Robotics in Environmental Site Assessment

Sixth International Symposium on Bioremediation and Sustainable Remediation Technologies

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Austin, Texas

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Agenda for Robotics in Environmental Site Assessment

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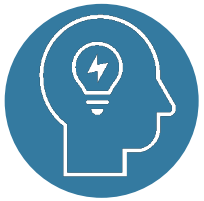
Background
Perspective of Presentation

Case Study
Robotics in Environmental Industry

Application
Surface Soil Delineation

Application
Excavation Monitoring



Limitations
Areas of Learning and Improvement

Going Forward
Current and Future Application

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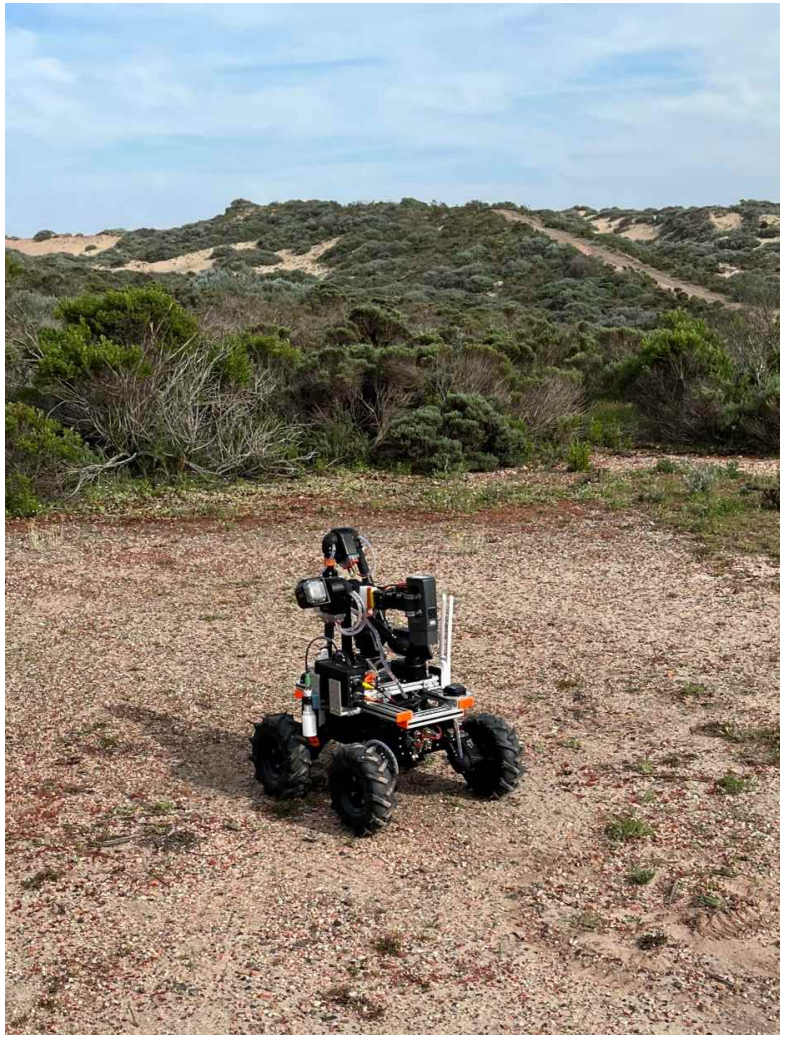
Background

- Robots Tested
  - Remote and autonomous ground robots
- Part of a larger research effort
  - Chevron Technical Center
  - Trihydro Corporation
  - Carnegie Mellon University
  - HEBI Robotics
- Perspective of an end user
- Many potential uses, but will focus on environmental application



Background

- Robotics Applications in the Environmental Industry
  - Unsafe Work Environment
    - Hazardous Atmosphere
    - Hard to Access Spaces
  - Advantages in Comparison to Human
    - Data processing
    - Repetitive tasks
    - Terrestrial and aquatic

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Applications/Case Studies

- Surface Soil Delineation
  - Land Treatment Unit (LTU) adjacent to former refinery in Midwest U.S.
  - Use of controlled and autonomous vehicle to delineate lead concentrations in surface soil
- Excavation Monitoring
  - Former oil fields in central coast of California, U.S.
  - Use of controlled vehicle to retrieve soil sample to keep worker from hazardous areas

Image 1: Robot at LTU in Midwest U.S.

Image 2: Robot at Excavation Pit in California, U.S.

Surface Soil Delineation

- Site Background
  - LTU for treatment of petroleum waste
  - Dense honeysuckle forest present mobility issues

Image 1: LTU Forest

Image 2: Former Refinery and LTU, Google Earth

Surface Soil Delineation

- Human Health Risk Assessment
  - Identified lead (Pb) as a potential risk-driver
  - Potential remediation incudes delineation and excavation of soil above lead cleanup goal
  - Elevated lead concentration identified in northern section of LTU
    - This area selected for robotics test

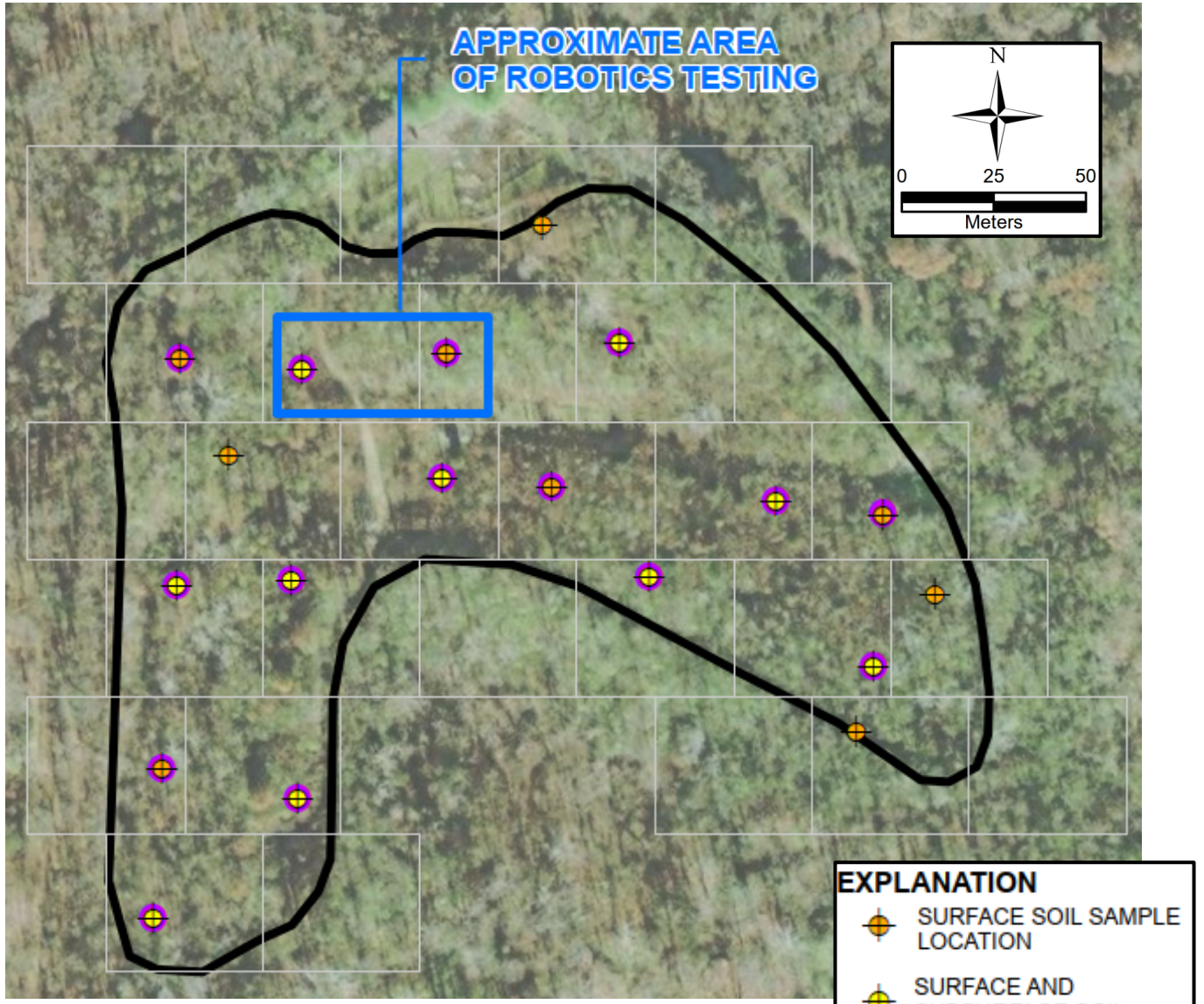

Image 1: Map of LTU and sample location

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Surface Soil Delineation

- Robotics delineation technique
  - Define sampling area
  - Screen surface soils
  - Sample location selected by dynamic algorithm
    - Areas with elevated lead concentration
    - Areas with unknown lead concentration
  - Use LiDAR to avoid obstructions
  - Return a contoured map of lead (Pb) concentration

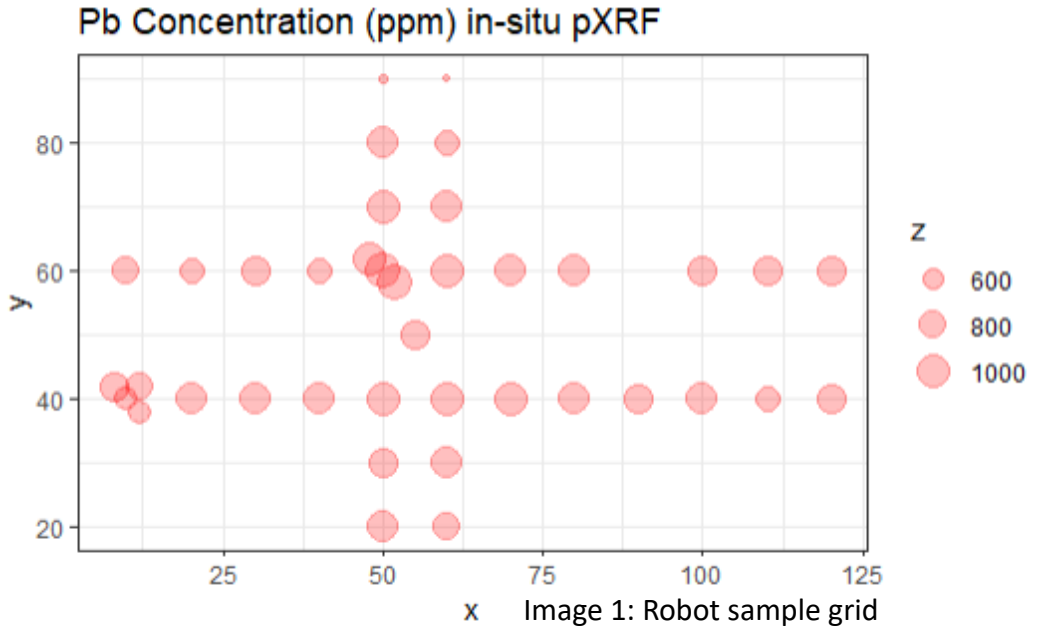

Image 1: Robot sample grid

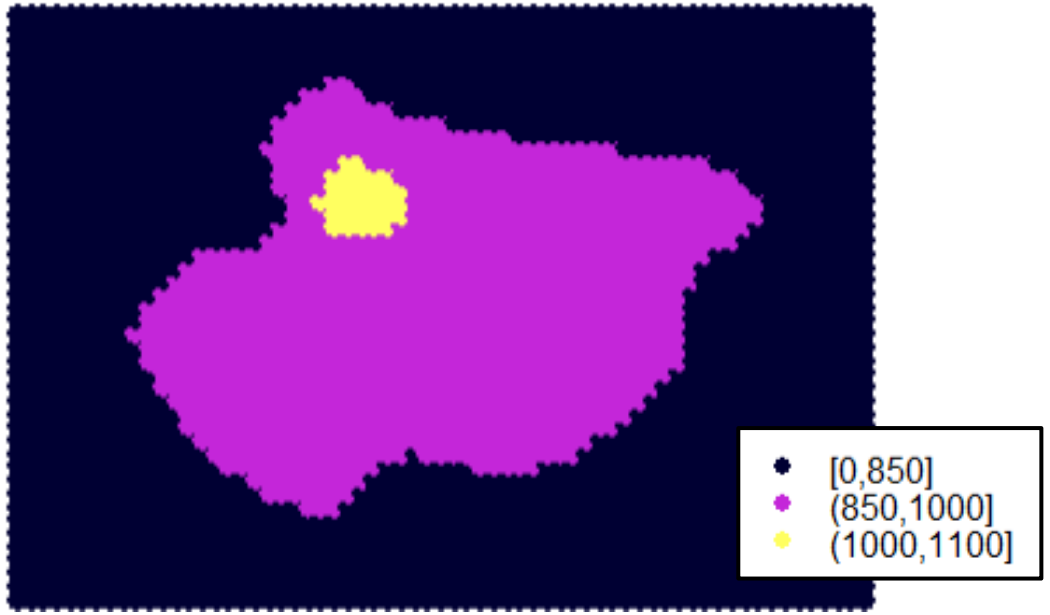

Image 2: Robot generated lead contour map

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Surface Soil Delineation

- Typical Soil Delineation and Removal
  - Adjacent former tank farm soil delineation and “hot-spot” removal
  - Stepwise sampling and analysis
    - Cost and time can be unknown
    - Additional expenses could be avoided
- Worker safety
  - Entering excavation
  - Working around heavy equipment
  - Contaminants in soil

Image 1-2: Photos of Former Tank Farm Excavation

Surface Soil Delineation

- Typical Soil Delineation and Removal
  - 1300 square meters (m^2) estimated but 2000 m^2 soil removed
  - 800 cubic meters (m^3) estimated but 1200 soil removed
  - 32 total delineation samples and 9 confirmatory samples
  - 7 delineation sampling events with minimum of 14 weeks sampling

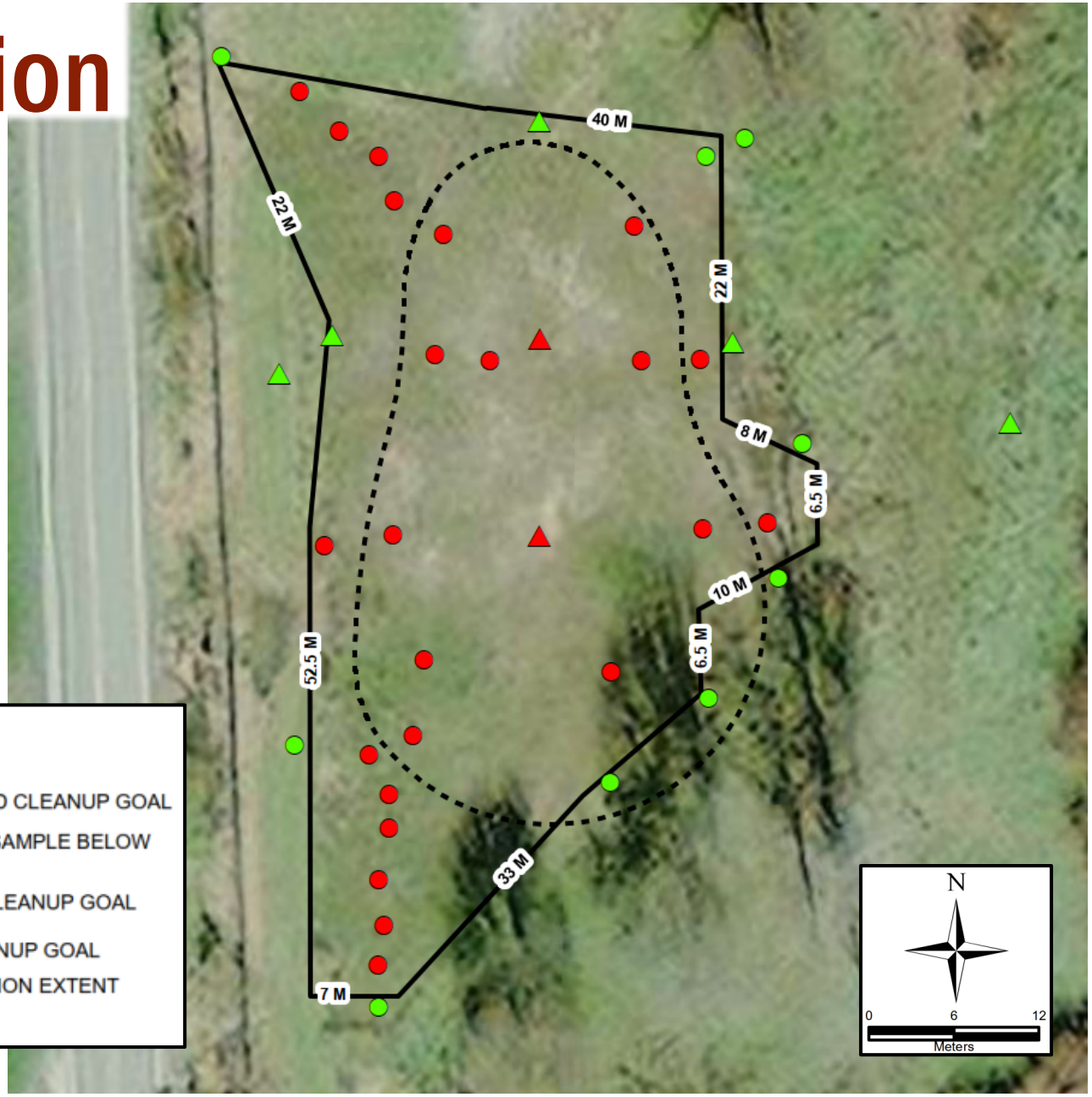

Image 1: Area of Former Tank Farm Excavation

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Surface Soil Delineation

- Typical Soil Delineation and Removal
  - Delineation of 2000 m^2 area cost approximately $9.5k vs robot assisted at $3.5k, excluding all costs associated with both methods
    - 65% cost reduction potential becomes more significant for larger excavations
  - Waste disposal cost approximately $120k vs estimate of $75k

Description	Unit Cost	Units	Existing Delineation an Excavation Method		Robotic Assisted with Dynamic Algorithm Excavation	
			Quantity	Cost	Quantity	Cost
Technician-Hours	$ 85.00	Hour	78	$ 6,630.00	20	$ 1,700.00
Robot Operator-Hours	$ 125.00	Hour	--	--	8	$ 1,000.00
Total Travel Days	$ 75.00	Day	7	$ 525.00	1	$ 75.00
Analytical Sample	$ 72.00	Sample	32	$ 2,304.00	9	$ 648.00
Total Cost				**$ 9,459.00**		**$ 3,423.00**

Table 1: Cost Comparison

Excavation Monitoring

- Former Oil Fields in Central Coast California
- Loose Dune Sand Terrain
- Petroleum Hydrocarbon (TPH) Impacted Soils
- Worker Safety Considerations
  - Excavation wall collapse
  - Heavy equipment
  - Contaminant exposure

Image 1: Photo of Excavation and Stockpile

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Excavation Monitoring

- Typical Soil Excavation
  - Former well pads
  - Former recovery sumps
  - Petroleum impacted surface source
- Excavation Oversite
  - Determine Extent of excavation based on visual, physical, and analytical methods
  - Safely collect analytical samples to confirm extent of excavation
  - Typical sample locations from middle and four edges of excavation

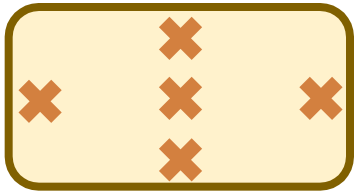

Figure 1: Excavation Sample Schematic

Image 1:Photo of Typical Soil Excavation

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Excavation Monitoring

- Robotics Assisted Excavation Monitoring
  - Use remote or autonomous controls to locate excavation sample location
  - Homogenize soils with auger at sample location
  - Use sensor to measure soil moisture content
  - Use infrared (IR) meter to measure TPH concentration
  - Track surface level carbon dioxide (CO_2) for qualitative biodegradation indicator

Image 1: Photo of Robot Used for Excavation Monitoring

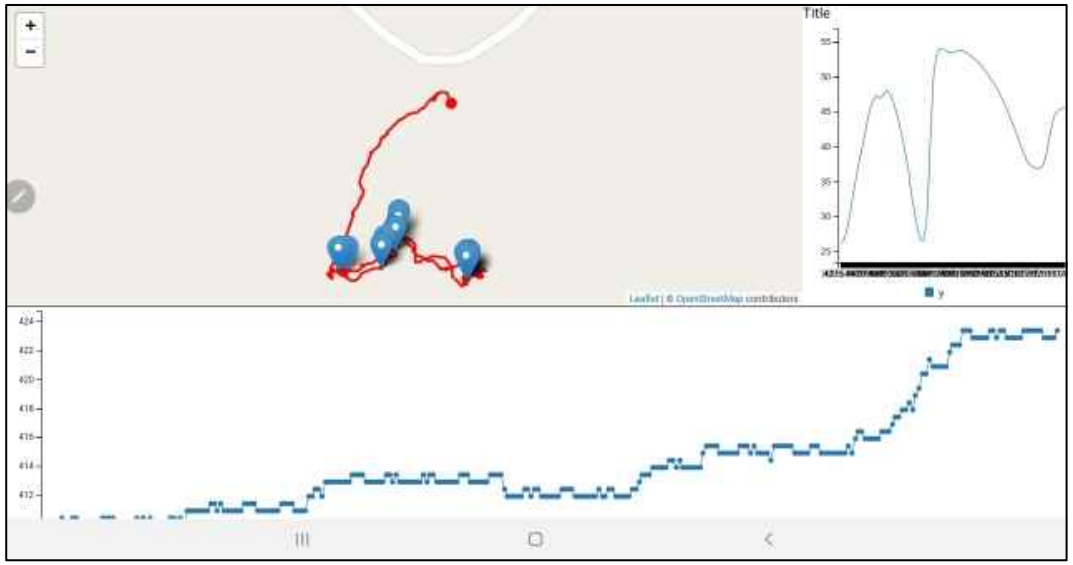
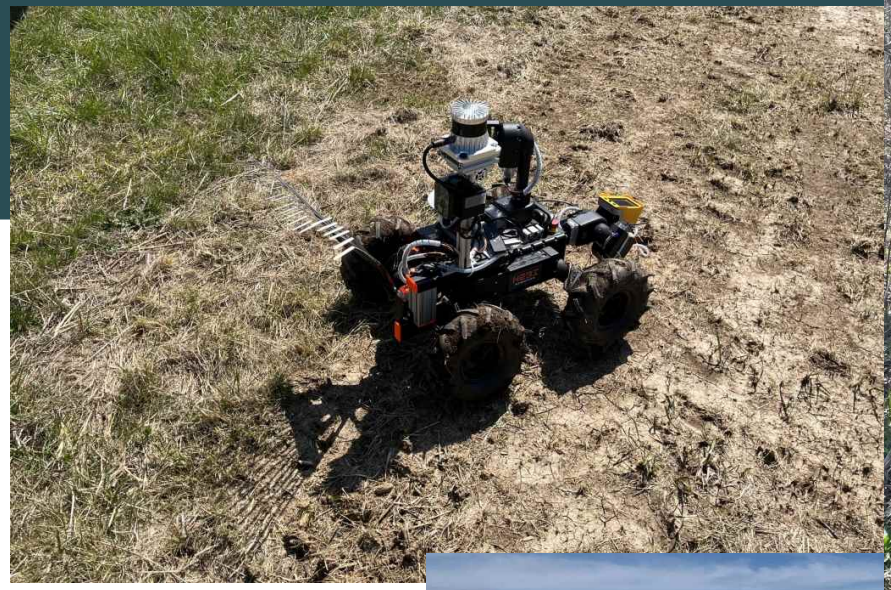


Image 2: Example observation view from field tablet

Limitations

- Primary Limitations
  - Mobility challenges
  - Field meter restriction
  - Sample depth and screening technique
- Practicality Limitations
  - Capital cost
  - Robot operation and assembly currently requires trained human support
  - Human currently better suited for many environmental assessment applications



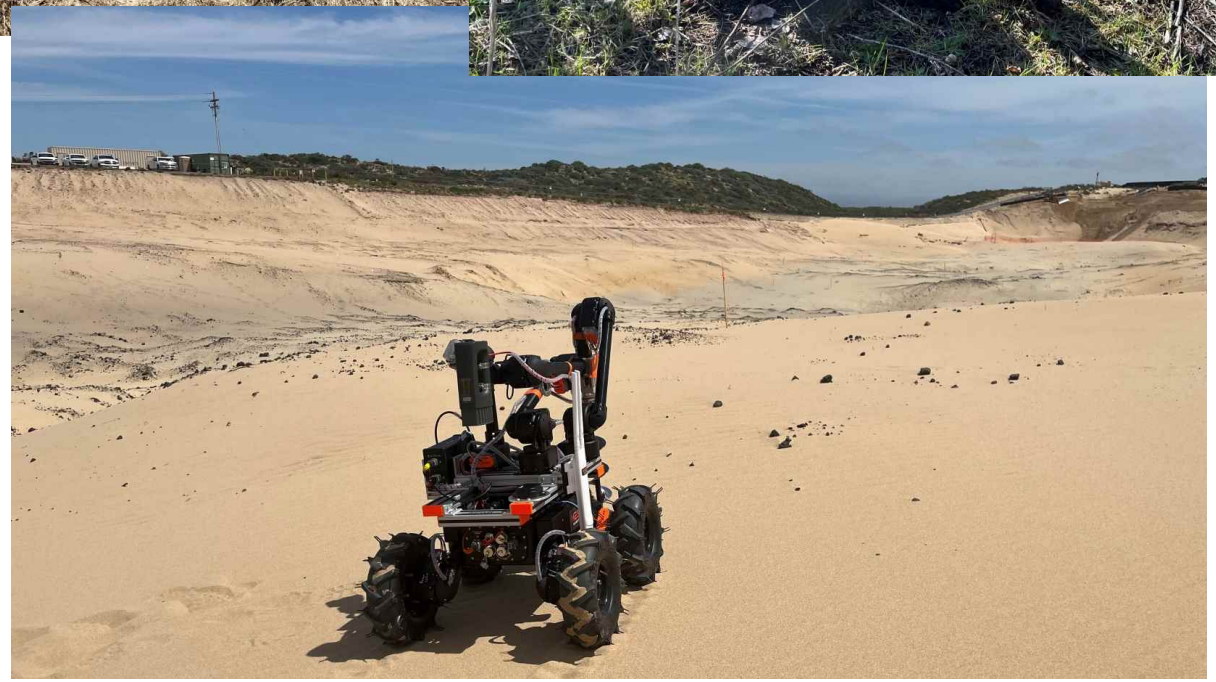


Image 1-3: Photos of Robots

Summary and Next Steps

- Robots should become important future resource for environmental practitioners
  - Can be used in environmental site assessment to reduce labor cost while keeping workers out of harm's way
- Overcoming Limitations
  - Test robot with different terrain and objectives
  - Engineer sampling device and instrumentation
  - Work with multi-disciplinary project team to further explore site assessment application

Image 1: Photo of Robot

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QUESTIONS / DISCUSSION

WHAT | WHY | WHERE | WHEN | WHO | HOW

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