

## Background

### Problem

In the US, 18% of methane is emitted from landfills<sup>(1)</sup>  
Surface emission monitoring (SEM) can reduce harm  
Manned SEM testing is costly (\$24,000 annually),  
dangerous, and time-consuming

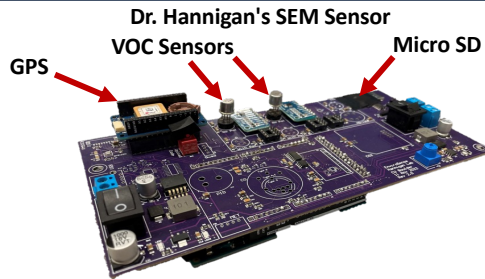
### Objective

Prove a low cost, automated process could be used for  
surface emission monitoring

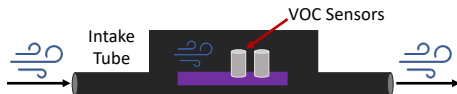
## Key Requirements

- ✓ Utilize HAQ Lab's SEM sensor
- ✓ Maneuver obstacles and ruts
- ✓ Traverse across inclines
- ✓ Travel autonomously
- ✓ Be low-cost & scalable
- ✓ Include a remote manual off switch

## SEM Data Collection

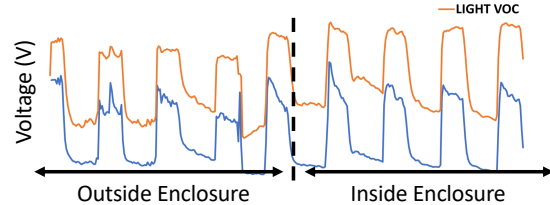


Sensor measures and records volatile organic compound (VOC) levels and their locations



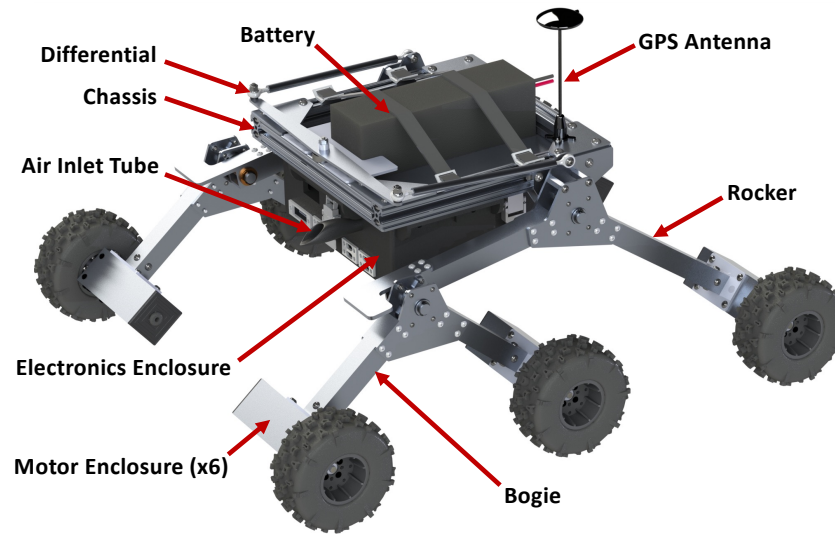
Air enters enclosure through the intake tube, flows over VOC sensors, and exits the backside

### Enclosure Validation



Test shows that the enclosure does not obstruct the sensor accuracy

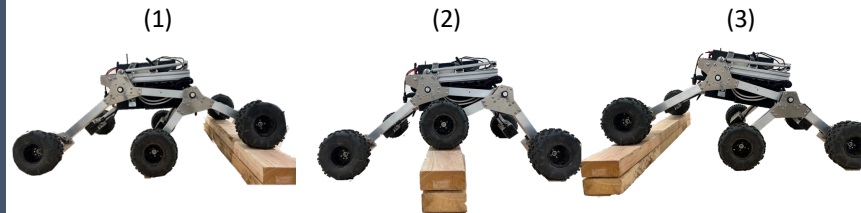
## RALPH-E



Height	Width	Length	Weight	BOM Cost
18 in	26.5 in	29.5 in	32 lbs	\$3100

## Rover Maneuverability

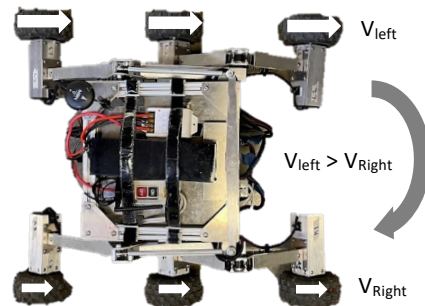
### Rocker-Bogie System



(1)  
100° bogie arm angle increases climbing ability

(2)  
Differential distributes weight equally

(3)  
Differential keeps chassis stable to prevent tipping

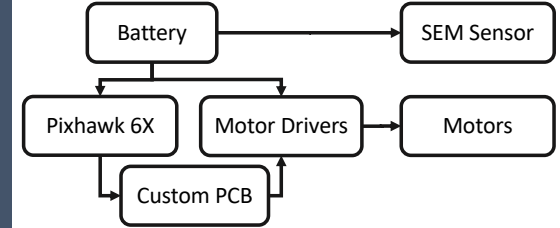


### Skid Steering

Simple and compatible with software  
To turn, one side is driven at a higher speed than the other side

To pivot turn, one side is driven forward and the other in reverse

## Critical Electronics



## Autonomous Navigation

### Mission Planner

ArduRover software for autonomous waypoint navigation



### GPS & Compass

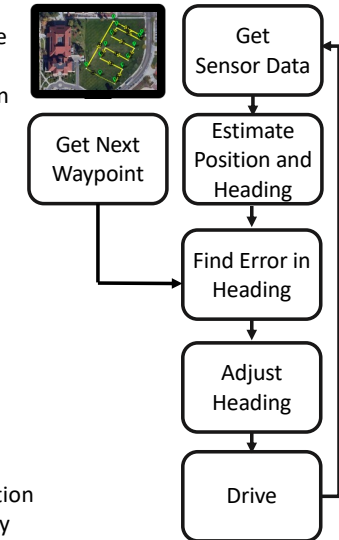


Measures position and heading

### IMU (x3)



Measures acceleration and angular velocity



## Conclusions

	Run Time	Current Draw	Max Rut Length	Tallest Obstacle	Travel Speed	Incline Travelled
Req.	1.5 hr	<20 A	5 in	3 in	2 mph	15°
Actual	5.75 hr	5.5 A	7 in	6 in	2.2 mph	30°

### Impact

Lowest cost of SEM testing  
Increases SEM data collection frequency in the field  
To be used in EPA funded research project next year

### Future Considerations

Implement obstacle avoidance capabilities  
Increase electronics protection from environment  
Implement self-charging capabilities