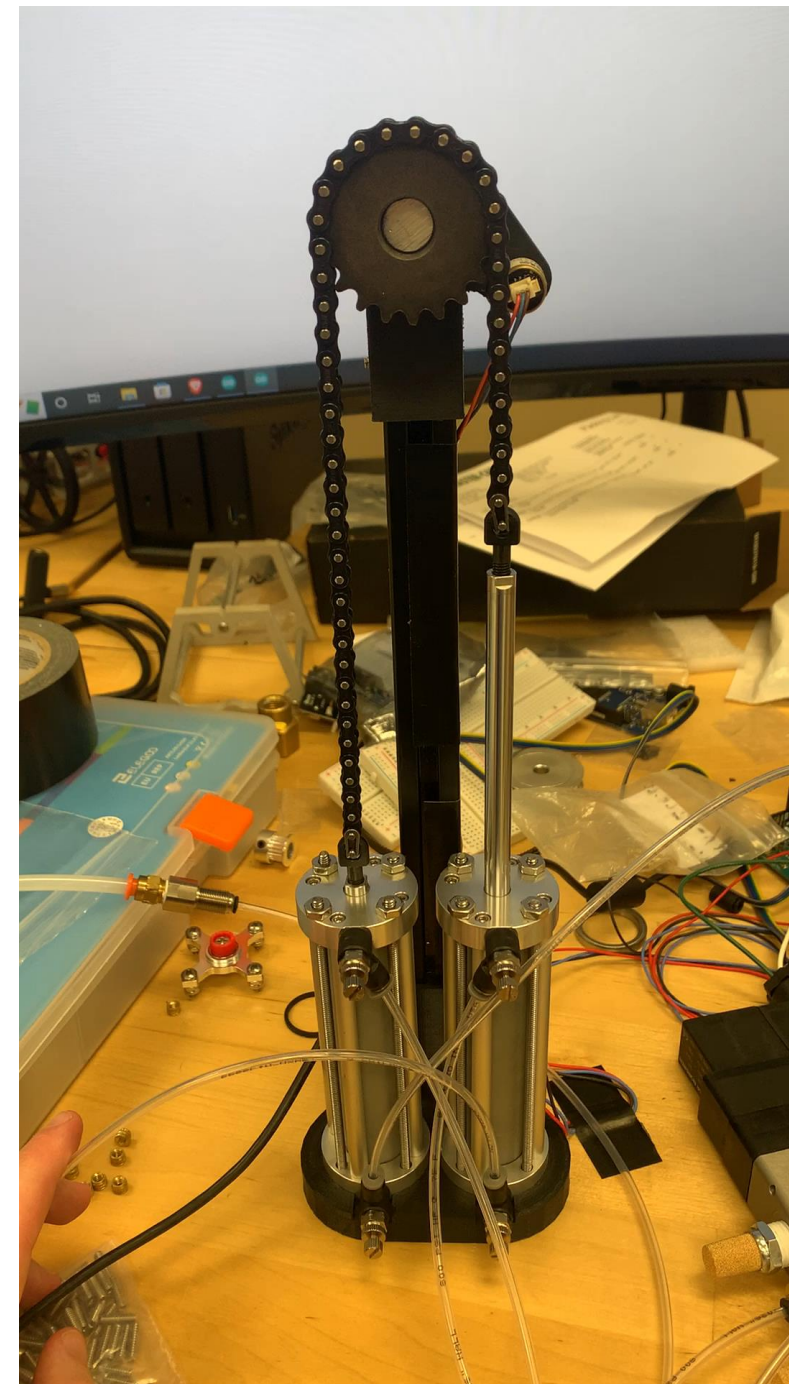
# 2022 Demonstration



# Off-Riser Sampling Arm



- 4 Degrees of freedom
- 3.5" Diameter
- Radiation harden
- Pneumatic



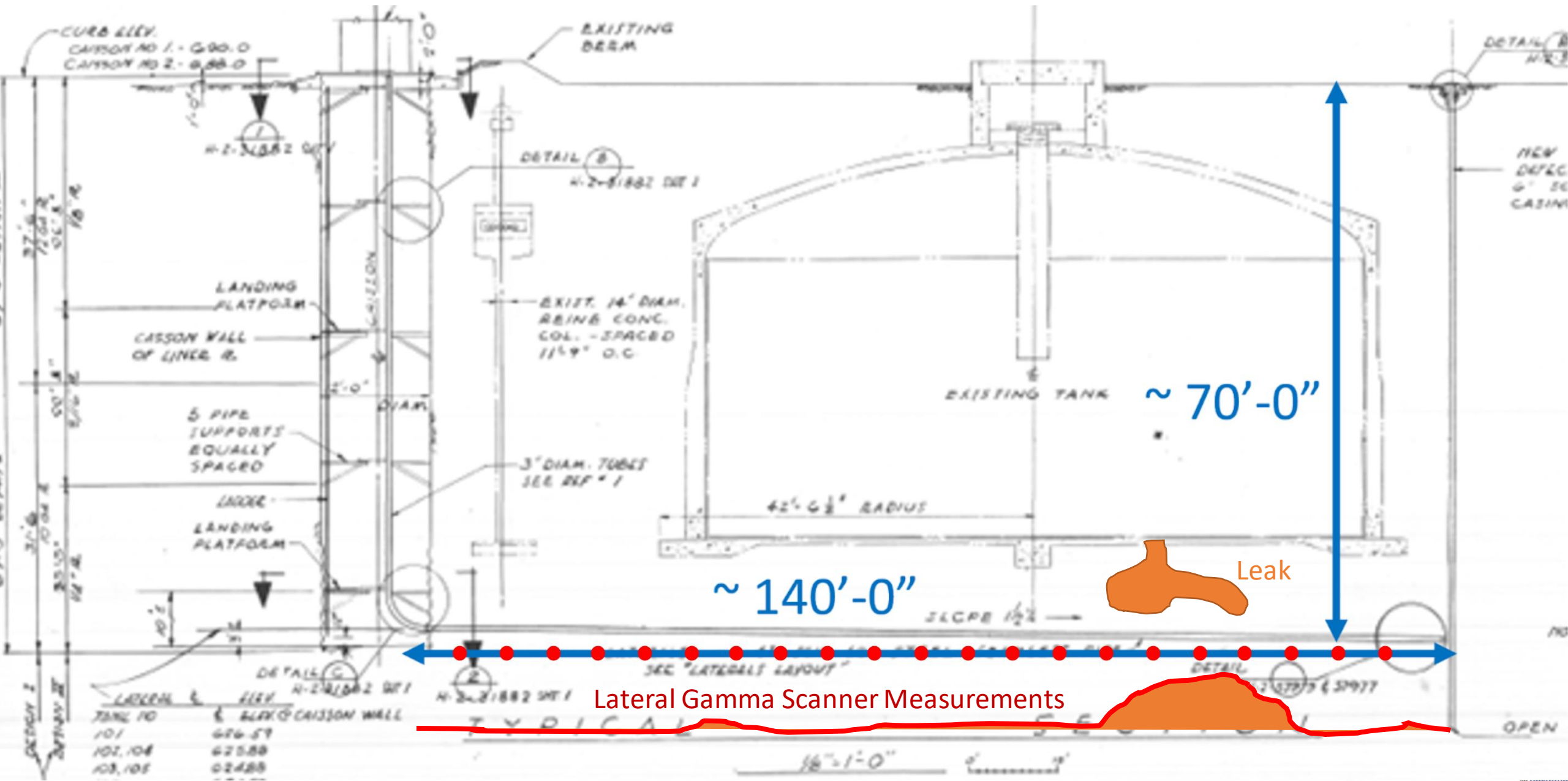
# Lateral Gamma Scanner Deployment for Hanford's Single-Shell Tanks

Josue Estrada, M.S. Mechanical Engineering

DOE-EM



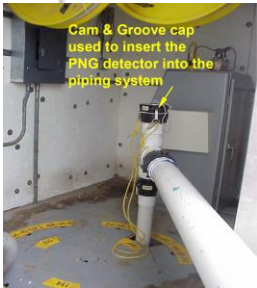
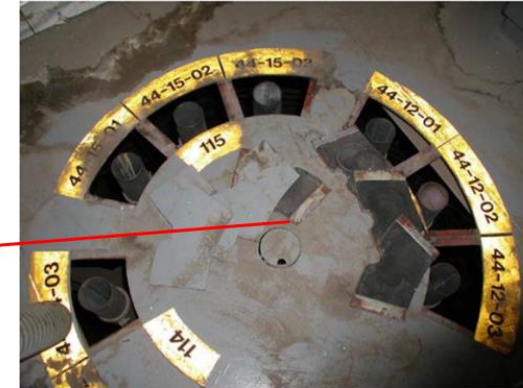
# Single Shell Tanks Lateral Gamma Scanner Automated Inspection



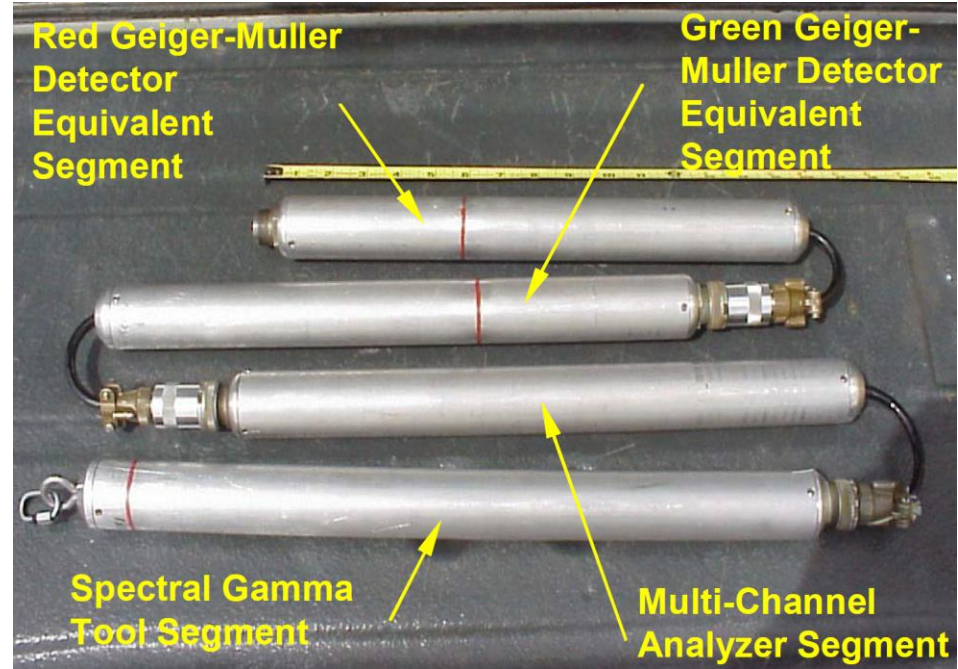
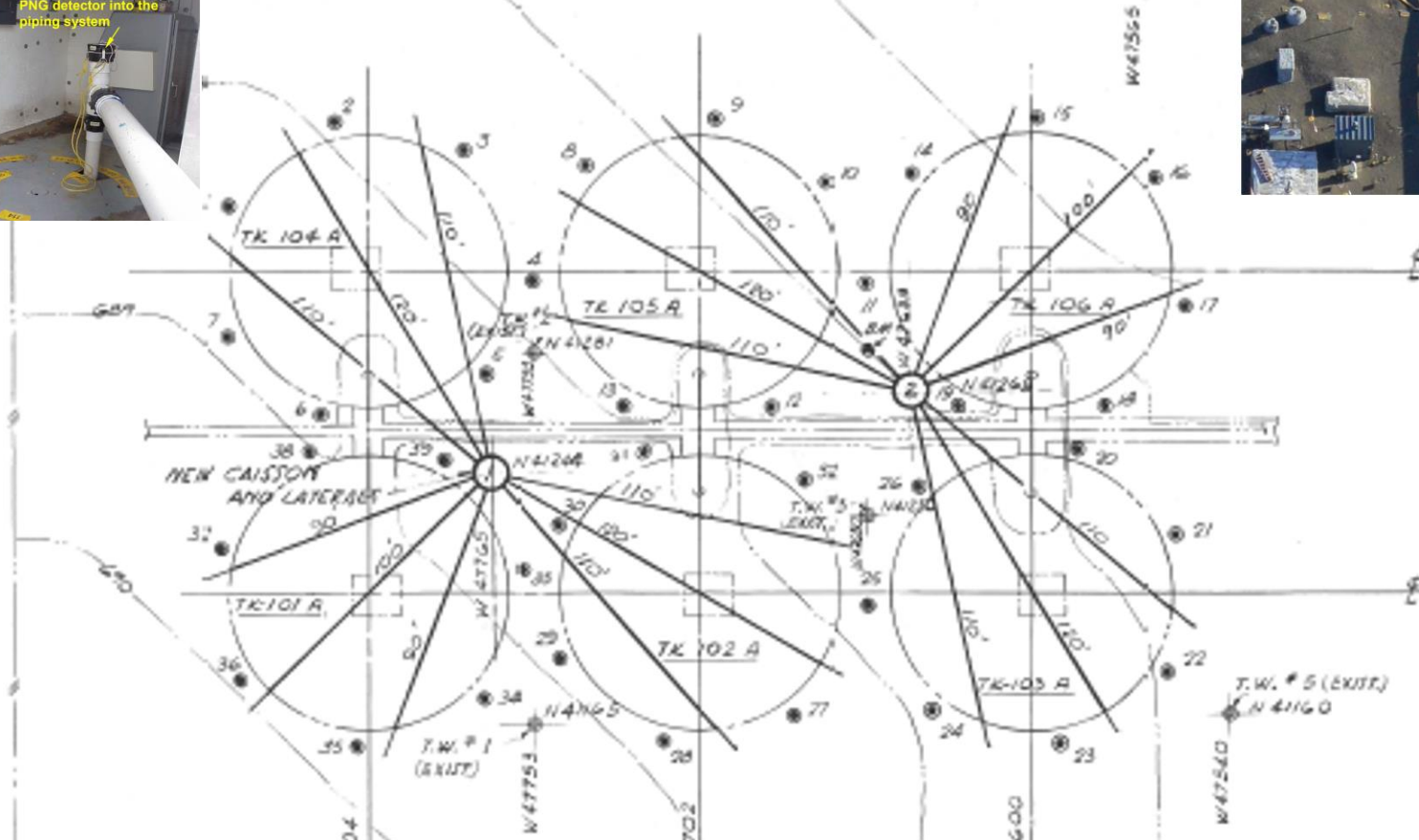
# 2005 Inspection



Lateral Shacks in A-farm



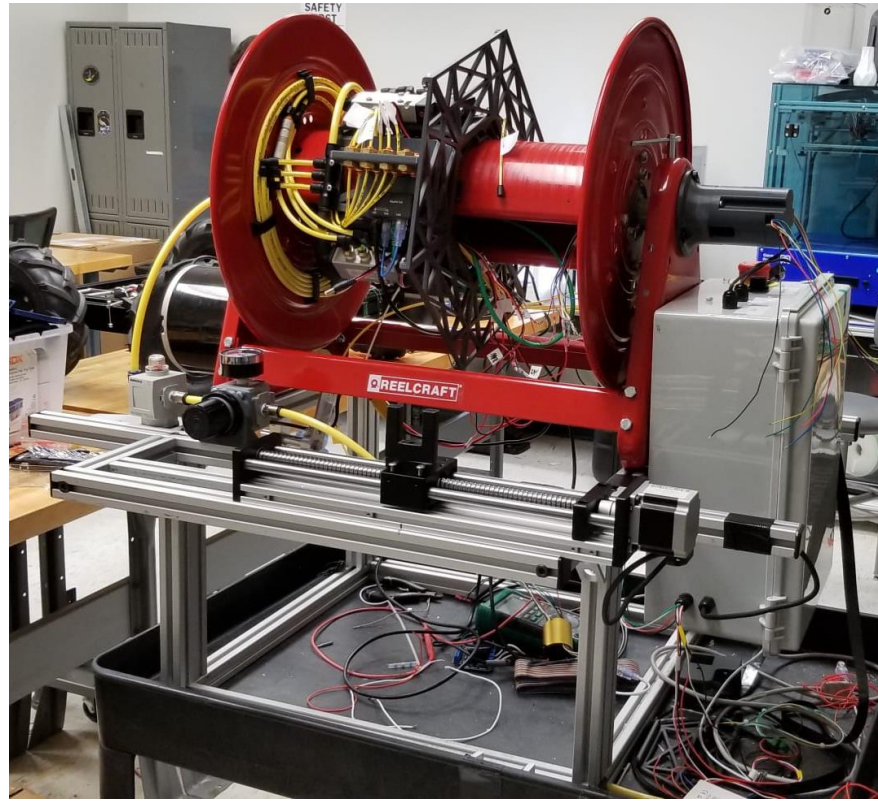
Cam & Groove cap  
used to insert the  
PNG detector into the  
piping system



# Lateral Gamma Scanner



220' Tether



## Mockup Sensory Package

- 15" length
- 1.9" diameter
- 3 lbs module
- Total 9 lbs!

Delivery Pipe Crawler + Sensor + Camera = ~ 8 feet

# In-house Deployment



# 2021 and 2022 WRPS's Cold Test Facility Deployment

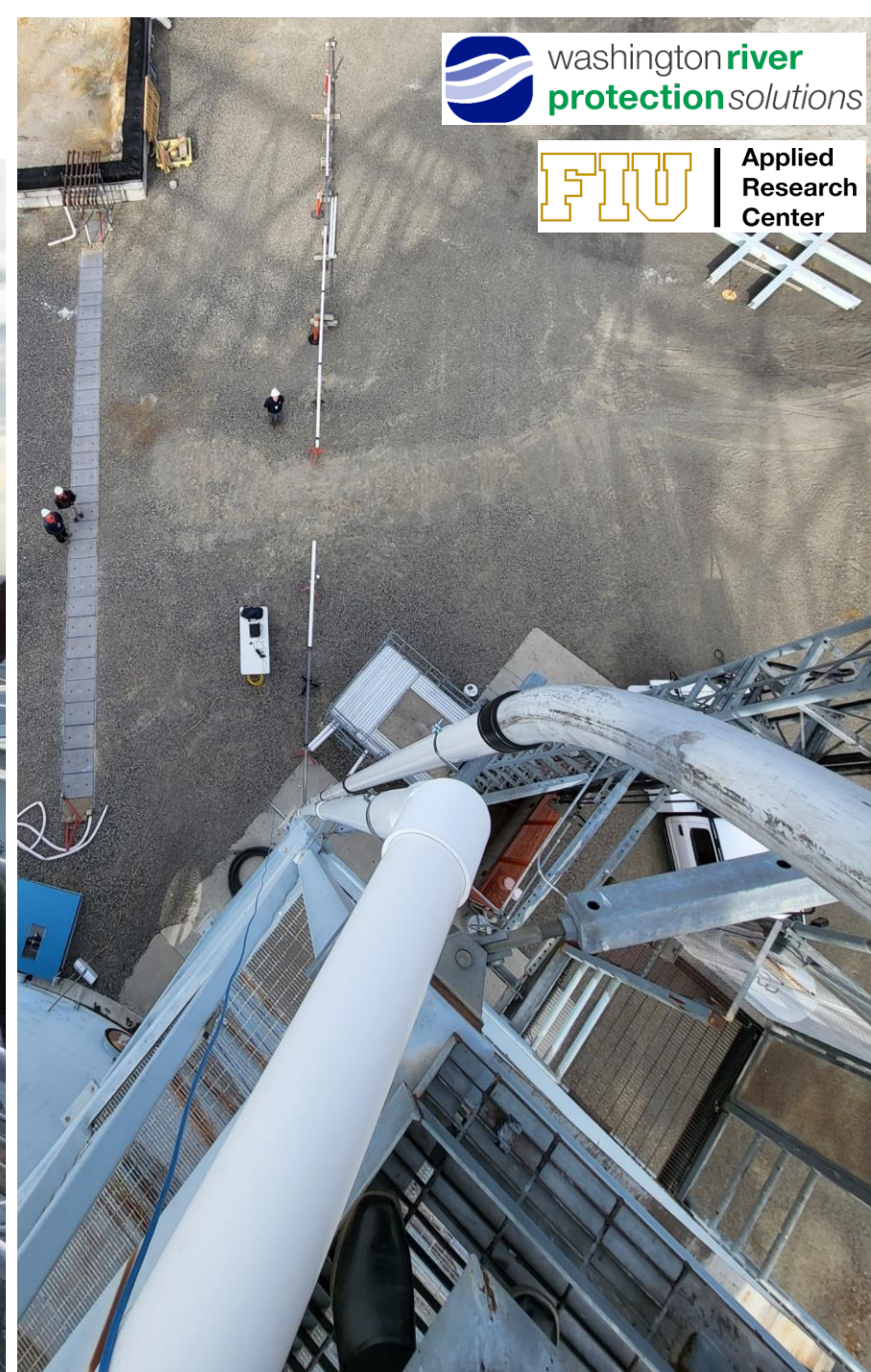
washington river protection solutions  
**FIU** Applied Research Center



# WRPS's Cold Test Facility Deployment



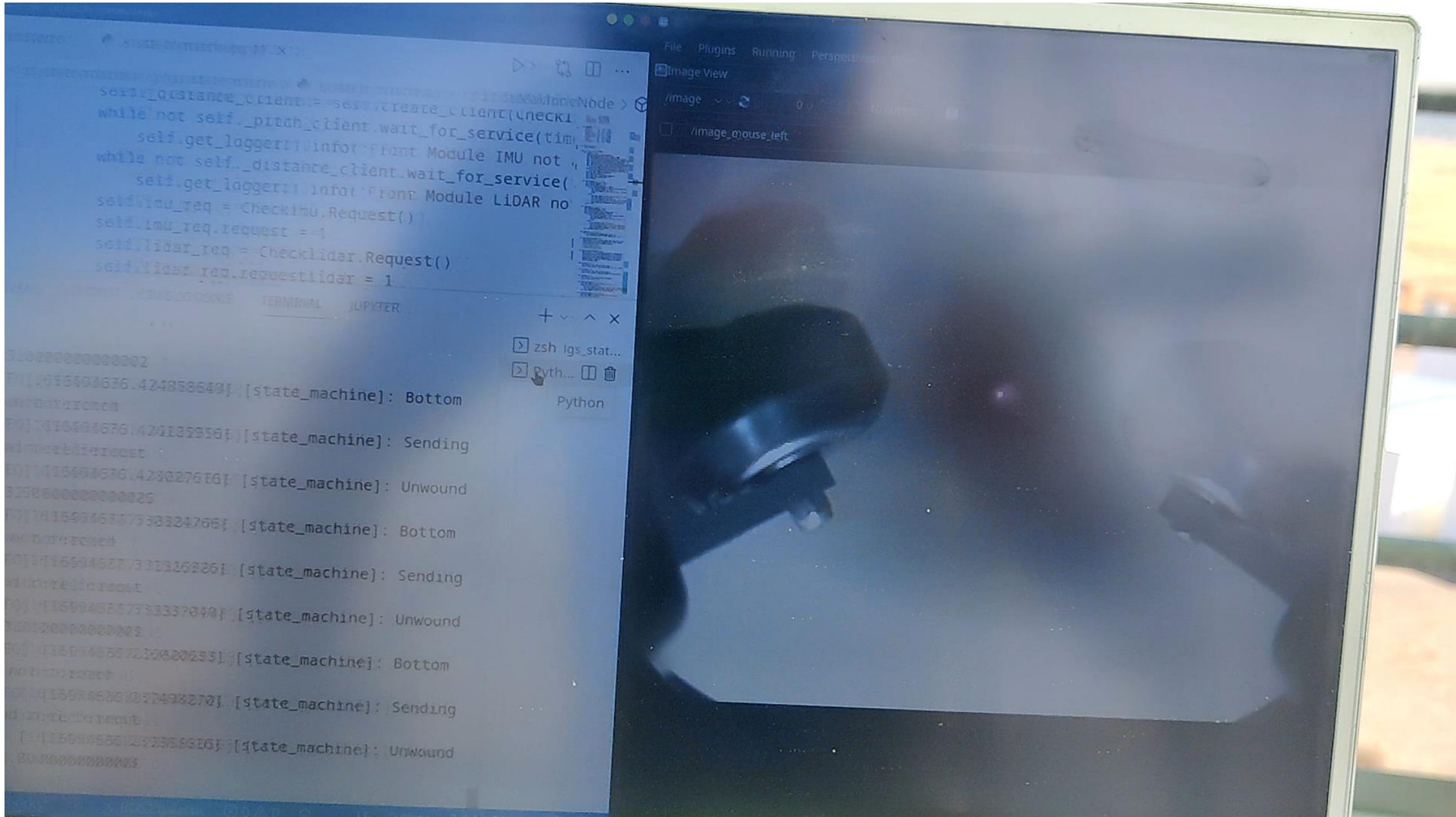
# WRPS's Cold Test Facility Deployment



# Cold Test Facility Deployment



# Cold Test Facility Deployment



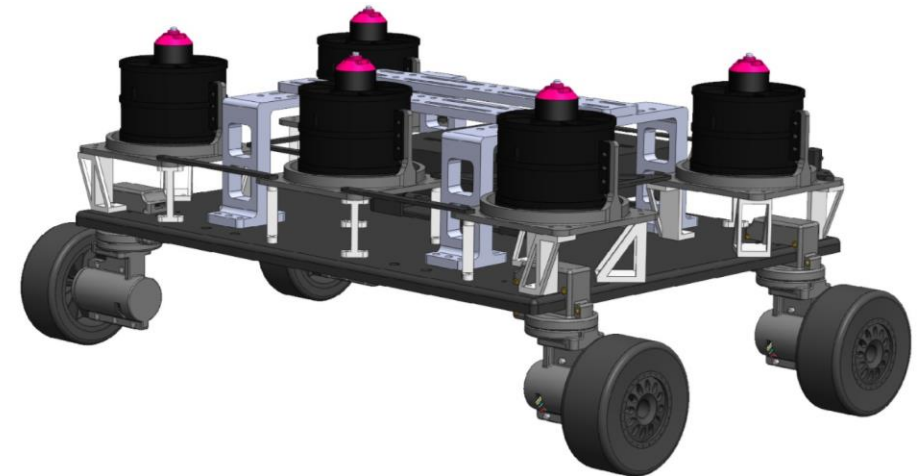
# Cold Test Facility Deployment



# Wallcrawler Development for Savannah River's H-Tunnel Repair

Nicholas Espinal, B. S. Mechanical Engineering

**DOE-EM**



# H-Canyon Concrete Wall Repair



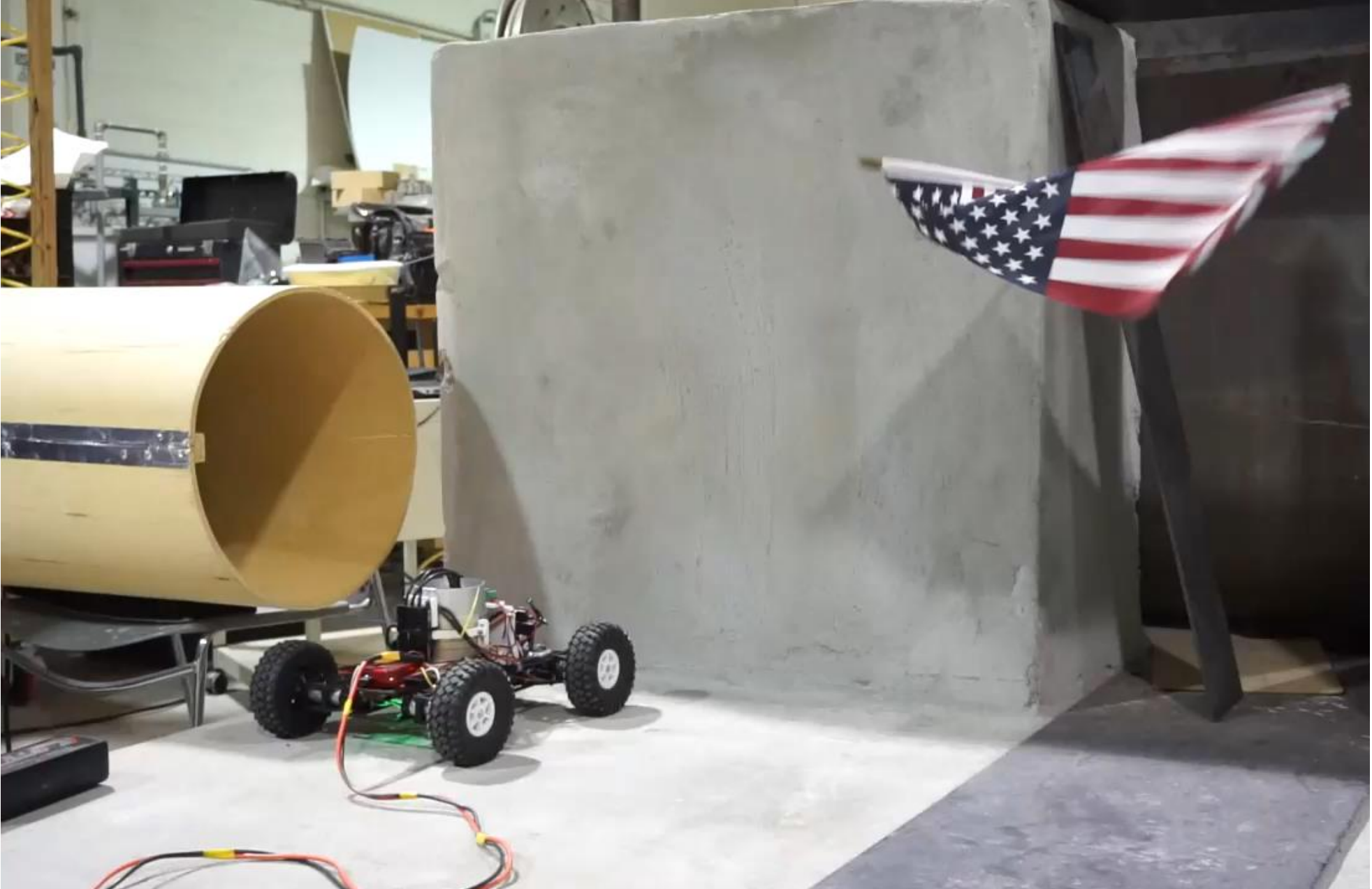
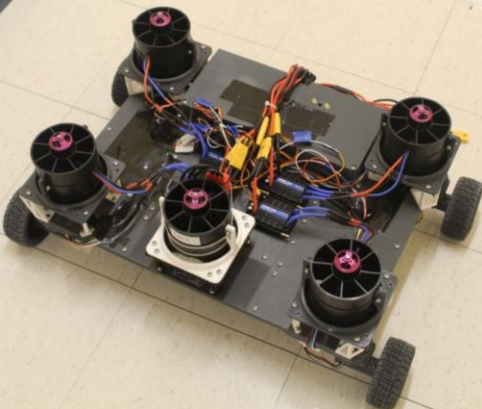
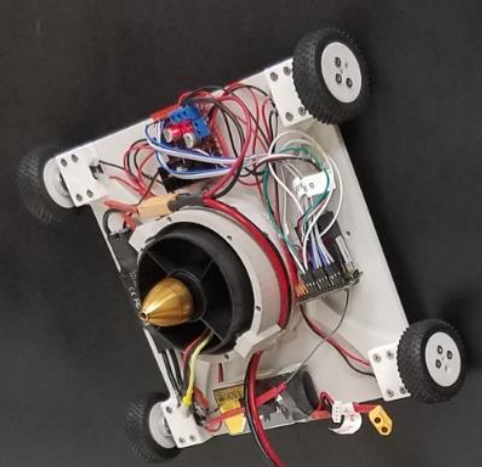
Savannah River Site has the only remaining plutonium/HEU reprocessing facility in the USA constructed in early 1950's.

# H-Canyon Concrete Wall Repair

30 mph lateral winds  
Rough surfaces  
Debris



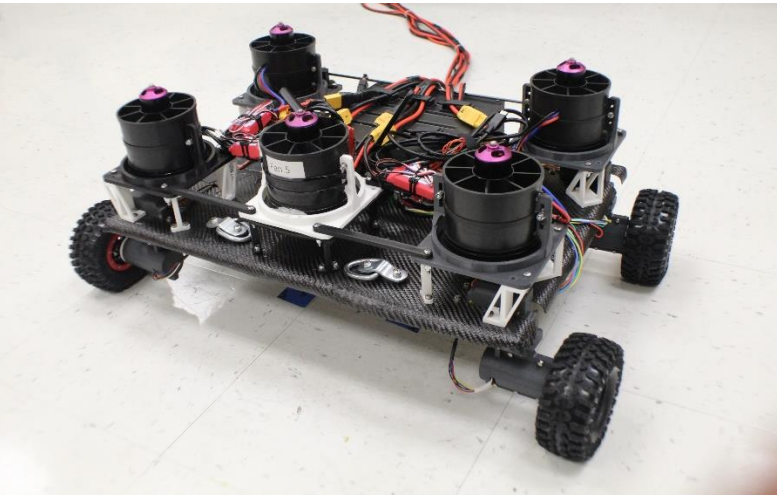
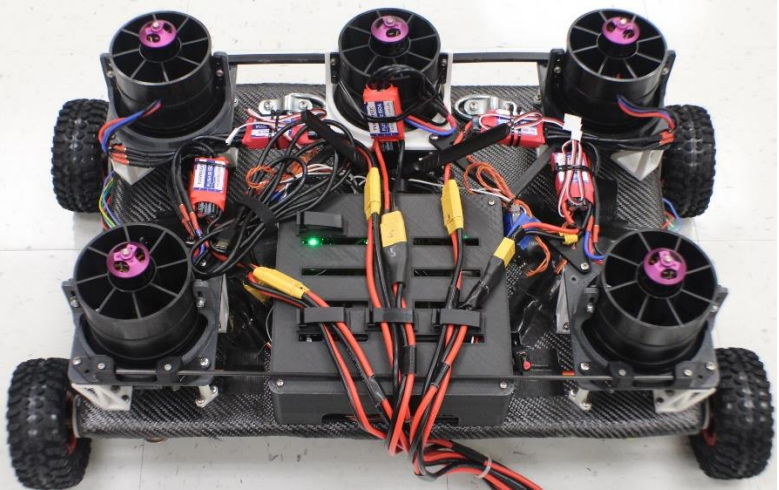
Applied  
Research  
Center



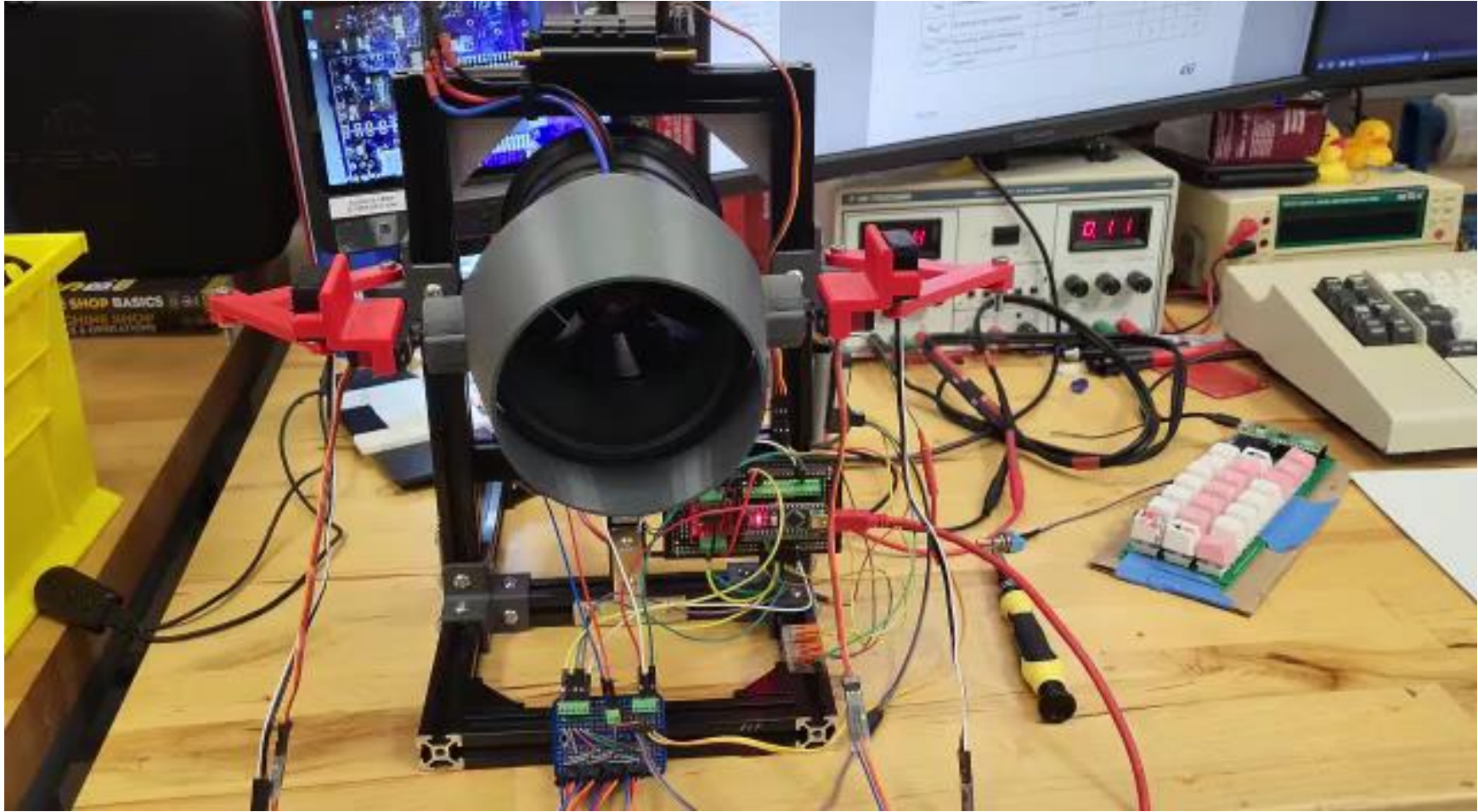
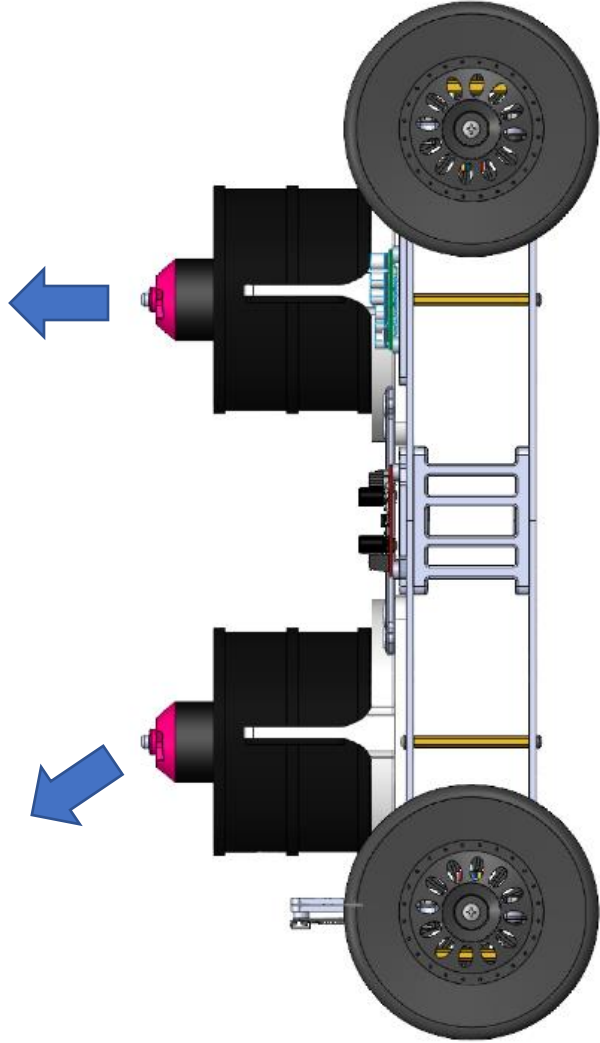
# H-Canyon Concrete Wall Repair



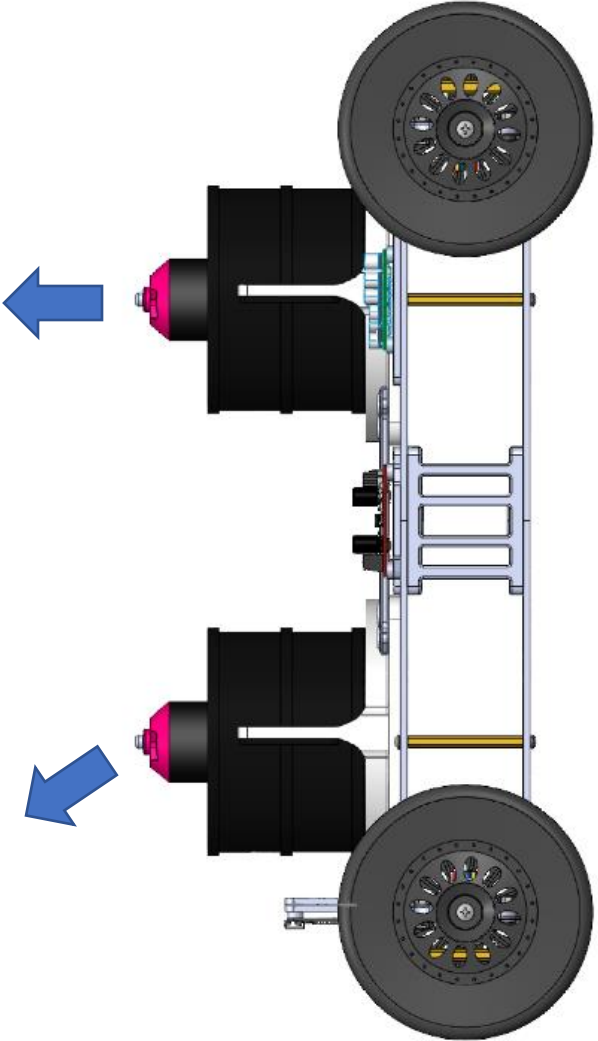
# H-Canyon Concrete Wall Repair



# Thrust Vectoring System



# Compliant Thrust System

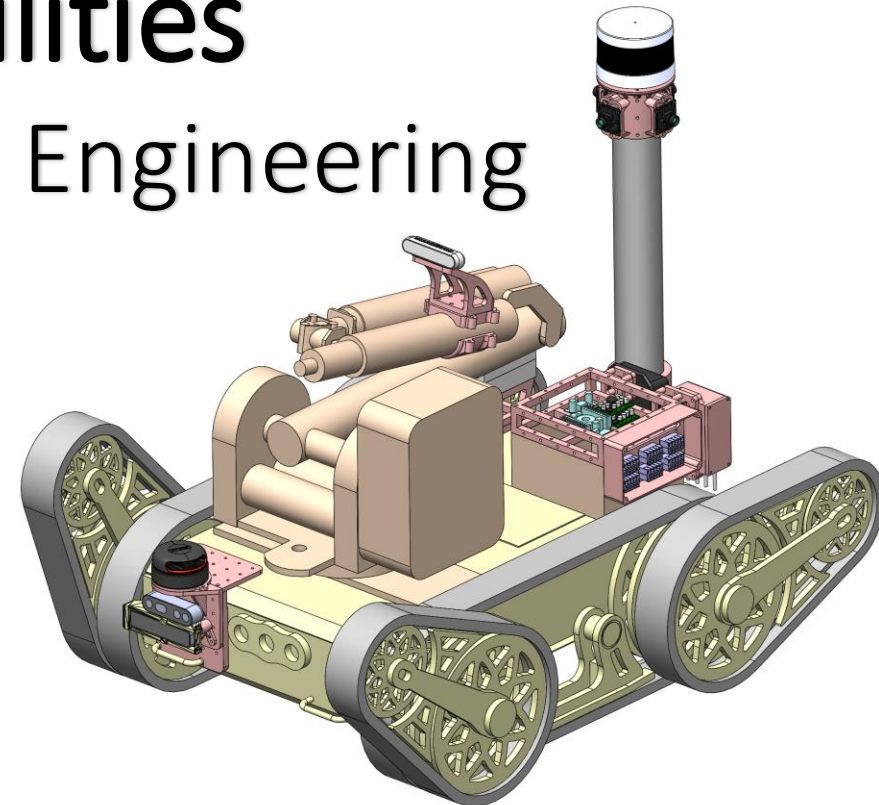


# Long-Term Surveillance using Mobile Platforms

## Part I – Nuclear Facilities

Joel Adams, Ph.D. Mechanical Engineering

DOE-EM



# Long-Term Surveillance 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

## Objectives

Automate aboveground routine inspections, surveillances, and emergency response at Hanford's tank farms and LM's Repositories.

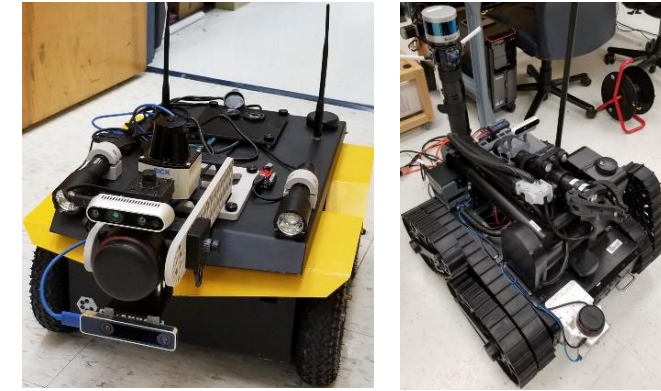
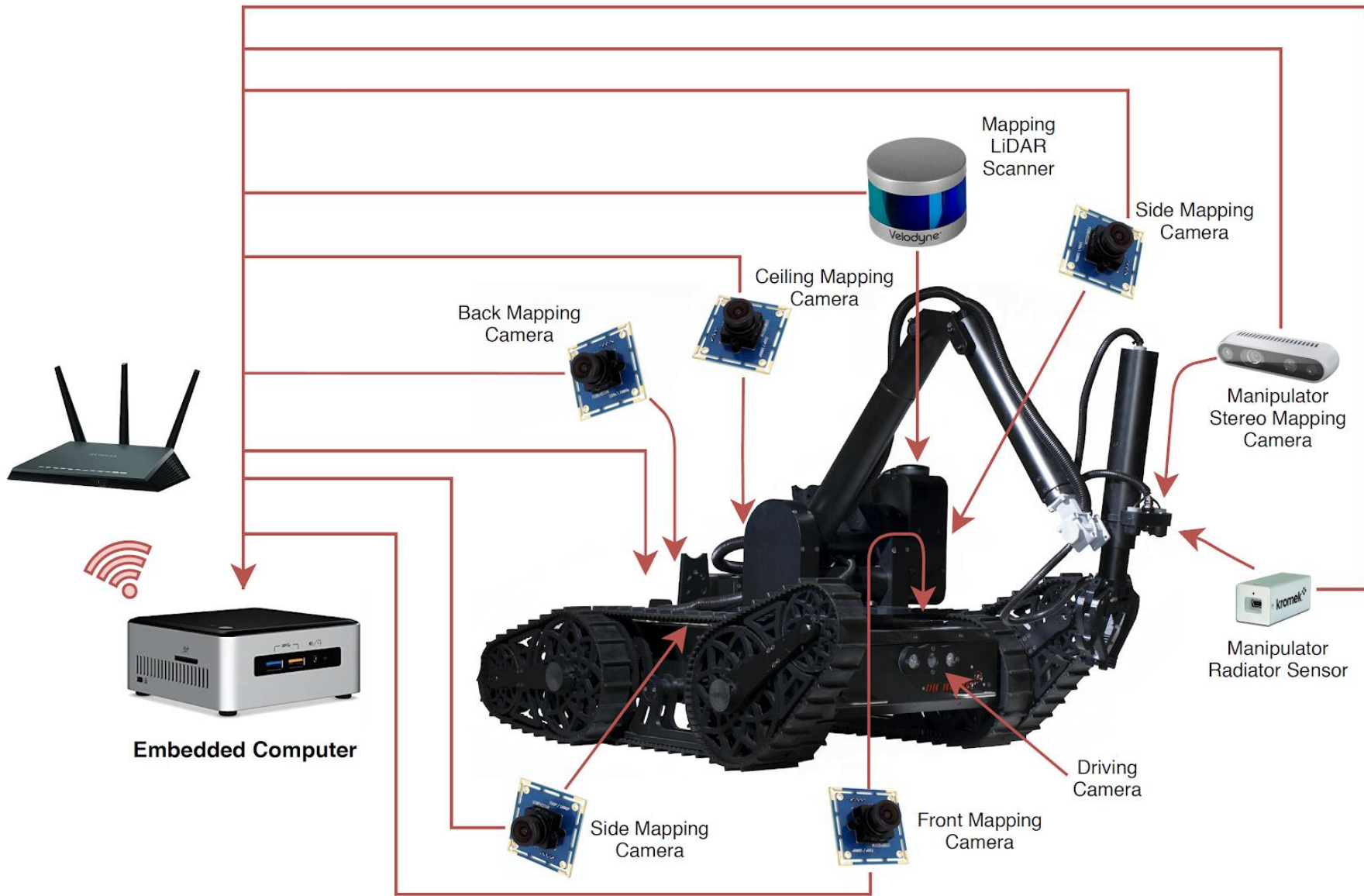


Conventional Site Inspections



# Sensor Fusion

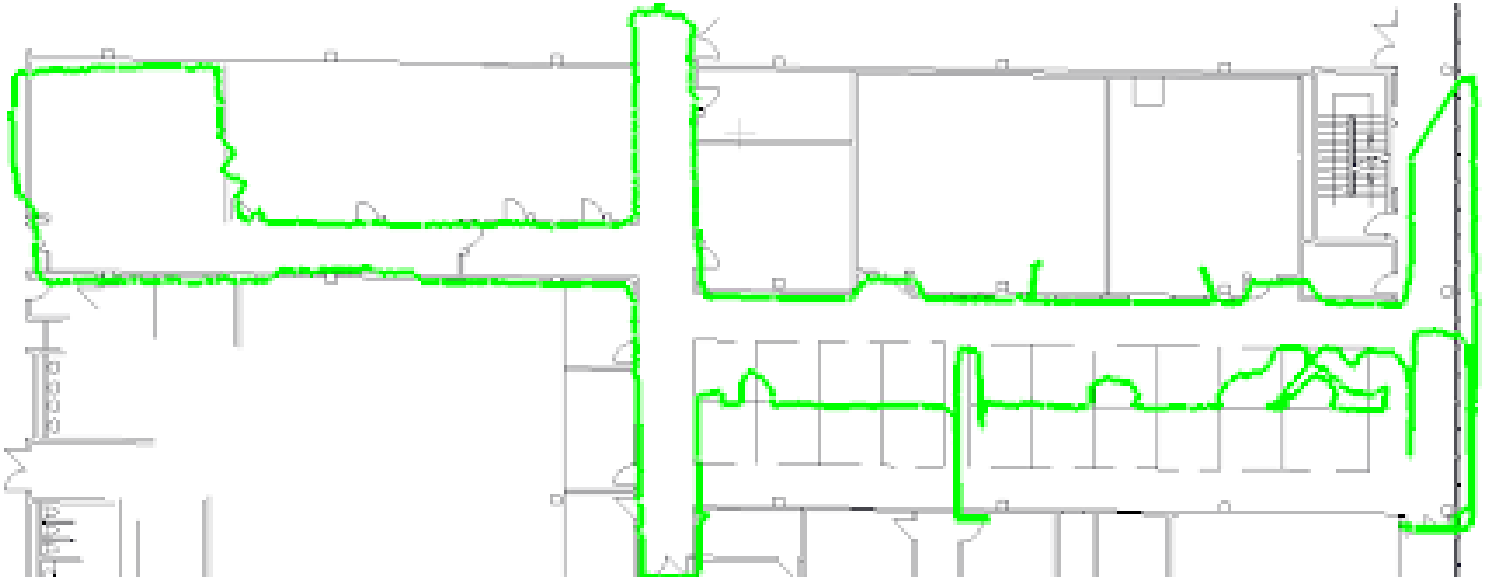
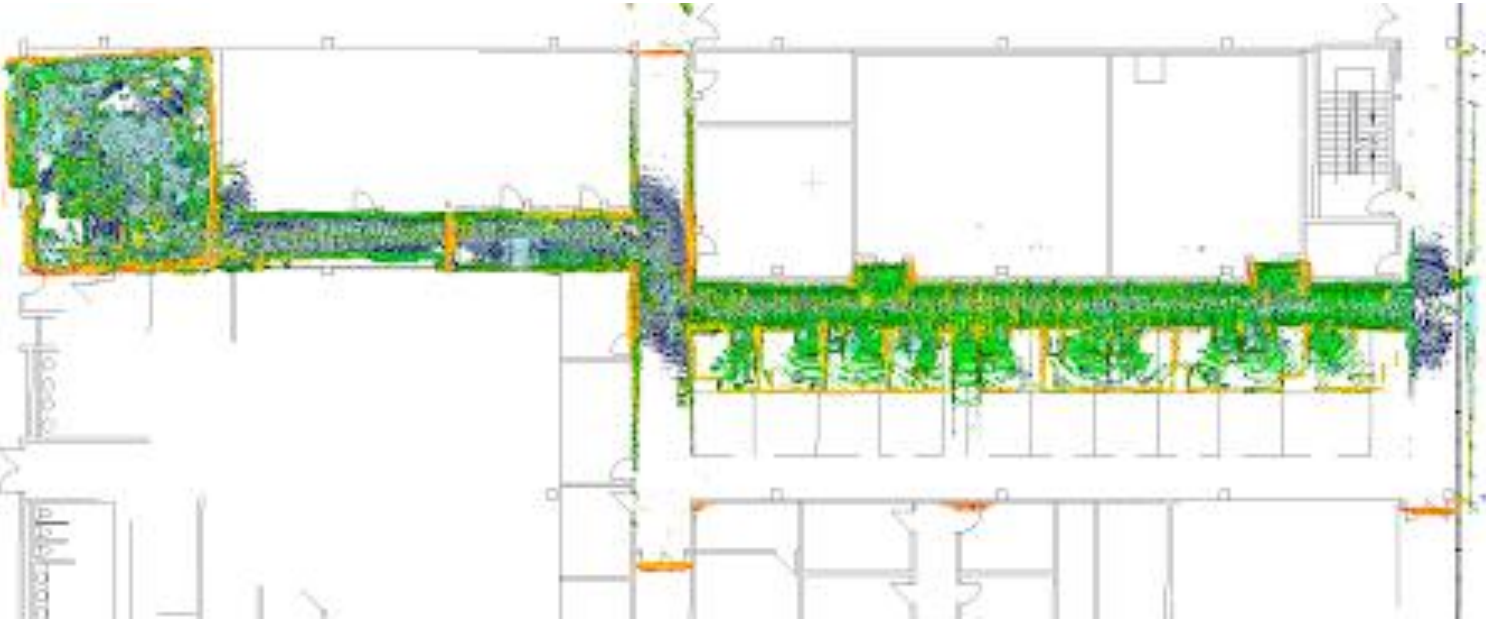
Radiation  
Inertial  
Environmental  
Chemical  
Mapping  
+ Sampling



# Hardware Integration



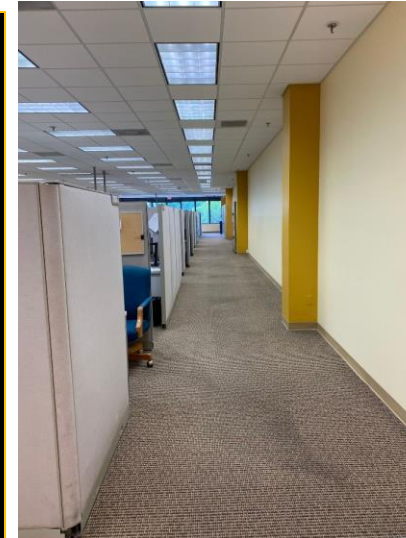
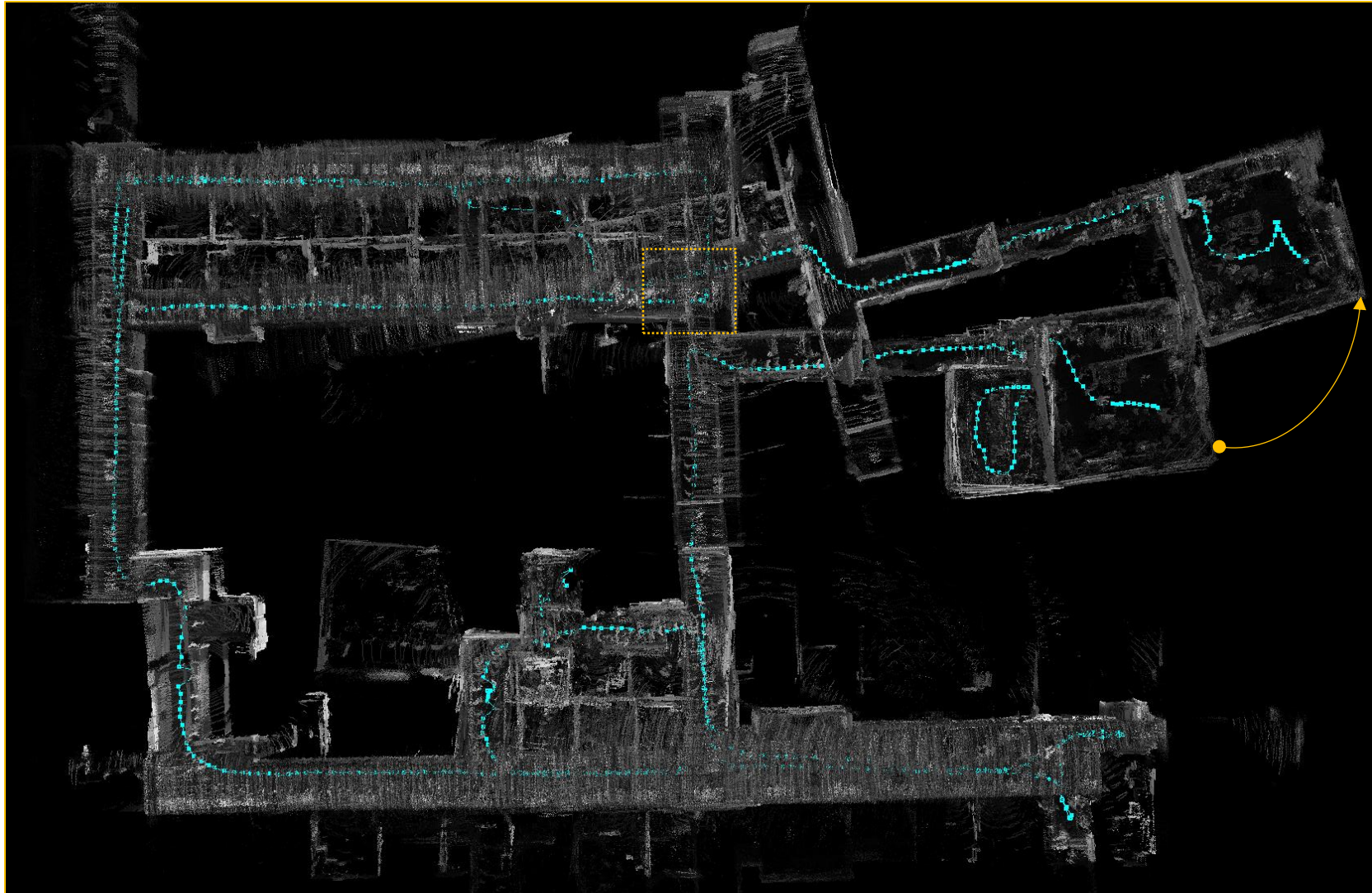
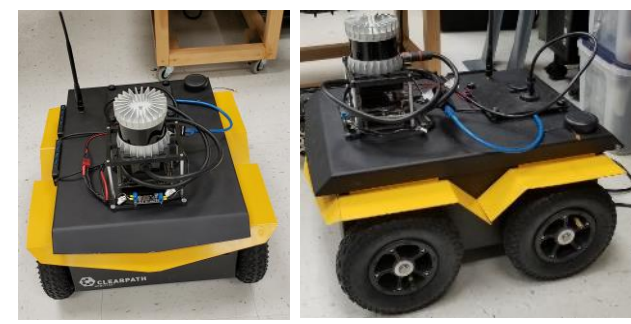
# Autonomous Surveillance



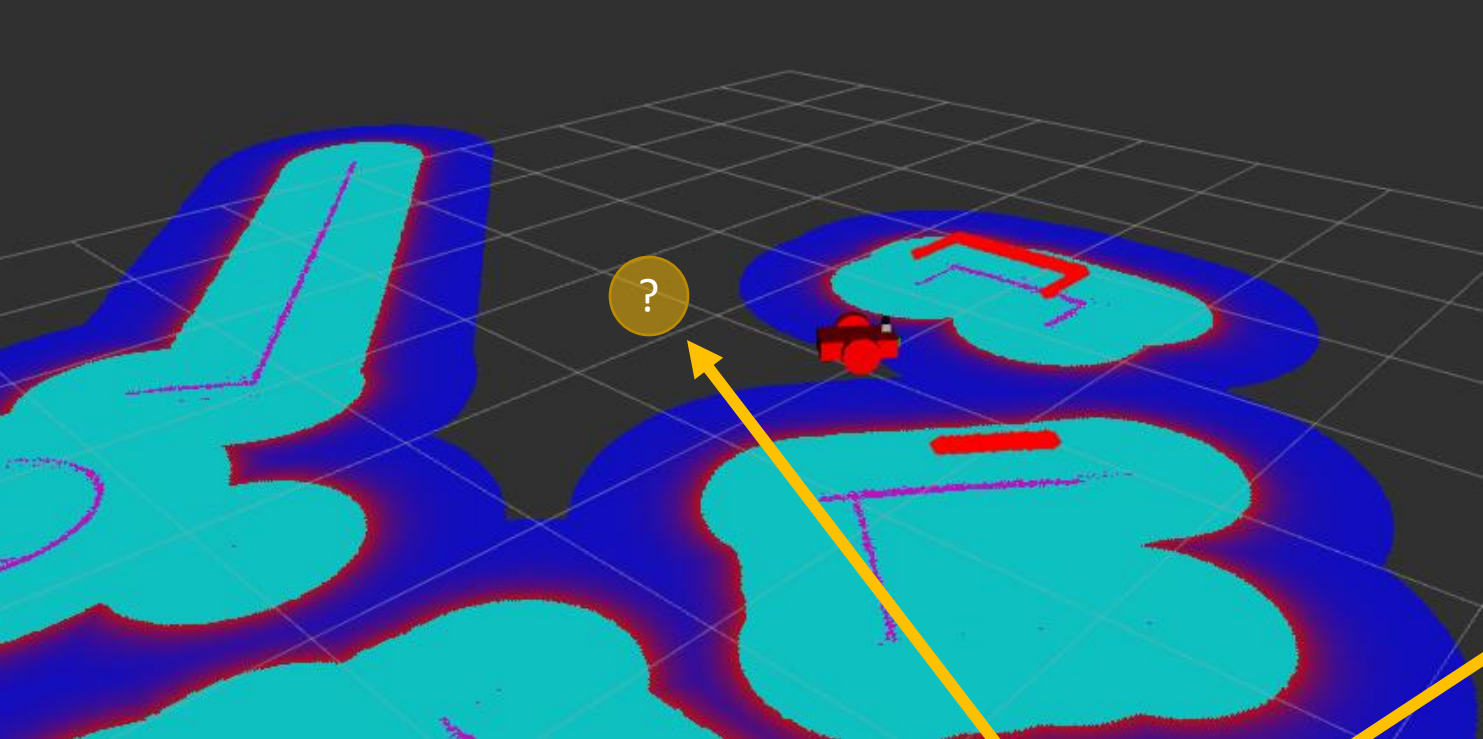
GPS denied, monotonous and indoor environments

# Information-driven planning and control

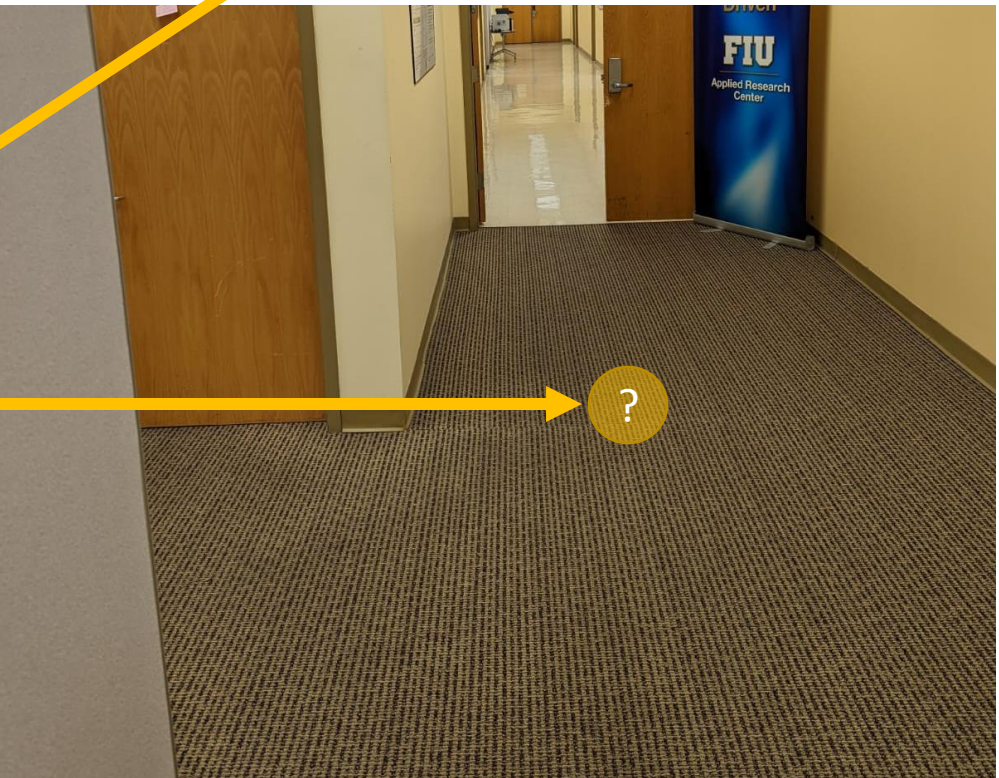
*“The sensing system acts as an agent using the perception of the environment to make decisions about actions to take.”*



# Onboard Terrain Risk-awareness



No obstacle!  
Is safe?



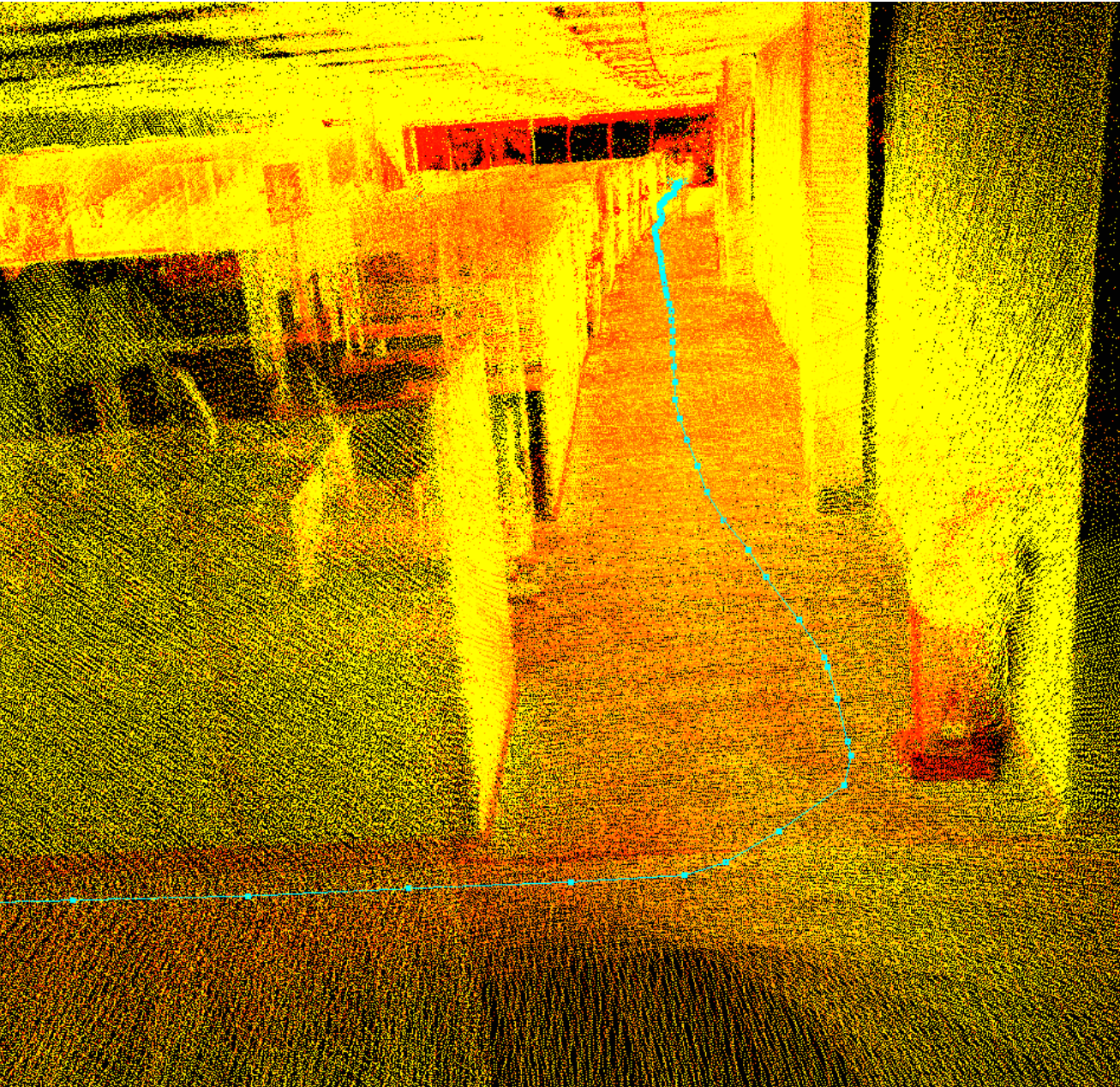
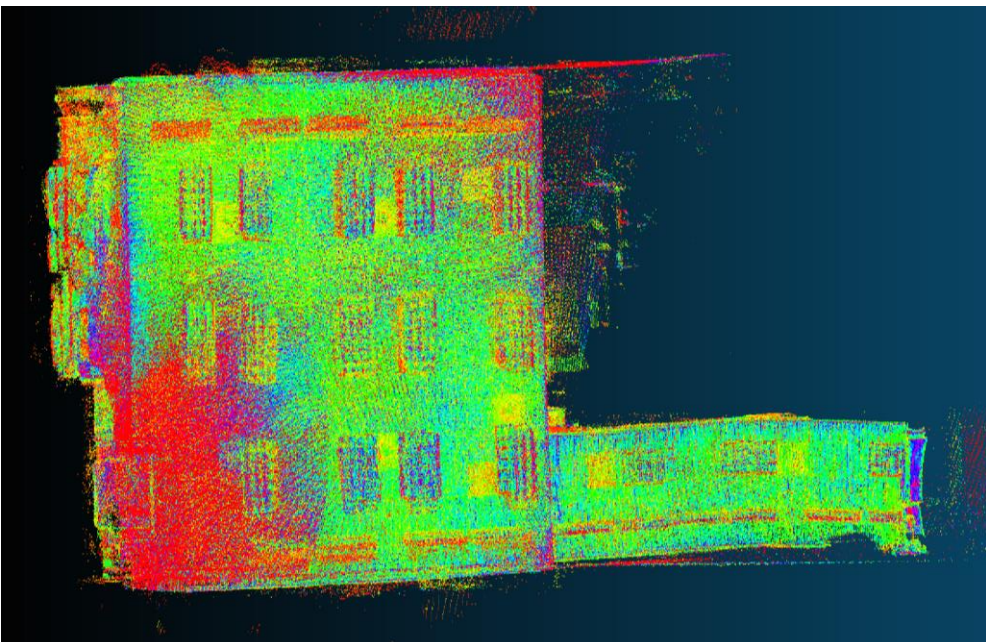
# Intelligent Feature Recognition



Video → Terrain types and Object classification

Point Cloud → Terrain elevations and geometric obstacles

# Digital Twin Reconstruction Over Time



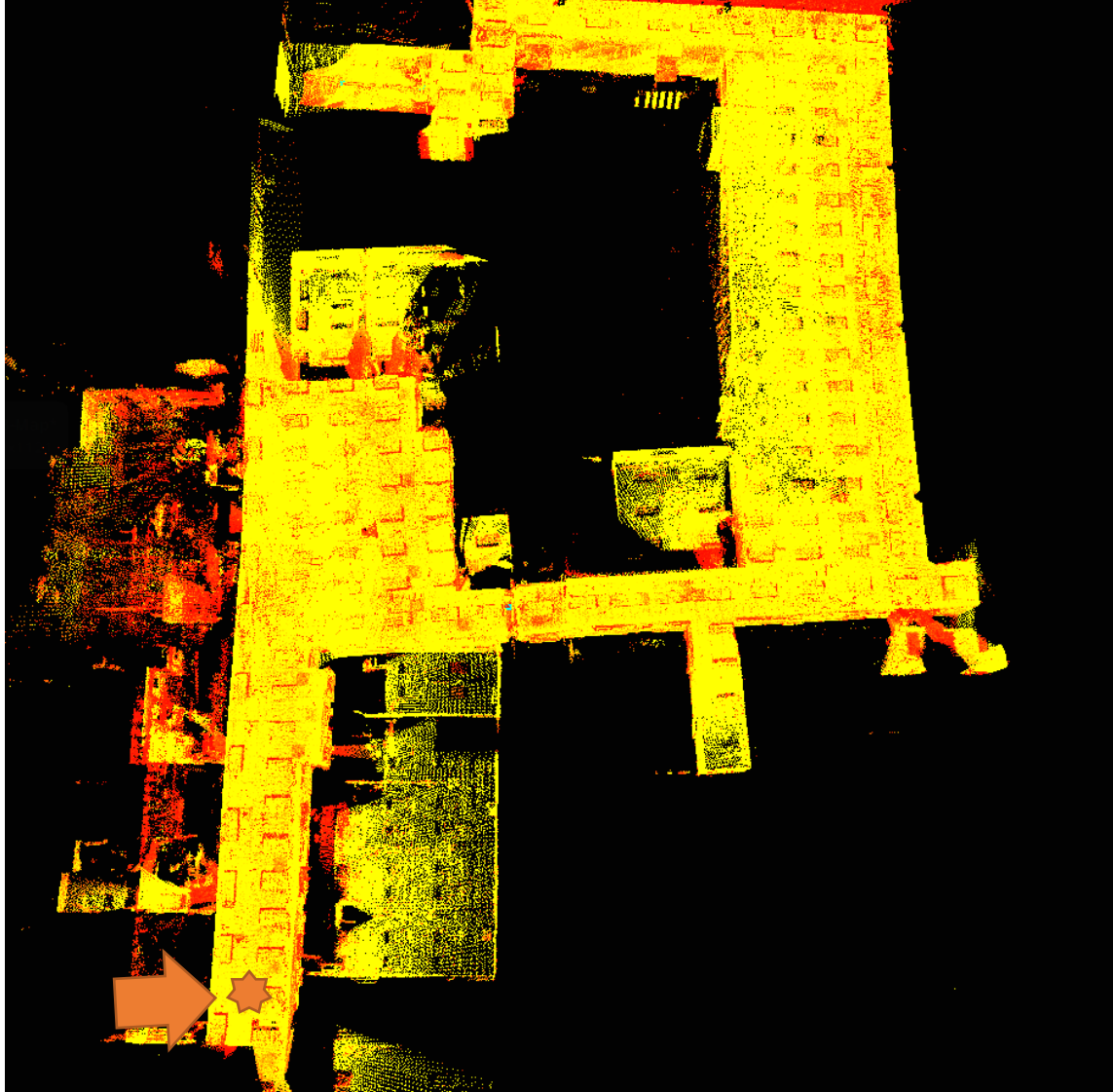
# Surveillance Maps and Events

- Object Detection
- Hallways, doors, offices, windows, furniture, etc
- Landmark labeling based on unsupervised learning

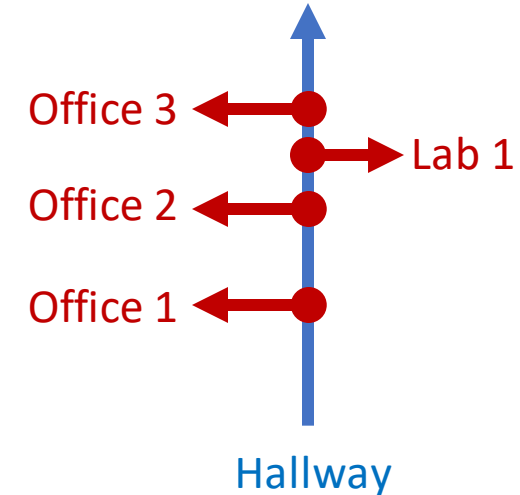
Objects



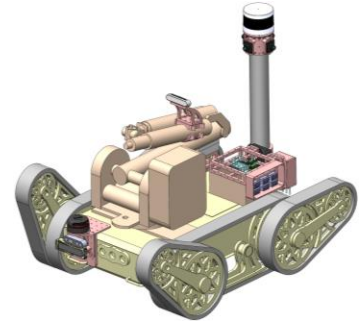
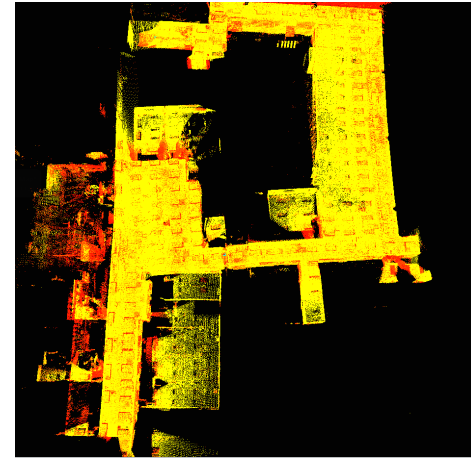
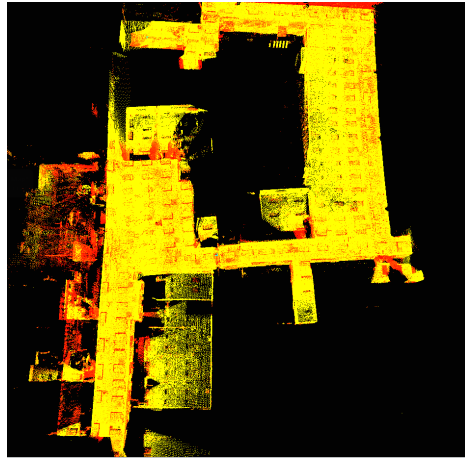
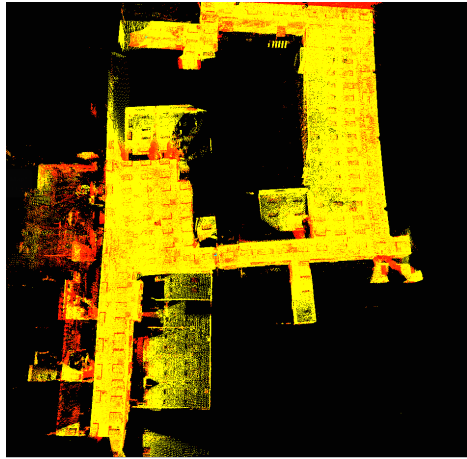
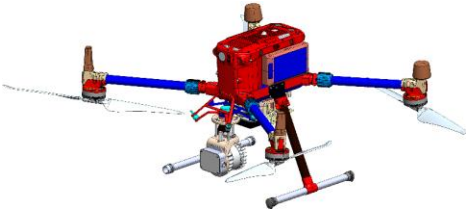
Facility Layout  
Terrain Landmarks



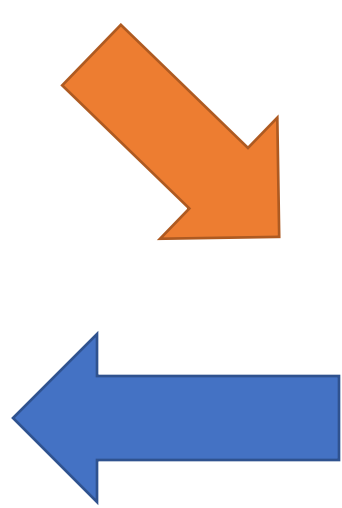
Semantic hierarchical Maps



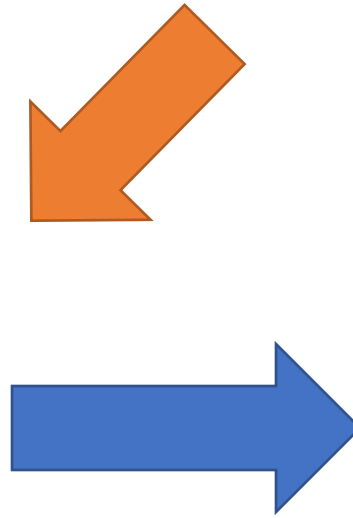
# Automated Data Storage and Management



Inspector



Network-attached storage (NAS)

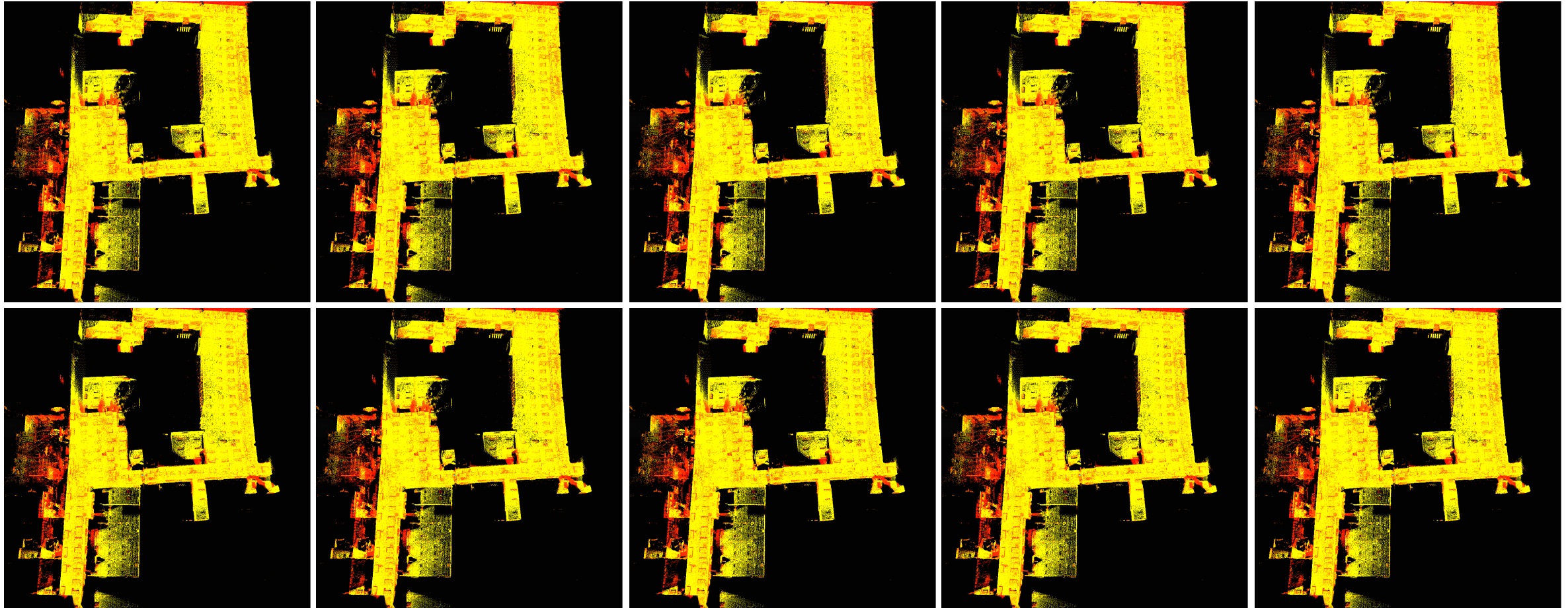


AI

# Data “Time Machine” And Alarms



Graphics processing  
unit (GPU)



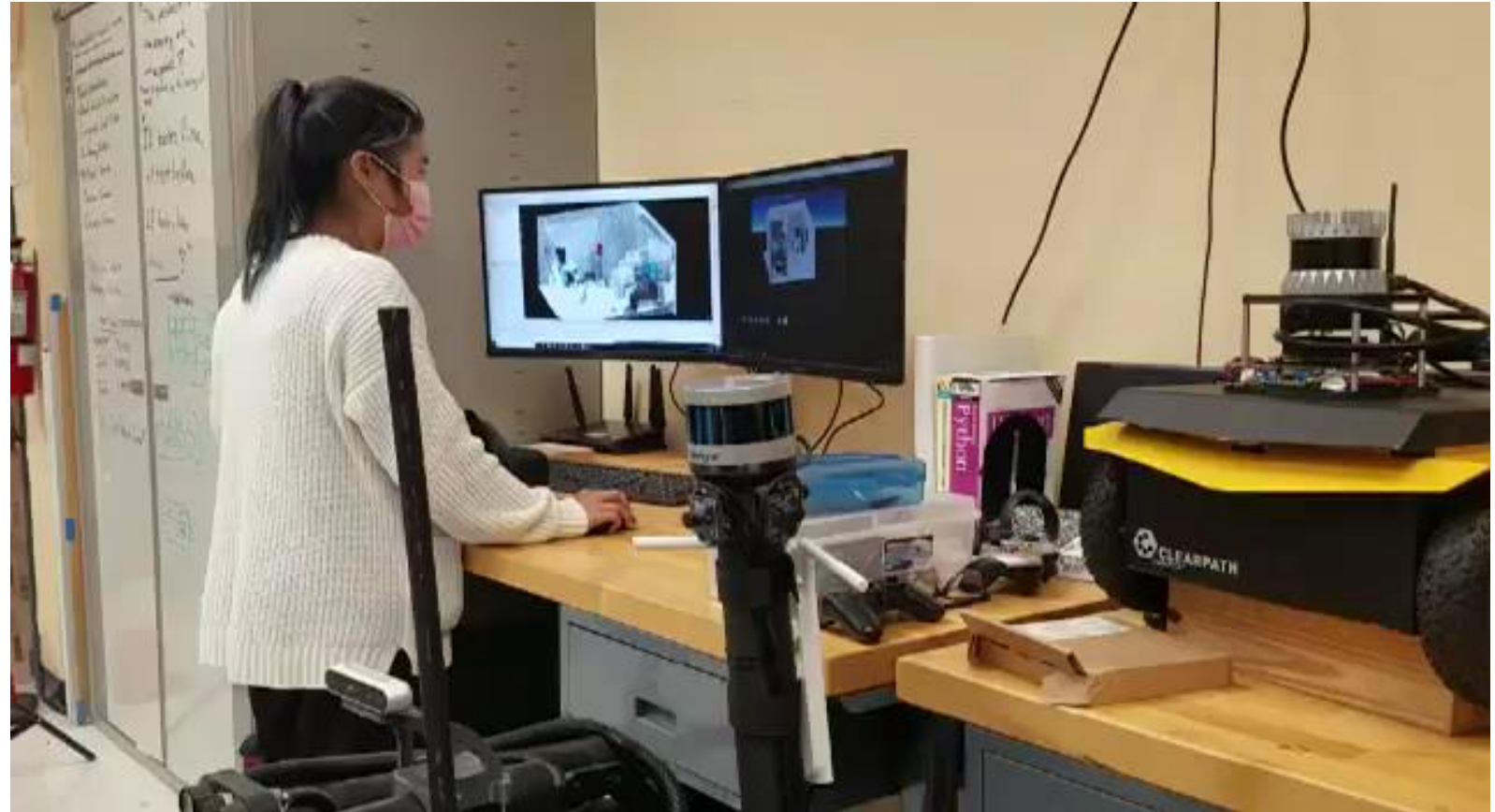
Automate change detection over time (Hands-off Framework)

# Virtual Reality Office Inspections

*“Off-site immersive inspection using captured digital twins”*



Inspectors interact with the data dynamically!

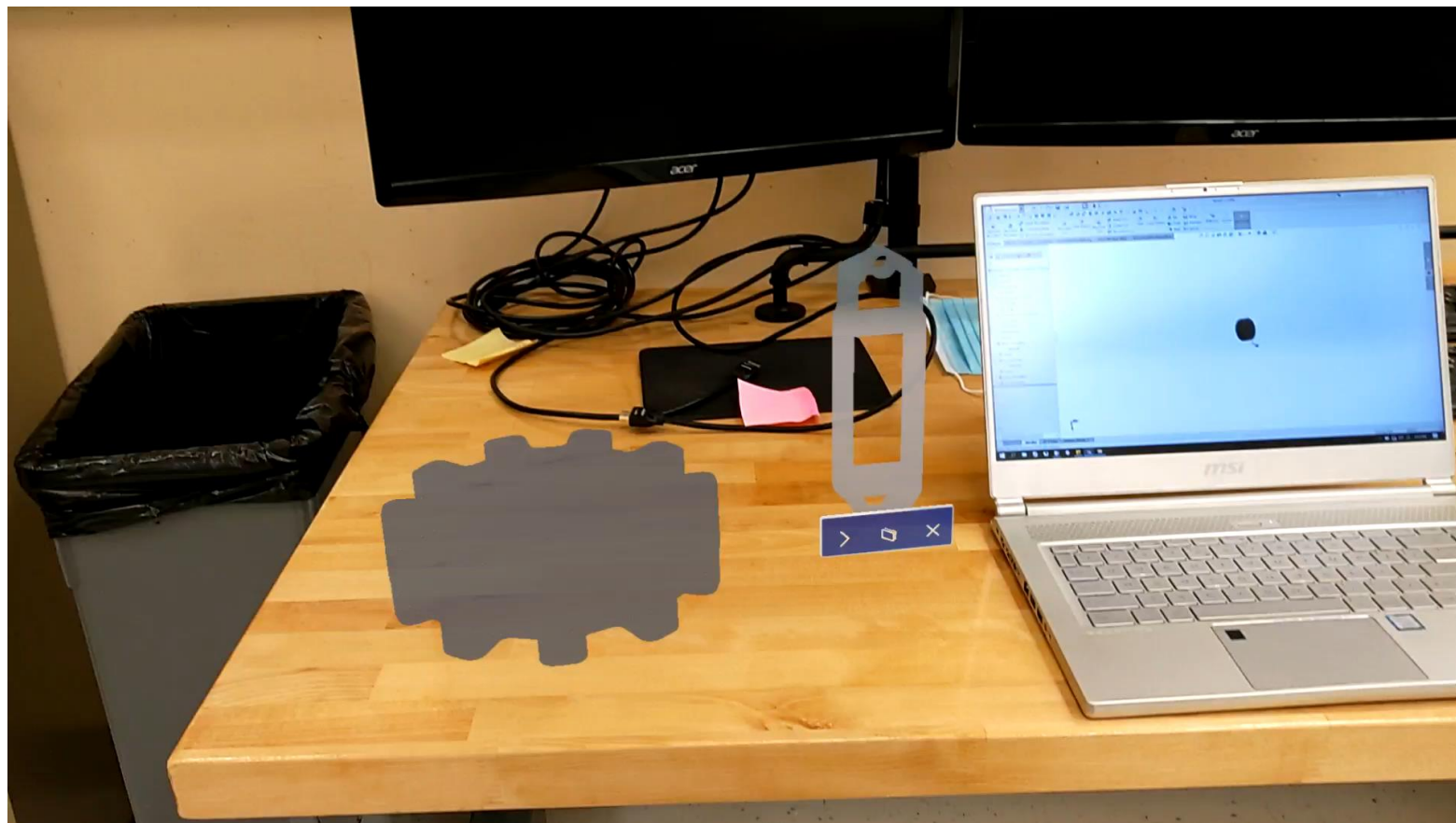


# Augmented Reality Site Inspections

*“On-site inspection using superimpose data analytics”*



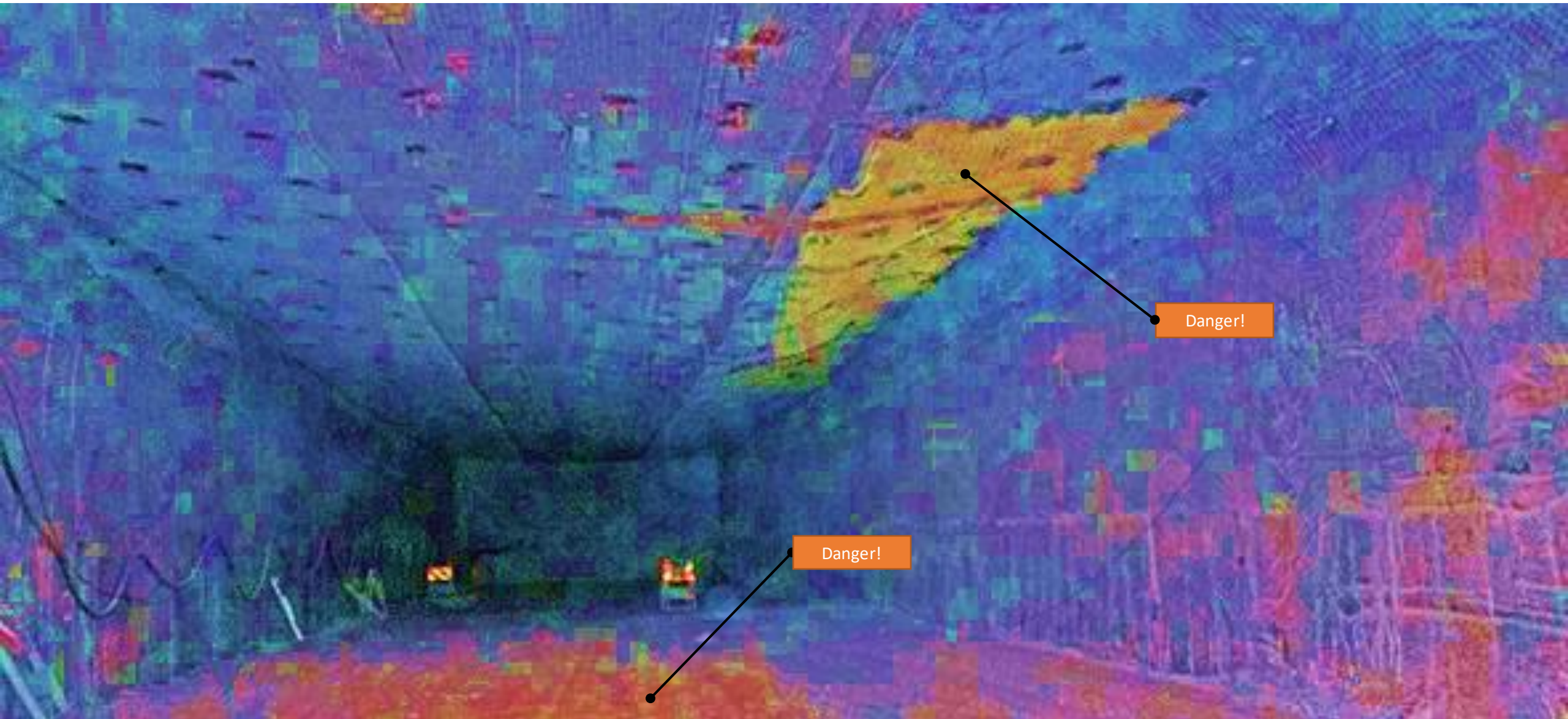
Inspectors interact with the environment during site walkthroughs!



# Augmented Reality Site Inspections



# Augmented Reality Site Inspections

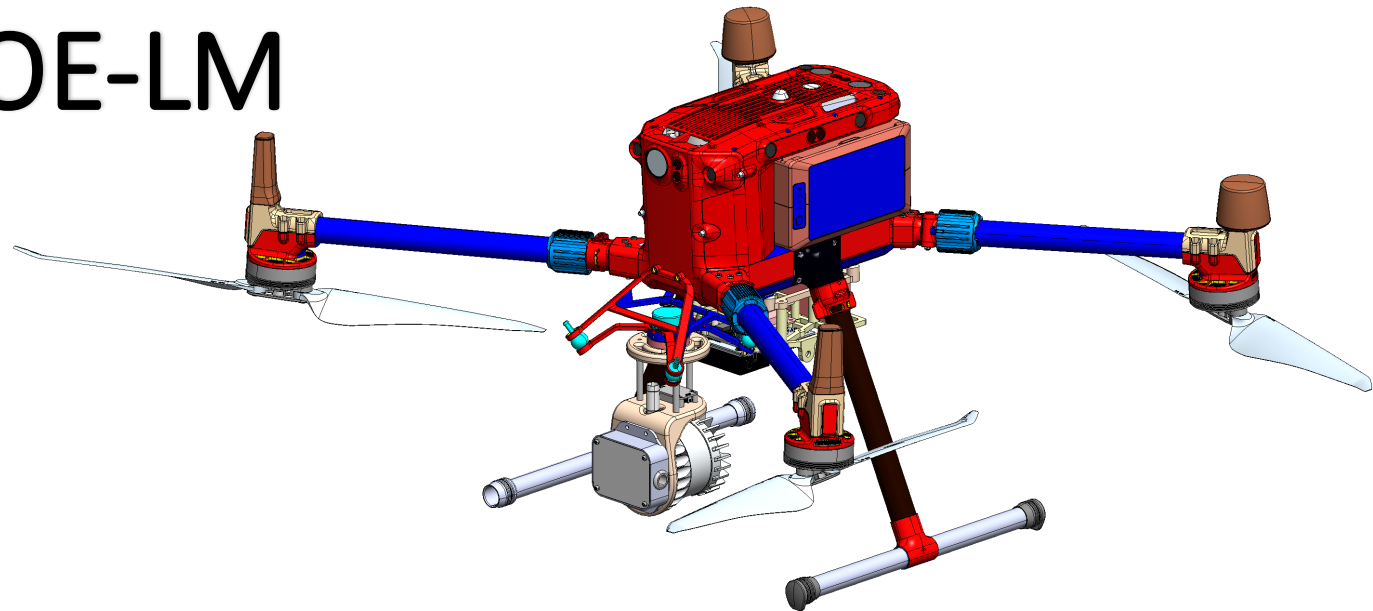


# Long-Term Surveillance using Mobile Platforms

## Part II – Nuclear Repositories

Shawn Cameron, M.S. Mechanical Engineering

DOE-LM



# Climate Resiliency Studies for Long-Term Surveillance of DOE-LM Sites

Develop noninvasive methods to investigate erosion features without risk of radiological exposure in case the radon barrier has been eroded Correlate contributing causes to climate change

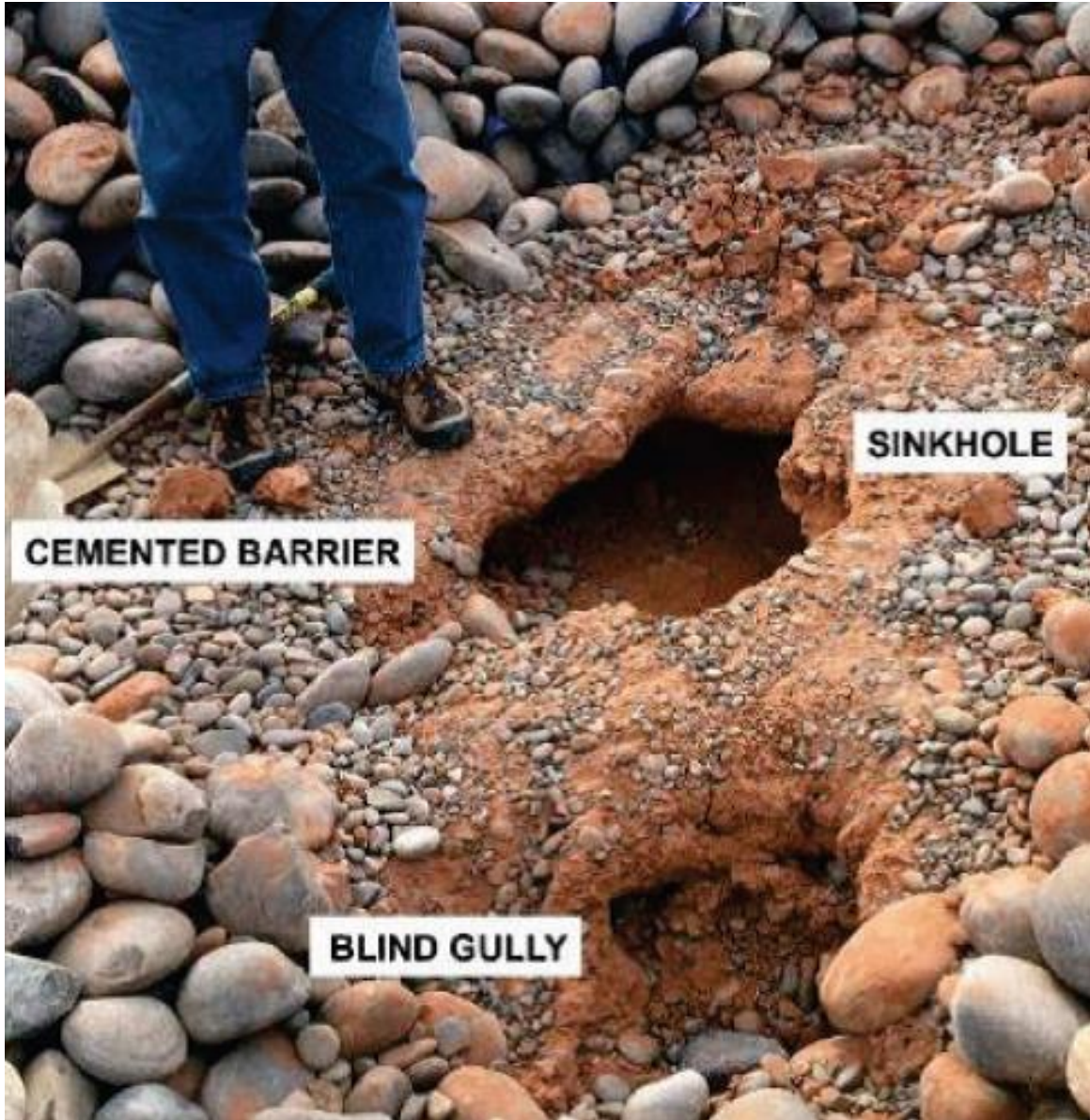
The Mexican Hat Disposal Cell in Utah occupies an area of 68 acres.

The site is also the location of a former uranium ore processing mill.

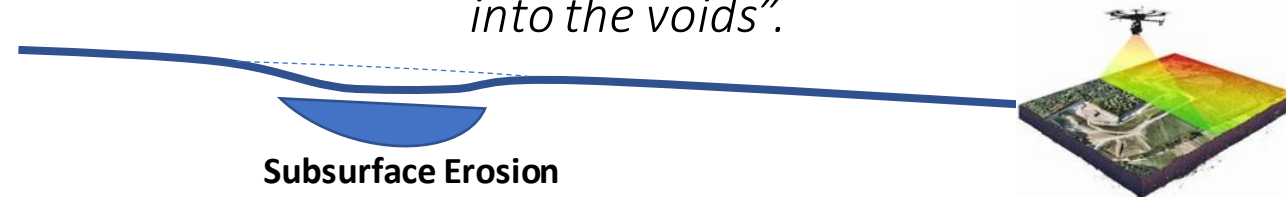
A total of approximately 3.6 million cubic yards (4.4 million dry tons) of residual radioactive materials were stabilized in the cell.



The disposal cell is designed to be effective for at least 200 years



*“The erosion only manifested itself on the surface as slight depressions where the rock cover had subsided into the voids”.*



Erosion discovered in 2017

# Potential Causes

Construction issues including the use of dispersive clays in the interbed layers between the radon barrier and the overlying rock cover.

However, LM does suspect climate change is a contributing cause.

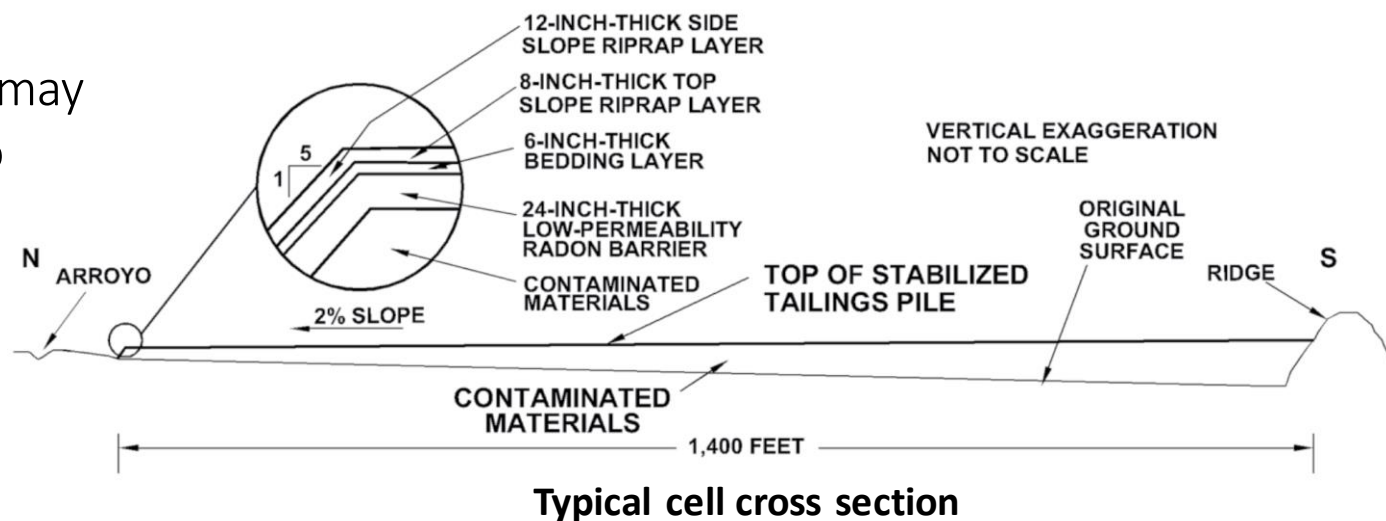
*“Despite the southwest USA being in a terrible drought, climate change projections that precipitation events will be more intense is showing up in the meteorological record for the site.”*



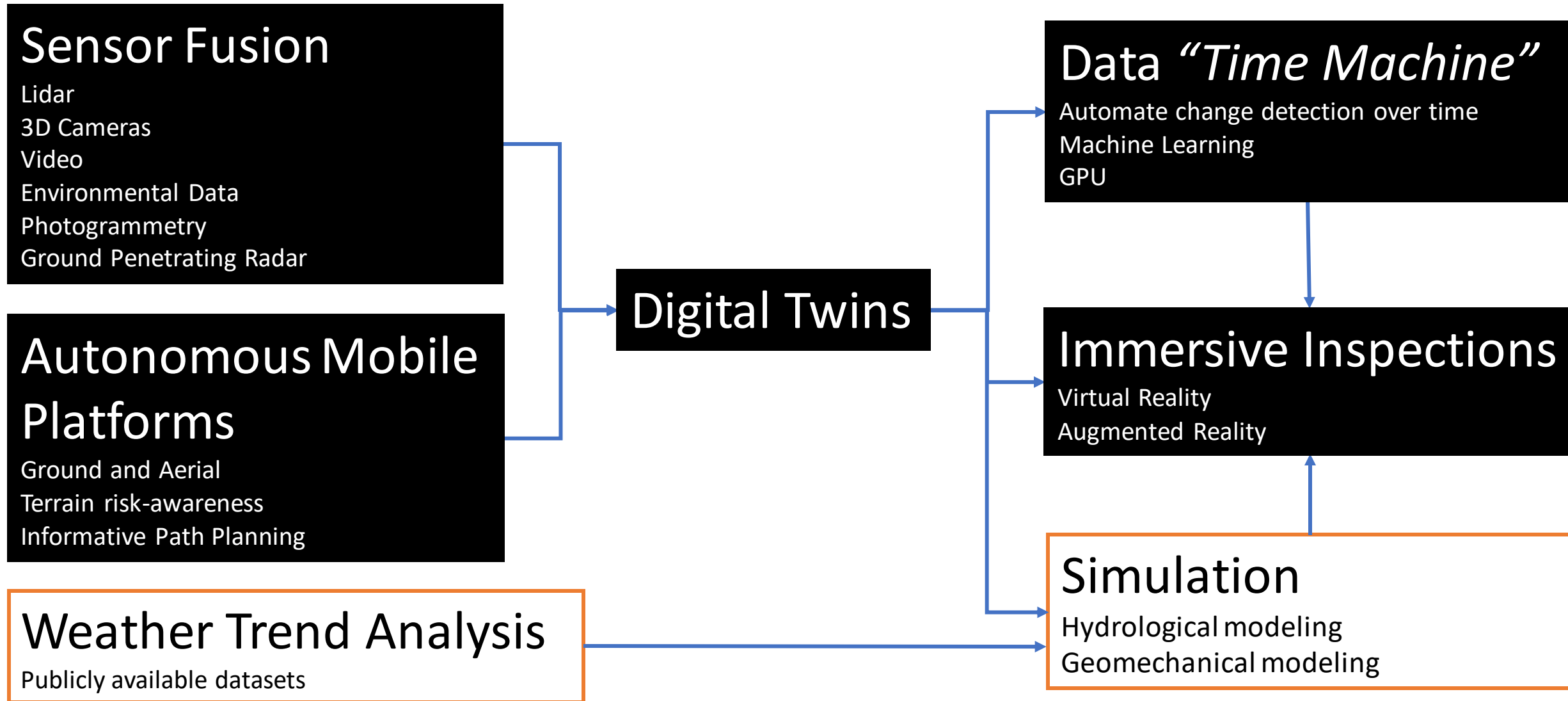
During short, intense rainfall events, the rock cover essentially plays little role in slowing runoff.

Rounded cobbles instead of angular rock probably may also, be a factor since water runs off them and into interstices faster than angular rock.

Other LM's sites may have similar features!



# Disposal Cell Non-evasive Evaluation Framework



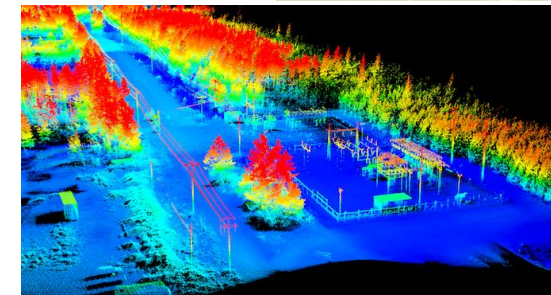
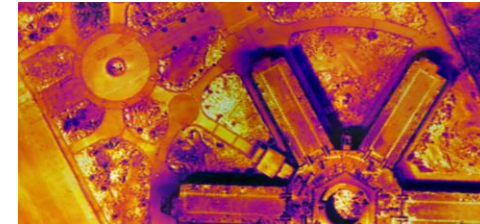
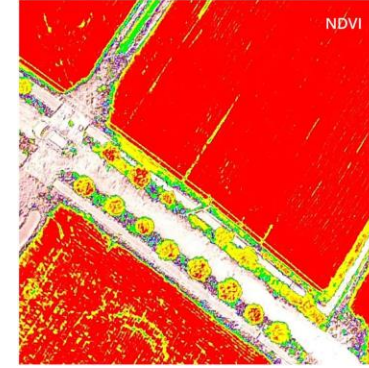
*"Investigate the extent and depth of such erosion features without having to pull back much material since if the radon barrier has been eroded there is a risk of radiological exposure."*

# Aerial Lidar and Photogrammetry Mapping

## Delivery Platform + Sensory + Applications

### Onsite UAV surveys?

- Centimeter-level precision
- Cost-effective
- Meaningful data at your disposal
- Broad custom-built sensory
- See beneath the surface
- Automated data collection
- Machine Learning historical change
- Data-driven decision-making



Multispectral



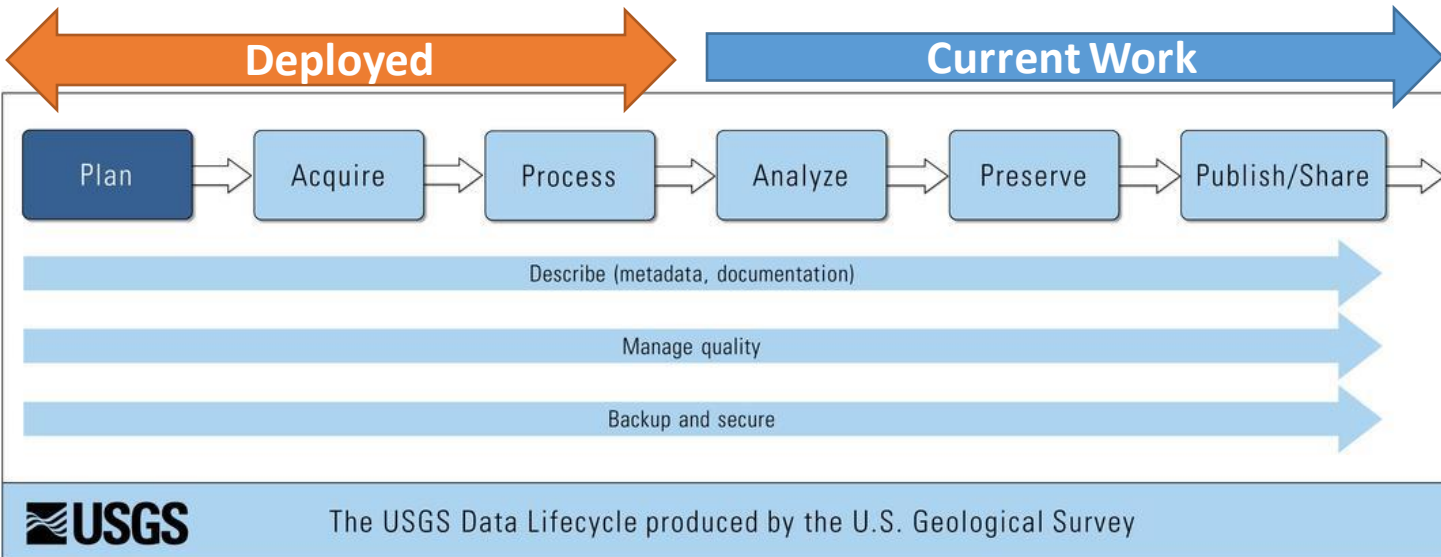
Thermal



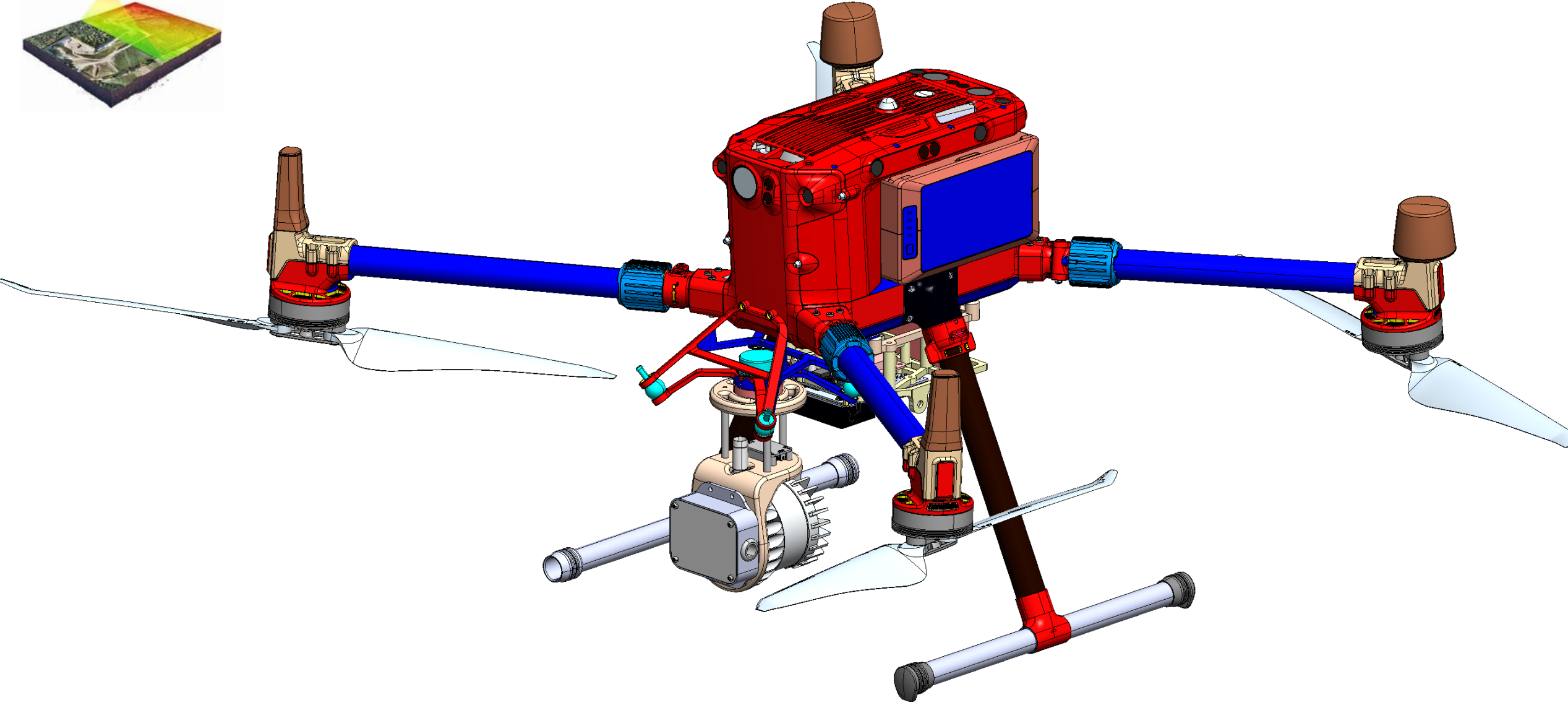
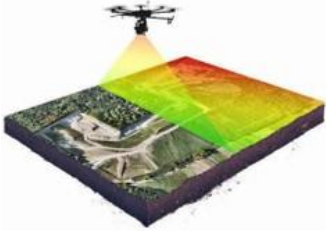
RGB



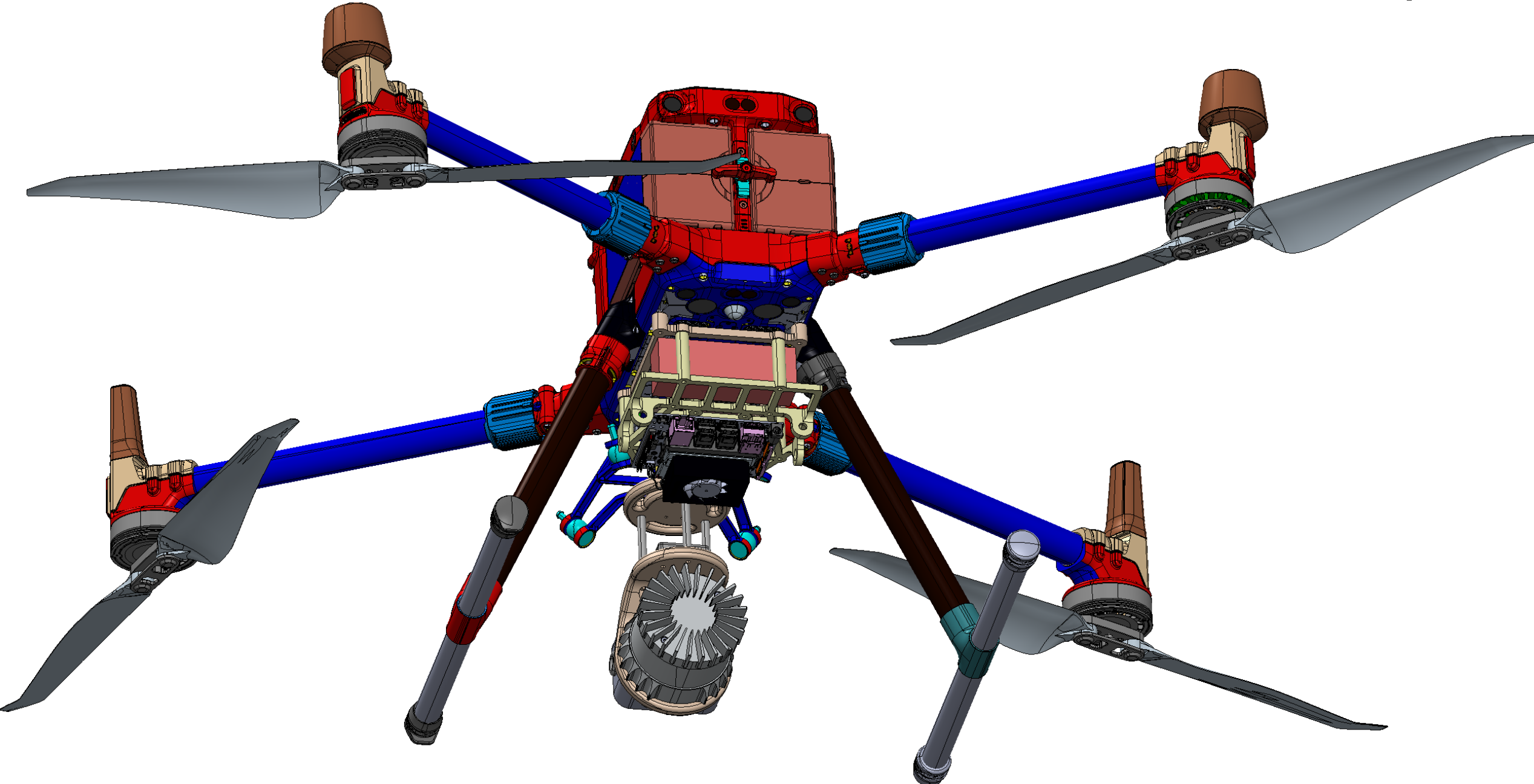
LiDAR



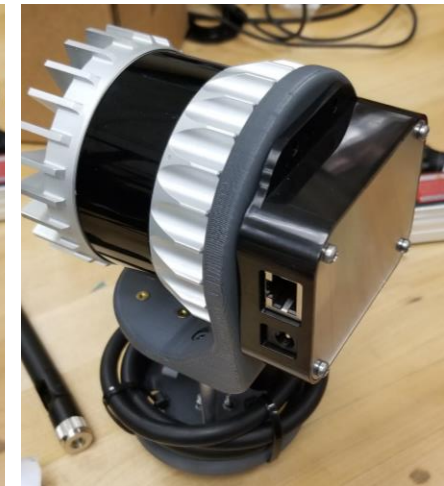
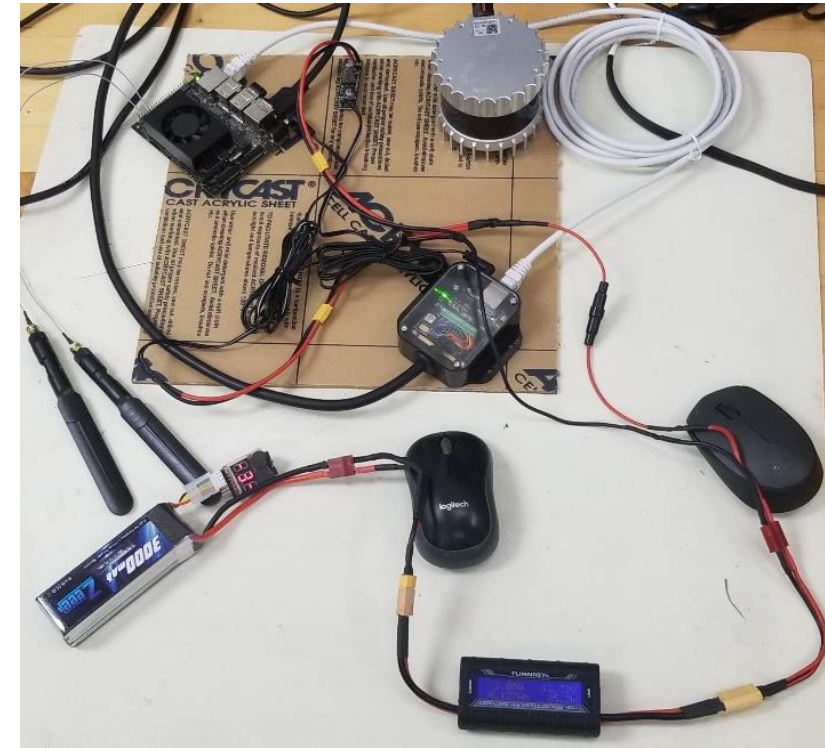
# In-house Lidar System



# In-house Lidar System



# In-house Lidar System



# 2021 Rifle Disposal Cell Deployment at Colorado

The Rifle disposal cell is roughly triangular and measures approximately 3,000 feet on each side; the cover encompasses an **area of 71 acres**.

About 3.5 million cubic yards of contaminated materials with a total activity of 2,738 curies of radium-226 are encapsulated in the cell.

# 2021 Rifle Disposal Cell Deployment



# 2021 Rifle Disposal Cell Deployment



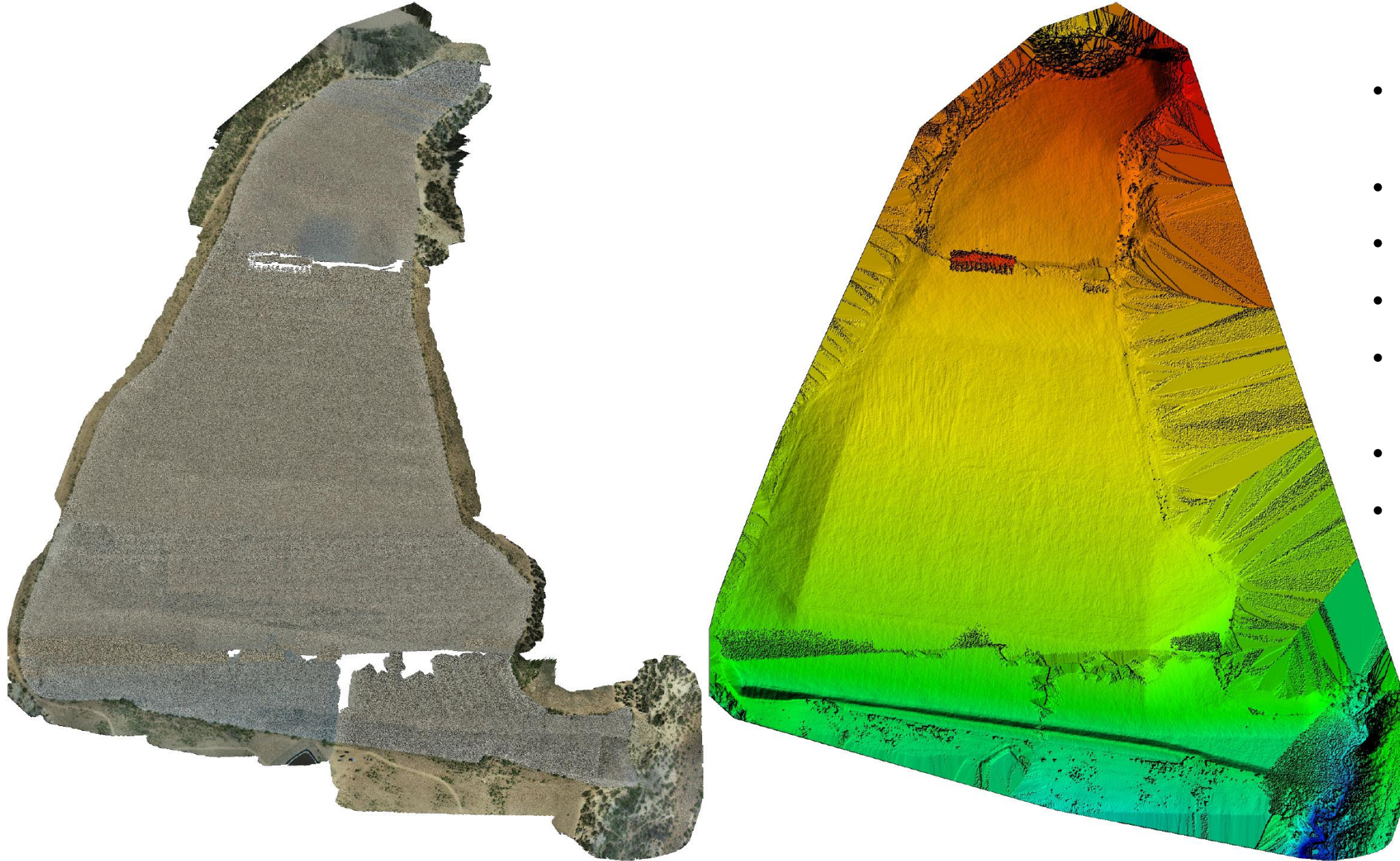
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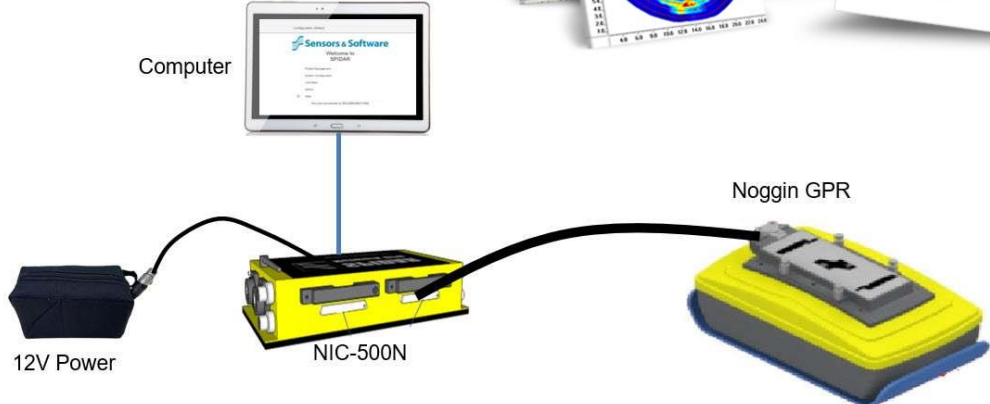
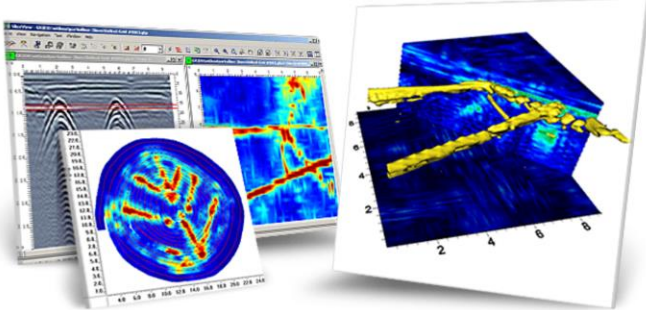
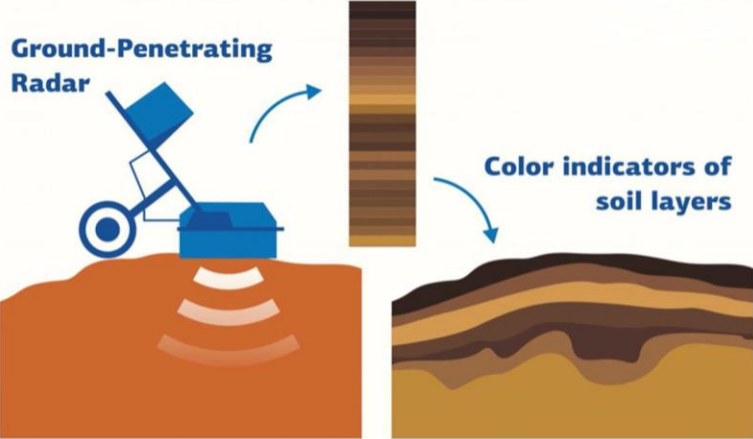
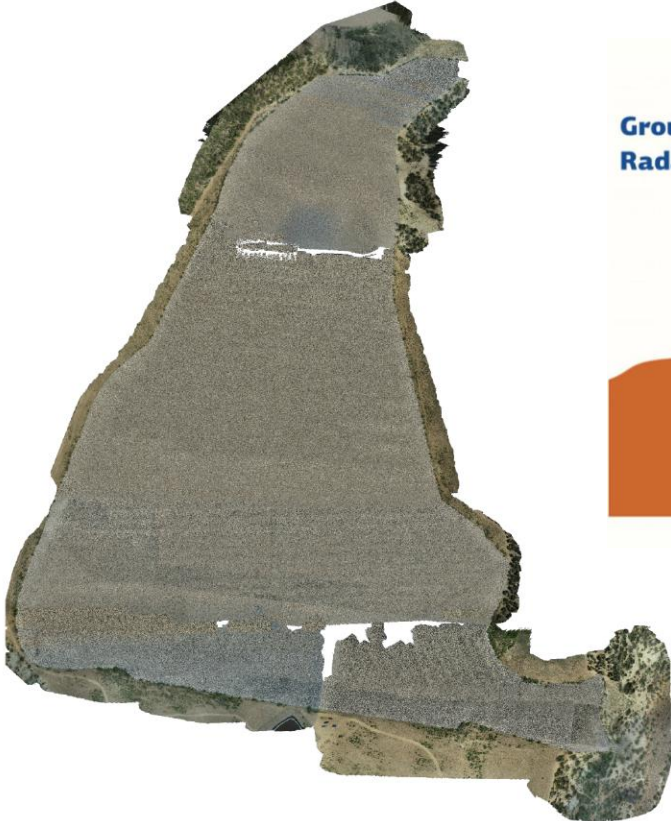
# Rifle's Digital Twin and Elevation Model



- 5,266 high-resolution aerial images
- One week survey
- Crew intensive
- High liabilities
- Restrictive FAA regulations
- Weather constrains
- Extreme heat

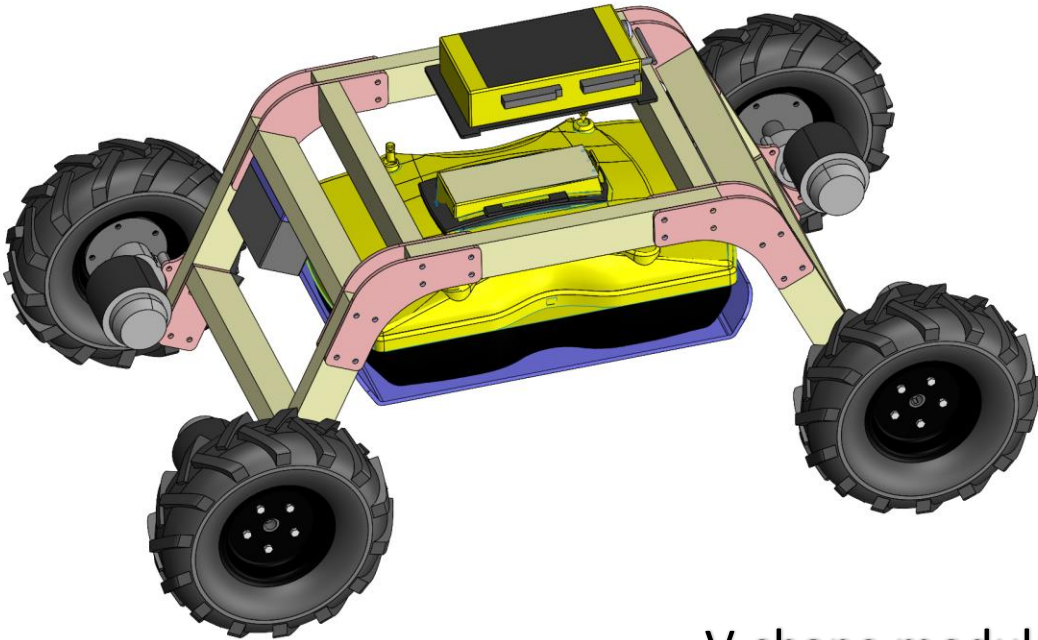
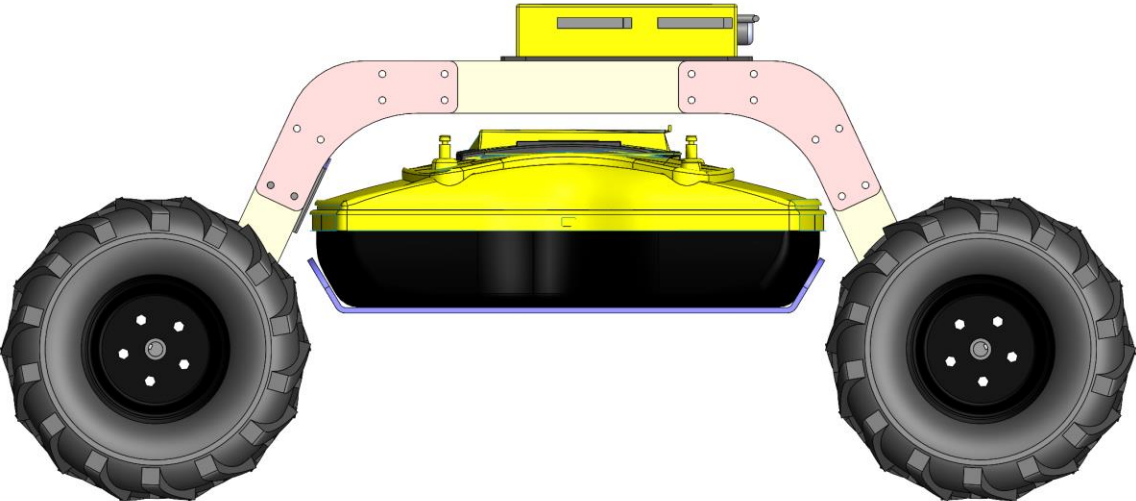
# Ground Penetrating Radar (GPR)

## Autonomous Ground Platform



Application Program Interface (API)

# Autonomous Platform Ground Penetrating Radar (GPR)



V-shape modular frame



# Exoskeleton for Glovebox Applications

Rodrigo Ramon, Post-Doctoral Associate

**DOE-EM**



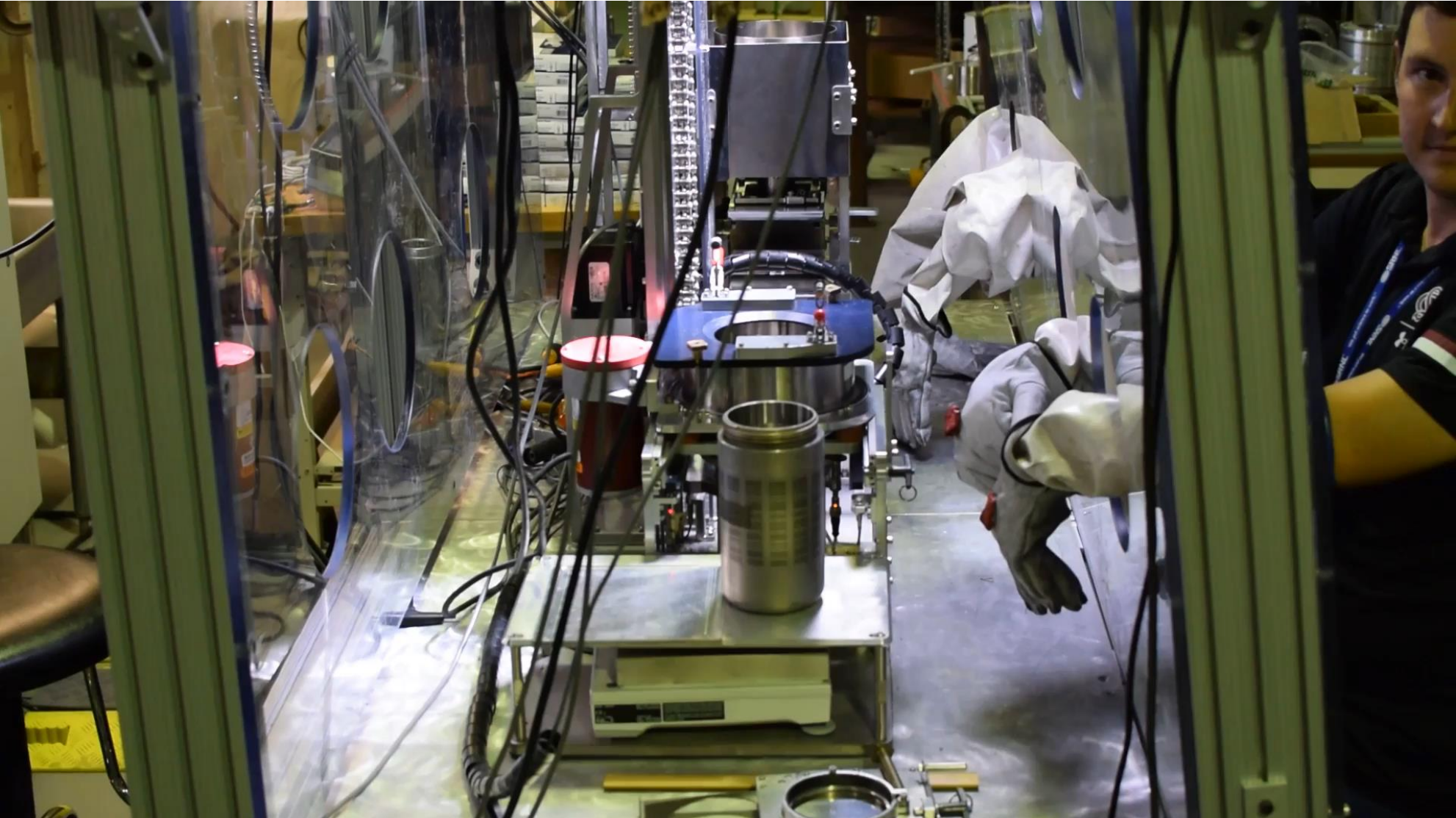
# Glovebox Automation



Quantify human fatigue during glove box operations and to evaluate the feasibility of a dexterous robotic manipulator for use in glove boxes and hot cell



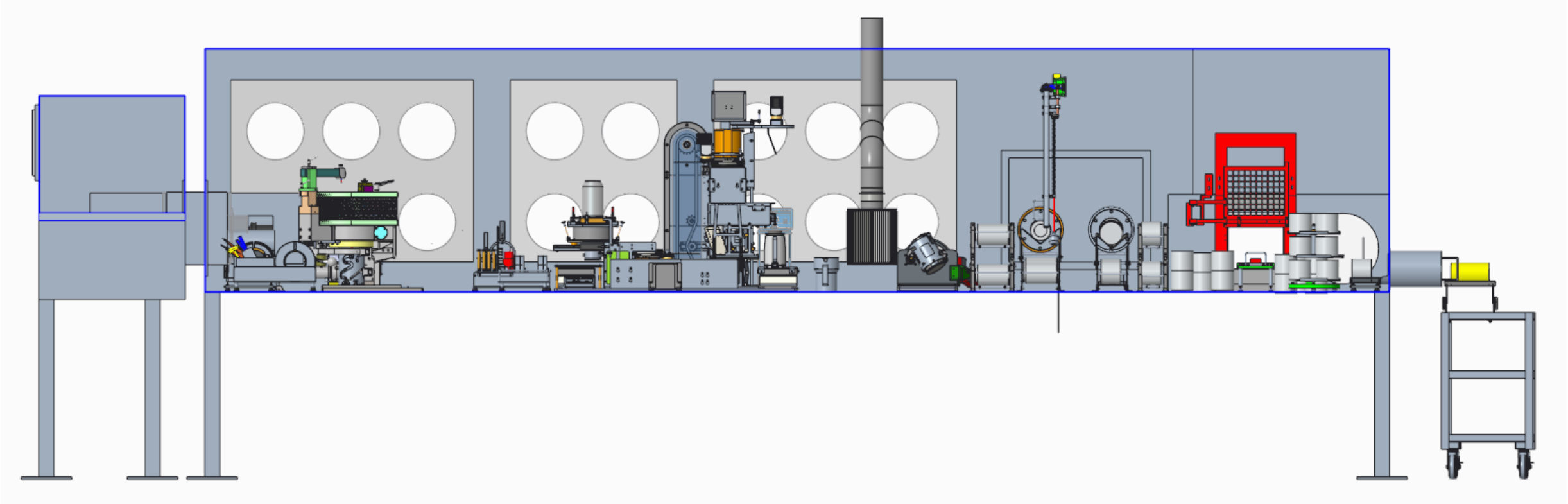
# Glovebox Automation



# SRNL's Surplus Plutonium Disposition Glovebox Process



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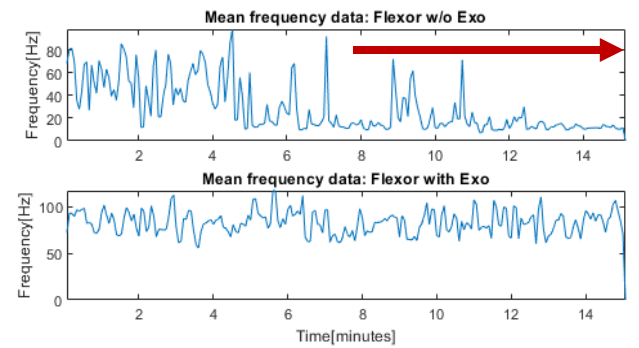
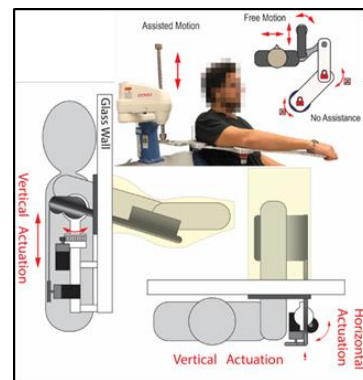
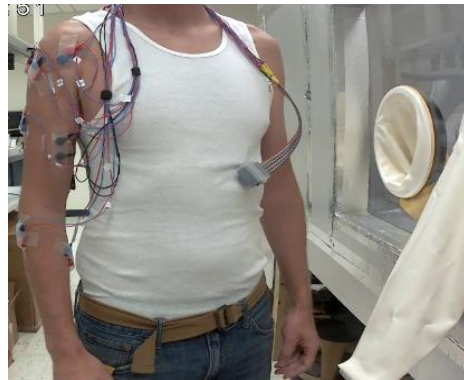
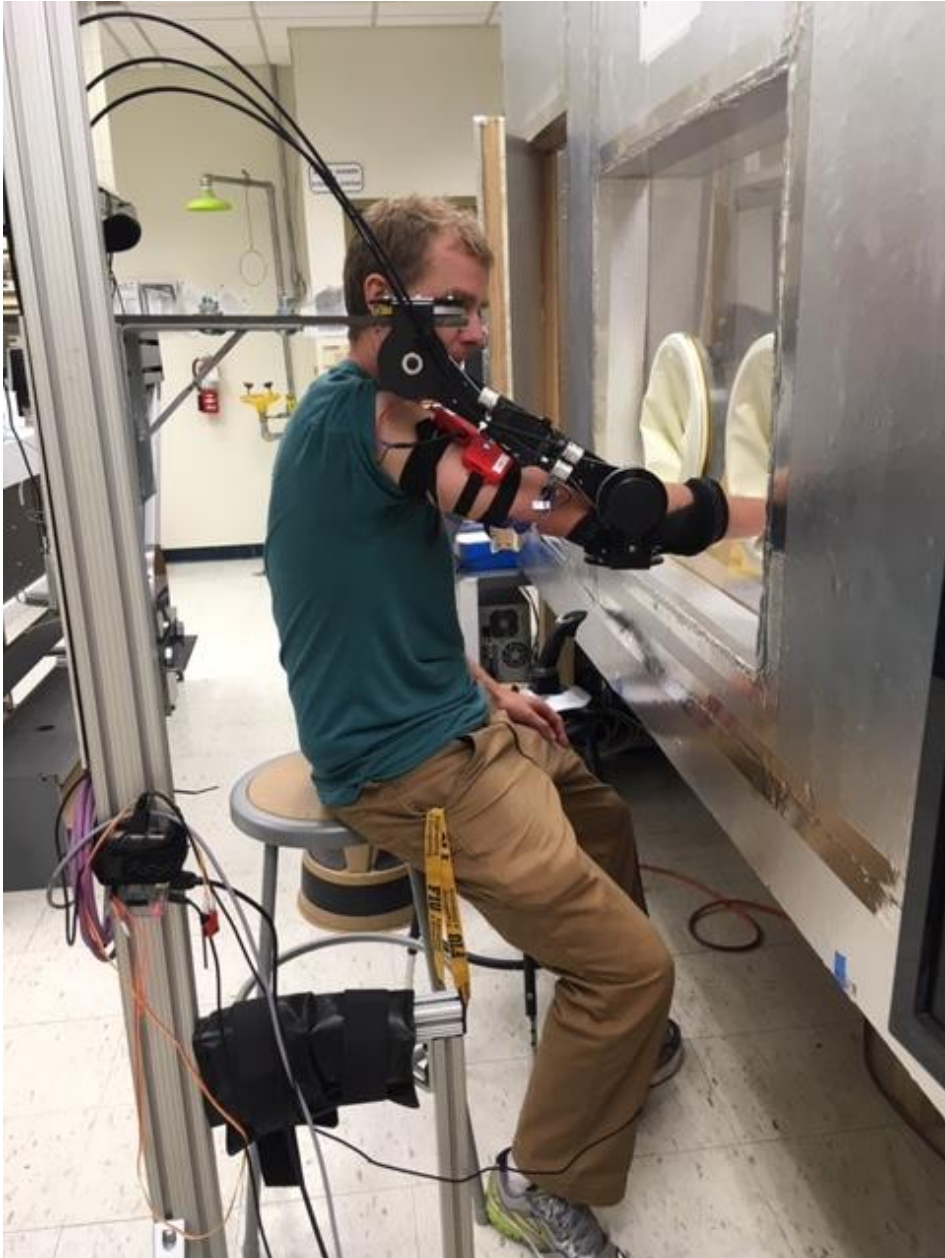


Blend Can Loading System

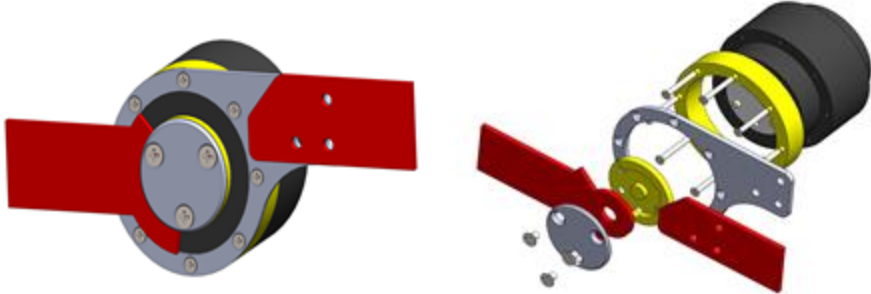
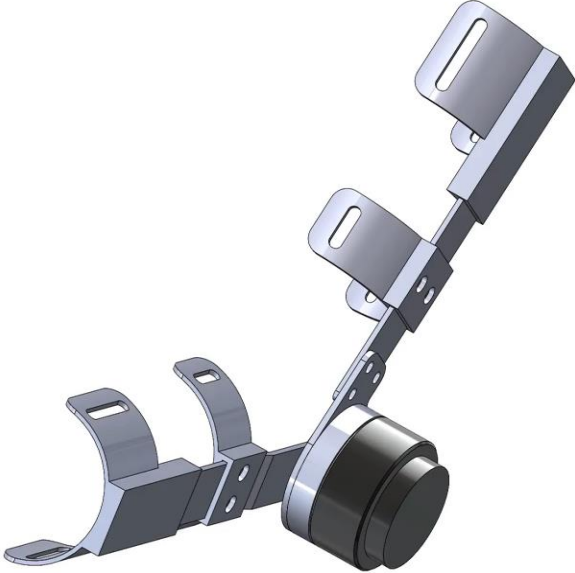
# FIU's Mobile Glovebox Device



Applied Research Center



# FIU's Modular Glovebox Device



A large, central logo for FIU, with the letters 'FIU' in a bold, blue, serif font with a yellow outline, set against a white rectangular background.

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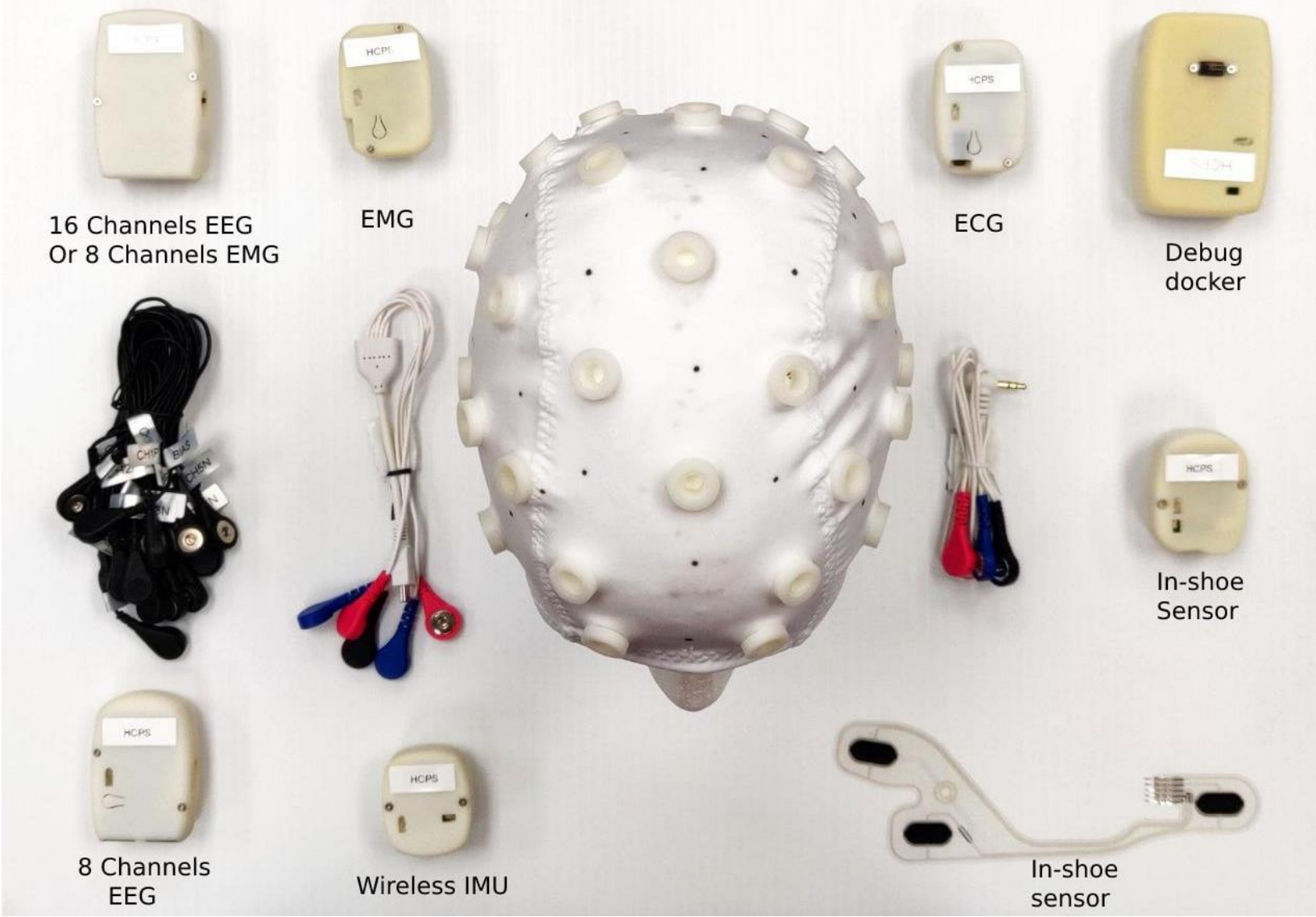
# FIU-HCPS's CyberSense Sensor Suite



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Real-time subject monitoring for device evaluation and physiological control of robotics



## Technology Roadmap

2020

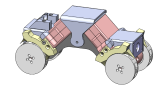
2021

2022

2023

2024

Tank Farm  
Hanford



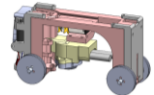
Minirover

In-house Deployment

Site Deployment

Site Deployment

Technology Transferred



UT Rover

Conceptual Design

Evaluation

In-house Deployment

Site Deployment

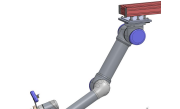


Lateral Gamma

Integration

Cold Test Facility Deployment

Site Deployment



Off-Riser Sampler

Conceptual Design/Integration

Cold Test Facility Deployment

Site Deployment



Long-Term Surveillance

Conceptual Design

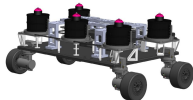
Sensor Integration

Evaluation

In-house Deployment

Site Deployment

H Canyon  
SRNL



Wall Crawler

Conceptual Design

Sensor Integration

Evaluation

In-house Deployment

Site Deployment

WIPP  
MSIPP



Salt Closure Inspection

Evaluation

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

In-house Deployment

Site Deployment

