

Advances in Automation of Shuttle Cars and Underground Equipment

Joe Sottile, Zach Agioutantis, Steven Schafrik, Vasilis Androulakis
University of Kentucky, USA



Presentation Outline

- Introductory Comments
- Goals and Challenges of the Project
- The Approach
- Current Work and Results
- Future Work



Mining Automation in the News

The Mining Industry Could Strike Gold With Automation



Charles Towers-Clark Contributor

AI

I write about digital transformation and data in the digital age

liveWire LATEST TRENDING CONTRIBUTORS

EDITOR'S PICKS

1. A BULL THESIS FOR THE SHORT, MEDIUM AND...
2. 5 INVESTMENT LESSONS THAT STAND THE TEST OF...
3. DUMP VALU...



Rio Tinto's mining sector disruption

TIM GERRARD
Janus Henderson

When you pull up your car at a railway crossing in the Pilbara, switch off the engine and get out to stretch your legs – you'll be while as wagon after wagon rumbles by. While peace is restored, ever short-lived as Asia's insatiable demand for iron ore means need to make the journey from mine to port that day. Three locomotives typically haul 240 wagons of processed iron ore, delivering 28,000 tonnes of facilities in a single train load – day in, day out.

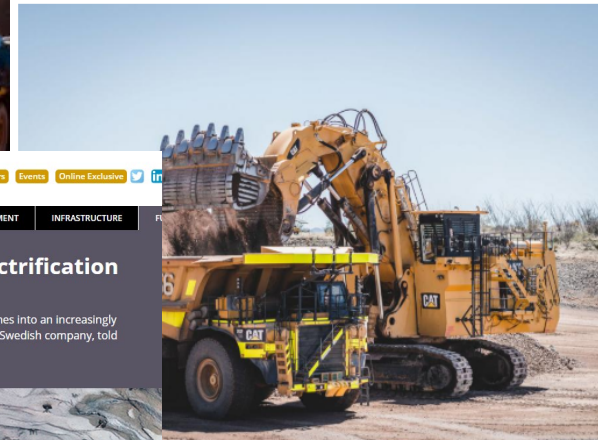
Why the Pilbara leads the way in haul truck automation

Posted by Daniel Gleeson on 6th August 2019



Cat Hosts Autonomous Haul Truck Demo in Tinaja Hills, Ariz.

TUE SEPTEMBER 11, 2018 - WEST EDITION #19
AARON WITT - CEG CORRESPONDENT



In the most remote places on earth, trucks hauling an upwards of 400 tons — about the weight of 200 cars — roam from pit to crusher with no humans in sight. These trucks are part of Caterpillar's Cat Command for Hauling system, commonly referred to as autonomous trucking. (Aaron Witt photo)



In the most remote places on earth, trucks hauling an upwards of 400 tons — about the weight of 200 cars — roam from pit to crusher with no humans in sight. These trucks are part of Caterpillar's Cat Command for Hauling system, commonly referred to as autonomous trucking.

Minjng Magazine

SURFACE MINING UNDERGROUND MINING PROCESSING ASSET MANAGEMENT INFRASTRUCTURE

Boliden introducing automation, electrification step by step

Automation and electrification are keys to continuing to transform Boliden Mines into an increasingly competitive and low-cost mining company. Stefan Romedahl, president of the Swedish company, told delegates at the CRU World Copper Conference in Santiago, Chile



Future gains are expected by automating

Future Of Mining > Investment "We are implementing a successful cocktail of electrification," he said.

11 April 2019

Resolute Mining starting to deliver automation benefits at Syama Underground

Posted by Daniel Gleeson on 30th July 2019



PEM, September 11, 2020

Related

ARIZONA
Technology

NEXT ST

TEMPERATURE
RIGHT TR

PREV

AHWATU
PROGRES



Like F

Be the fir



It's not all good news

From the flight manual to automation, why pilots have complained about Boeing's 737 MAX 8

Gus Garcia-Roberts, Steve Reilly and Alison Young, USA TODAY Published 6:00 a.m. ET March 13, 2019 | Updated 6:01 p.m. ET March 13, 2019



President Trump announces the FAA and Dept. of Transportation will ground all Boeing 737 Max 8 and 9 aircraft following recent crashes of the model. USA TODAY



Transportation

Pilots rely too much on automated tech, DOT says

And it believes the FAA should take steps to change that.

Mariella Moon, 01:13:16

While automakers are still in the midst of developing driverless tech for cars, pilots are already relying too much on automated systems. According to the Department of Transportation, the Federal Aviation Administration isn't even making sure they're properly trained on how to manually fly planes. In the audit report published by the

It's time for workers to worry about AI

GARY GROSSMAN, EDELMAN @GARYG02 APRIL 7, 2019 2:22 PM



Recent news of significant corporate investments in artificial intelligence (AI) suggests this technology is moving toward mainstream use. Evidence for this includes DocuSign injecting \$15 million into an AI contract discovery startup, Apple absorbing an AI camera developer, and CIO reporting that banks are expected to spend \$5.6 billion on AI solutions in 2019, "ushering in the next financial revolution." Indeed, the green shoots of AI are appearing everywhere.

Presidential candidate says driverless trucks will cause 'mass riots'

He predicts that truckers who lost their jobs to robots would "park their trucks across the highway and get their guns out."

By Ashley - March 18, 2019



Democratic presidential candidate is making headlines for his bold predictions on how he believes truck drivers will fight back violently if autonomous vehicles take away their jobs.



What are Our Goals?

- Reduce risk of injury to miners in the section
- Enhance and transform the role of the shuttle car operator
 - Shuttle car operators become shuttle car supervisors

To achieve this...

- Develop an accurate and reliable underground shuttle car autonomous navigation methodology and system
- Design, develop, and demonstrate a functional autonomous shuttle car
- Account for human factors related to the automation of certain tasks, evaluate the impact of an autonomous SC on the miners and work domain, and regulate human-machine interactions that allow remote task allocation between personnel and machine



Challenges

- Harsh environment
- GPS or similar localization technology not available
- Limitations in communications
- Environment is constantly changing
- Poor visibility (for people and sensors!)
- Difficult maneuvering



Approach

- Develop the framework for an accurate and reliable underground navigation system,
- Develop lab scale prototype for development and testing
- Develop and demonstrate a functional full-scale prototype of the autonomous shuttle car (non-production environment)
- Evaluate the impact of an autonomous shuttle on the miners and work domain, including changing work processes and organizational structures



Step 1: Lab-Scale Shuttle Car and Mock Mine

- A 1:6 lab-scale SC has been constructed
- 4-wheel drive and 4-wheel steering

Brushless DC Motors for Trammings



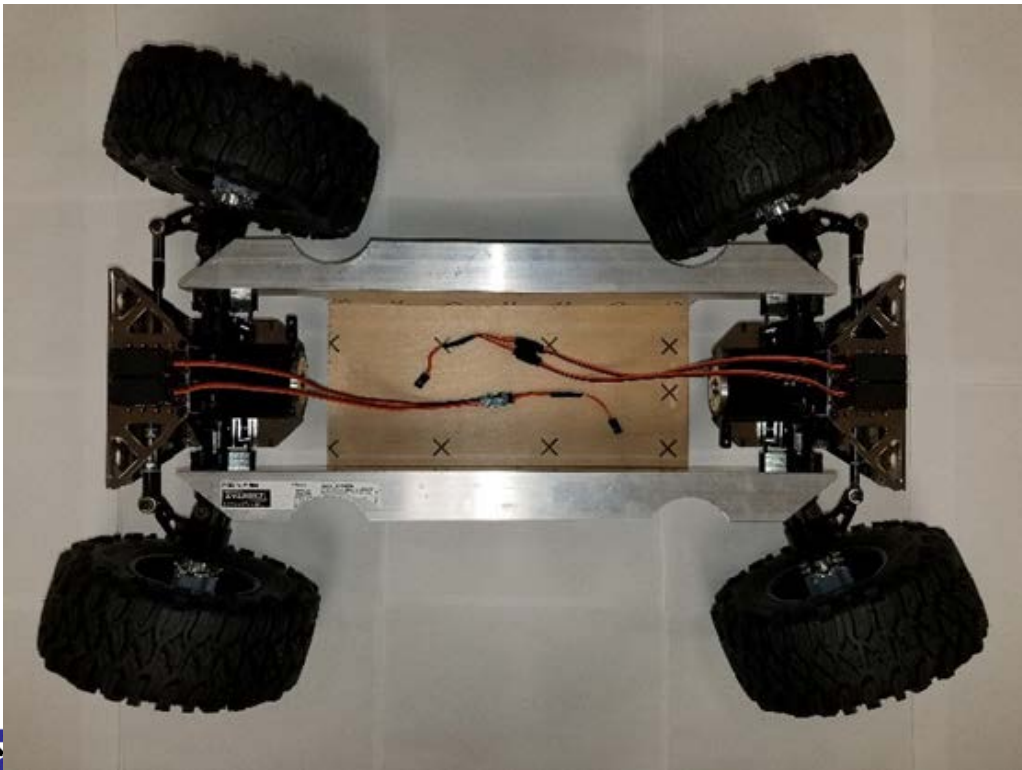
Two-Channel Motor Controller



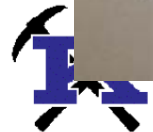
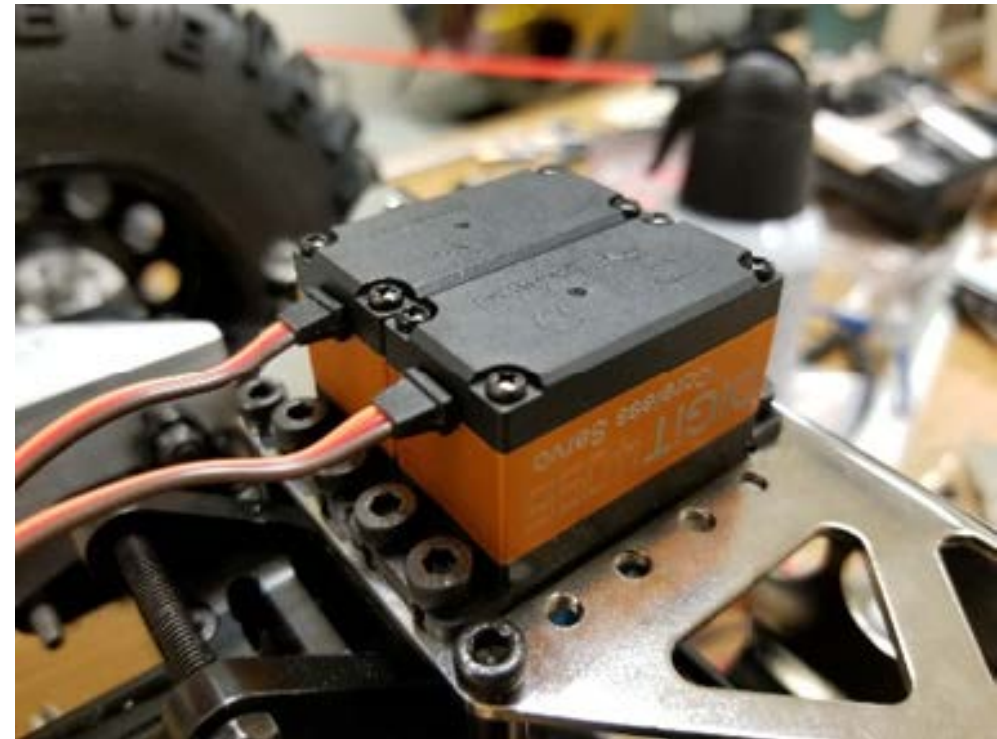
Step 1: Lab-Scale Shuttle Car and Mock Mine

- A 1:6 lab-scale SC has been constructed
- 4-wheel drive and 4-wheel steering

Frame and Axles

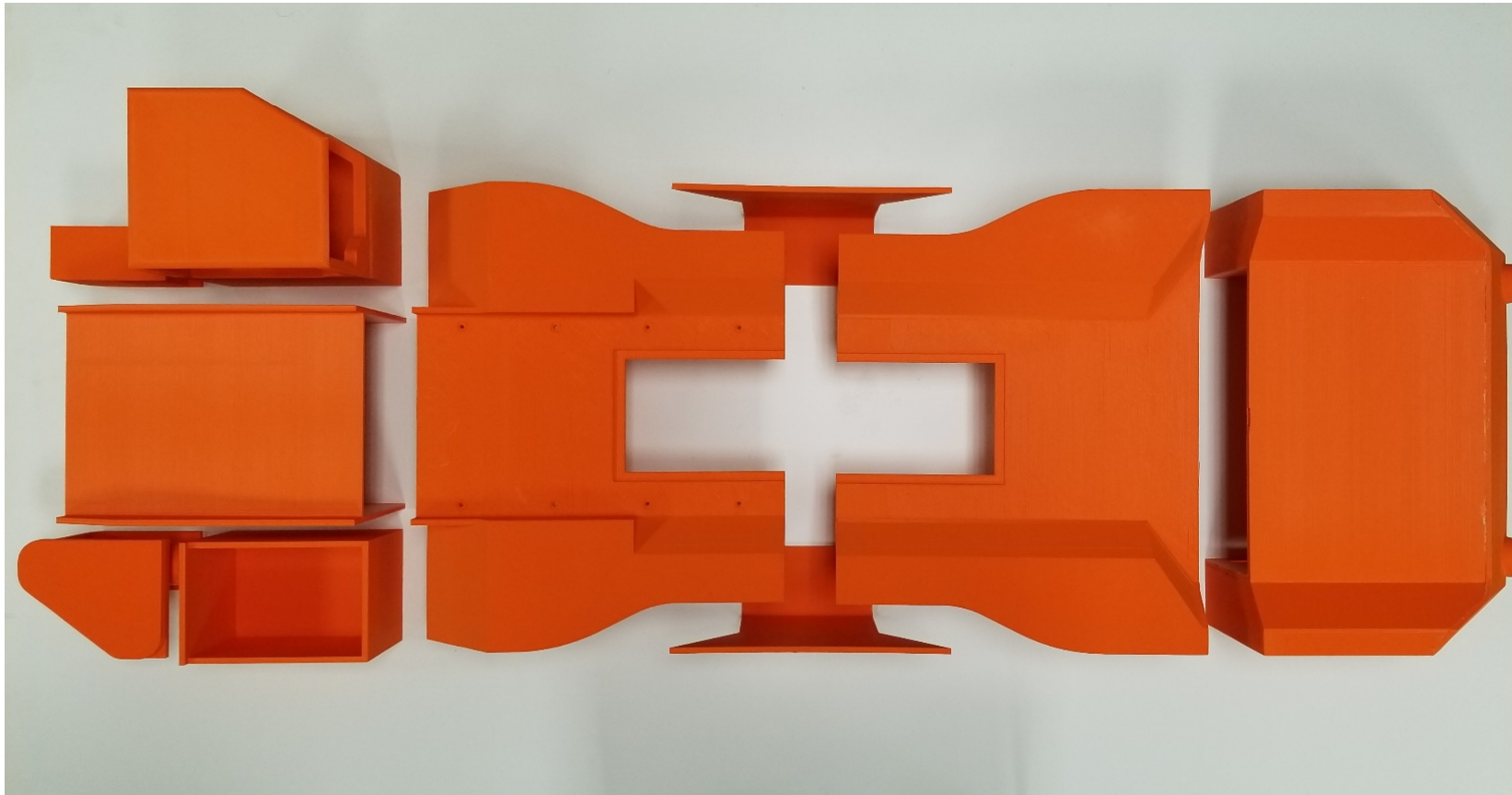


Servo Motors for Steering



Shuttle Car Body

- Body is based on Joy 10SC32B drawing provided by Komatsu Mining Corp.
- Scaled parts printed on Gigabot 3+ and Makerbot Replicator Z-18 3D printers



PEM, September 11, 2020



Lab-Scale Shuttle Car



Discharge-End

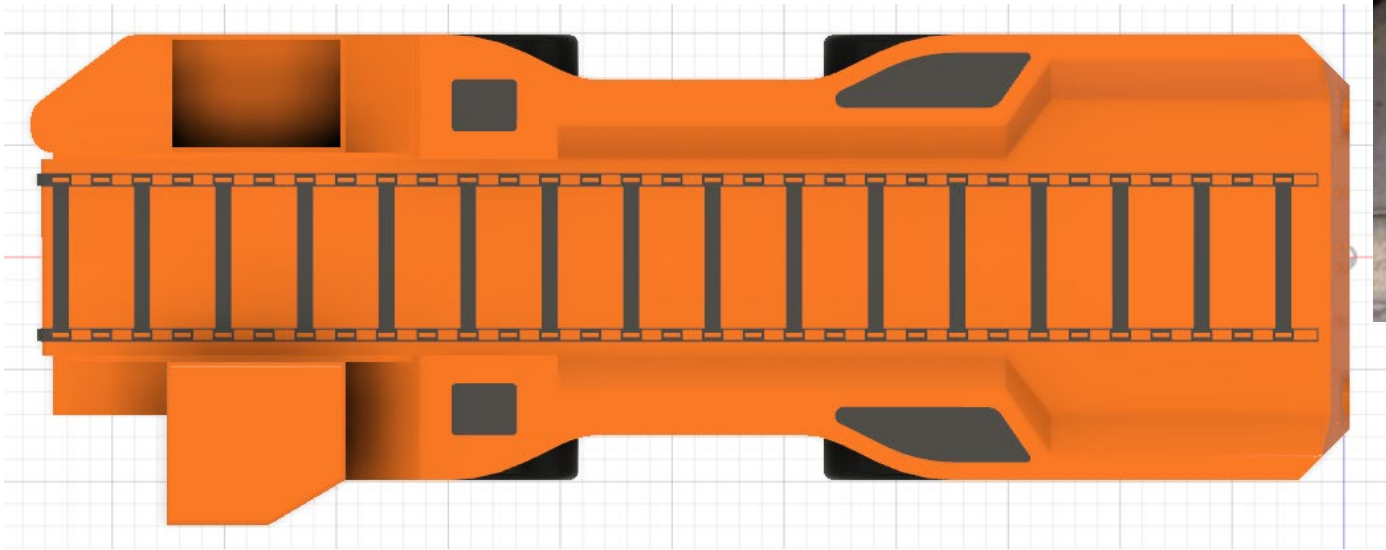
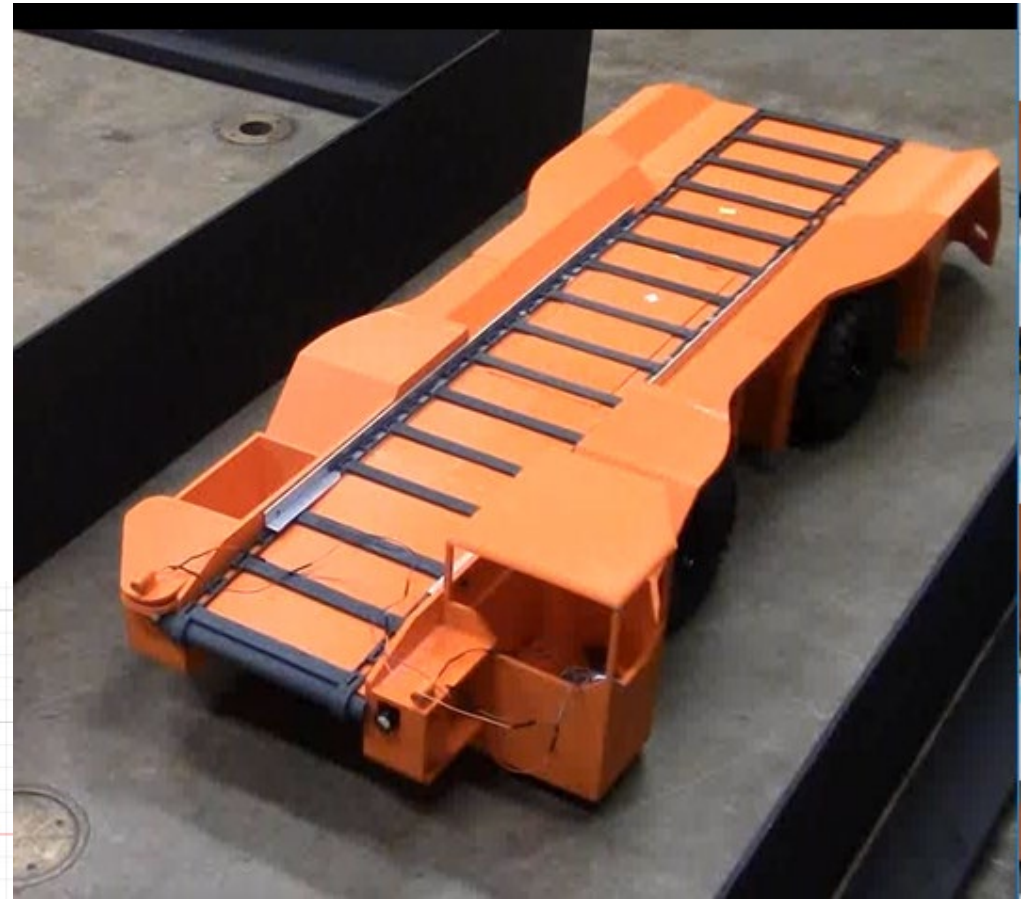


Load-End

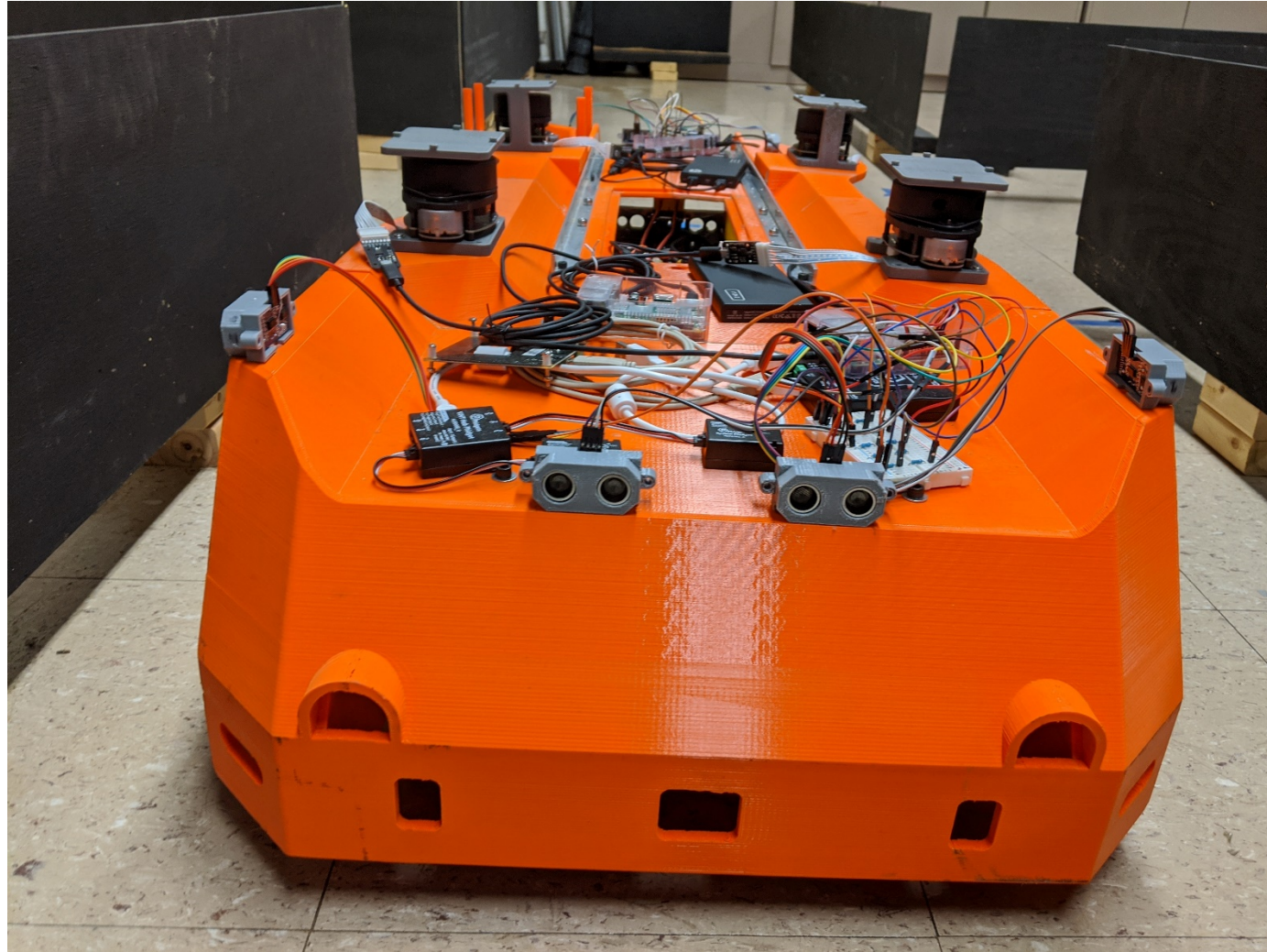


Lab-Scale Shuttle Car

- Length: 1448 mm
- Width: 500 mm
- Wheelbase: 480 mm



Lab-Scale Shuttle Car



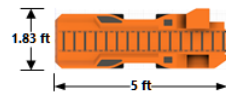
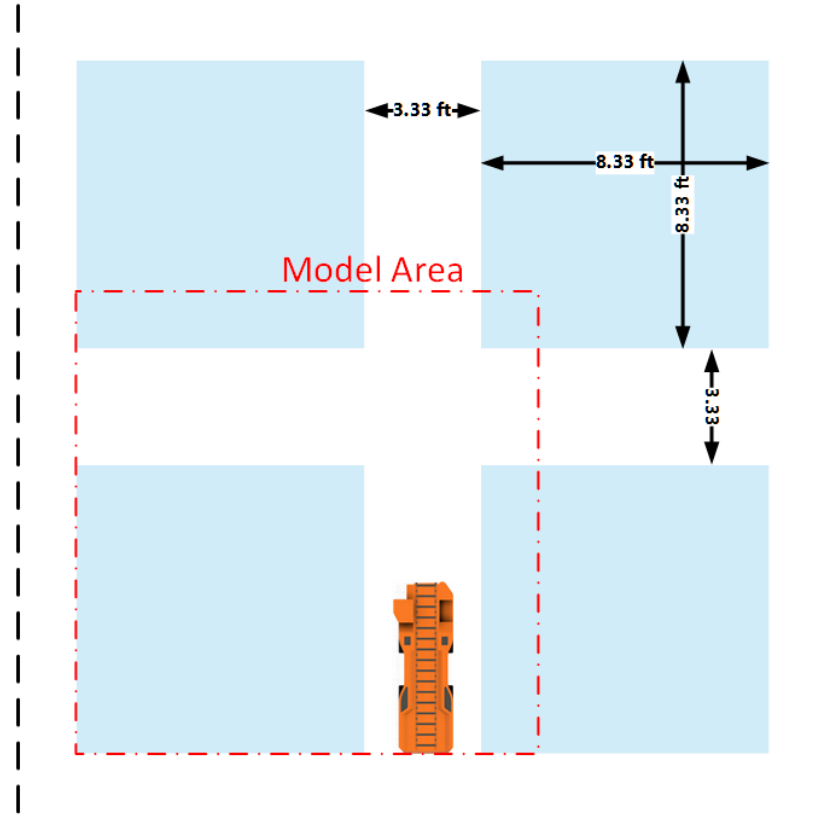
PEM, September 11, 2020



- 2D LiDAR Scanners (4)
 - Navigation
 - Obstacle Detection
 - Mapping
- Ultrasonic Sensors (8)
 - Proximity Safety
 - Obstacle Detection
 - Back-up Navigation
- IMUs (4)
 - Enhance Navigation



Scaled workings

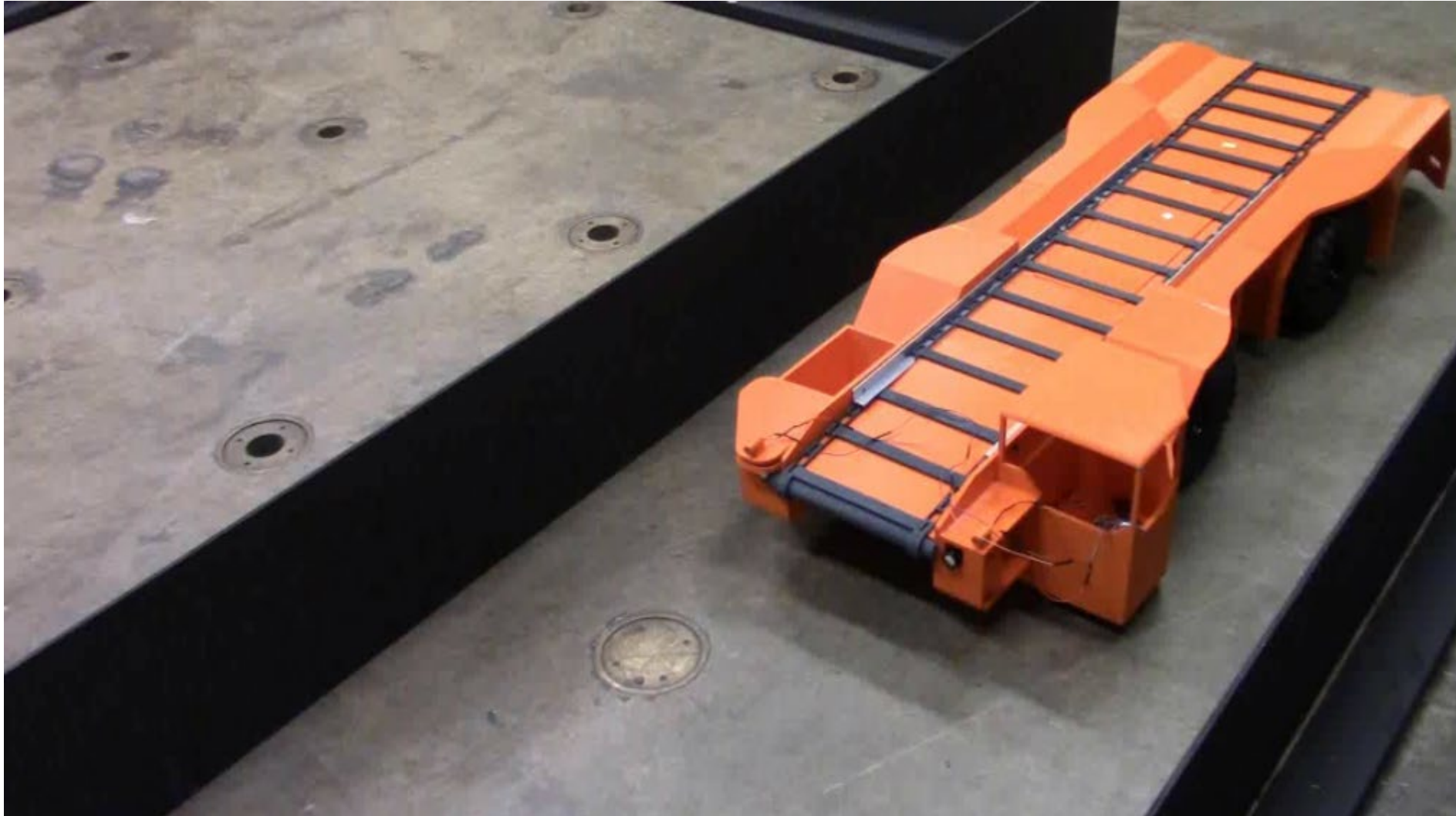


Alternate Layouts

Allows for multiple layouts



Functionality Testing



PEM, September 11, 2020



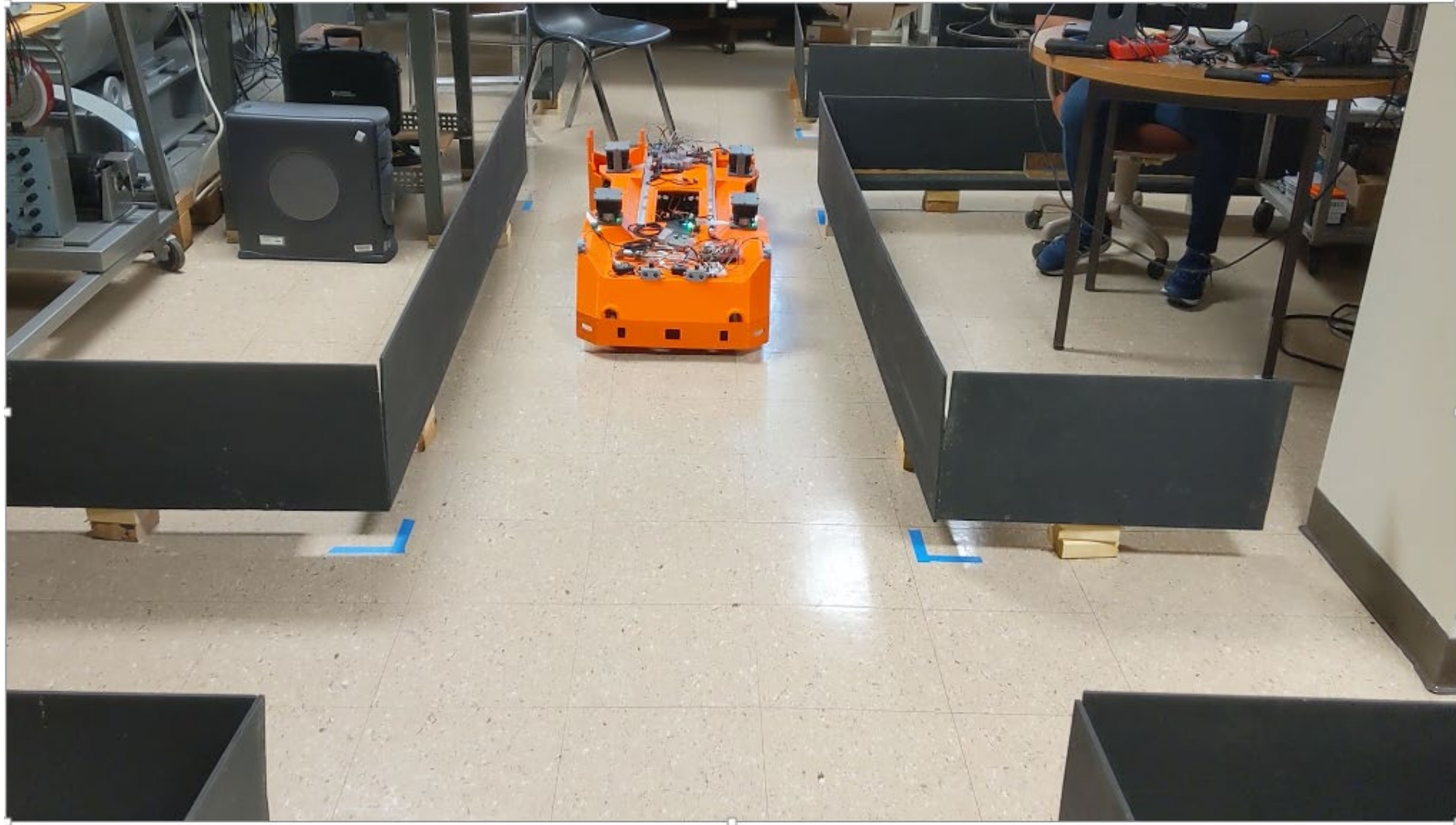
Autonomous Operation-Preliminary Testing



PEM, September 11, 2020



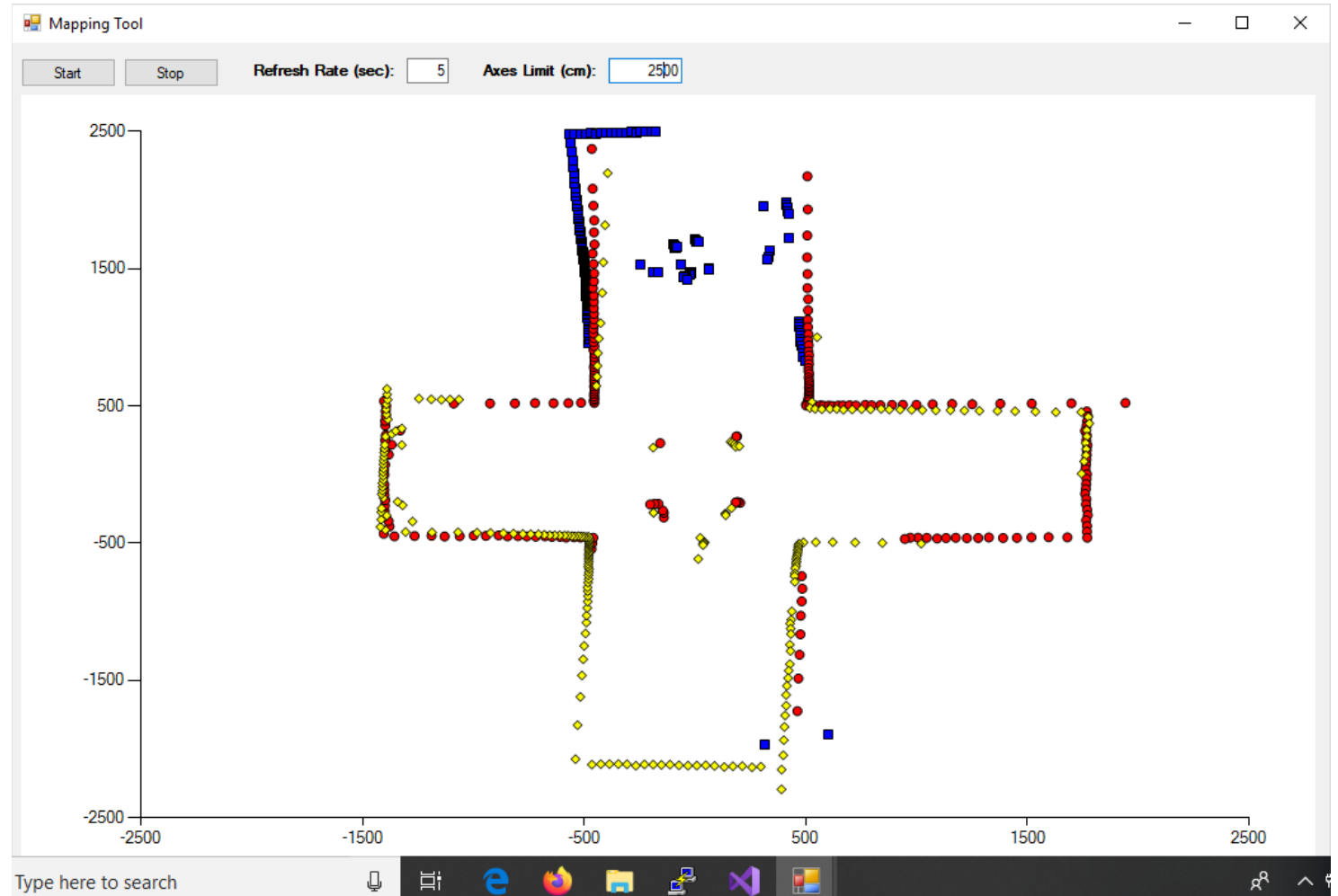
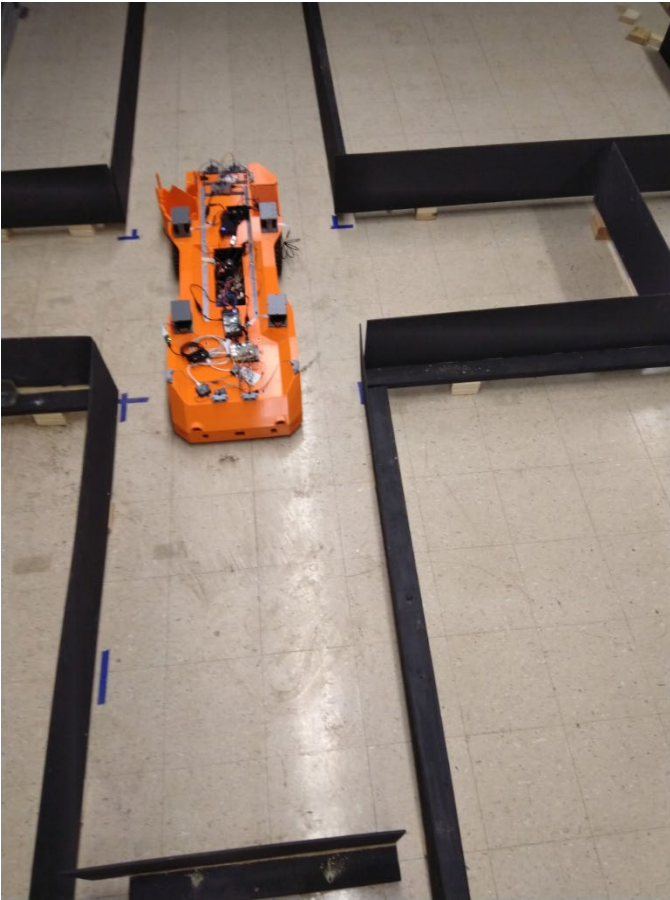
Autonomous Operation-Recent Testing



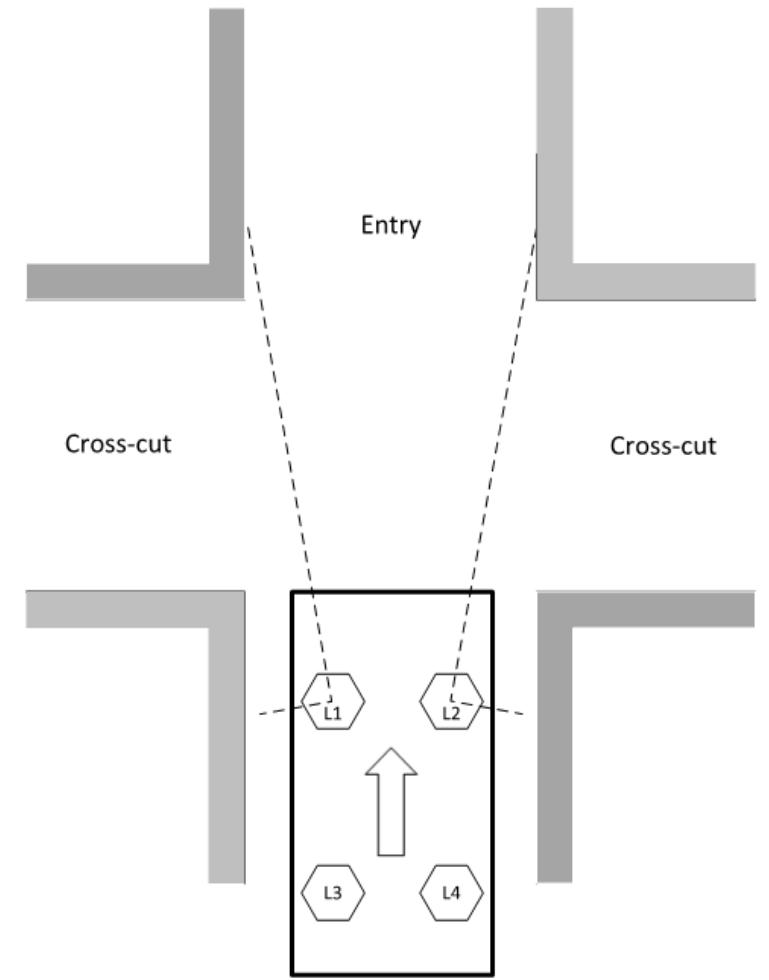
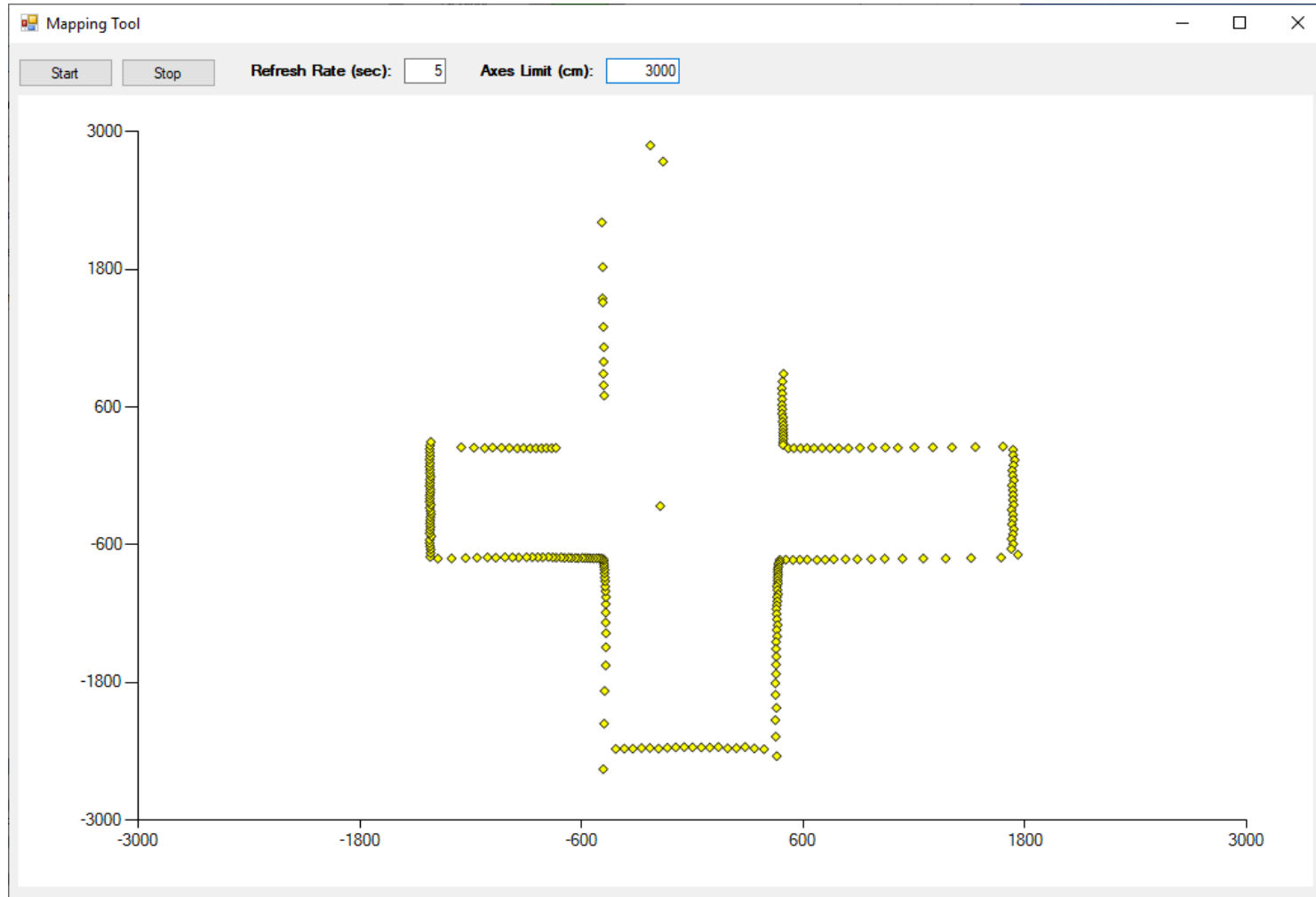
PEM, September 11, 2020



Sensors - LiDAR Scanning Patterns



Sensors - LiDAR Scanning Patterns

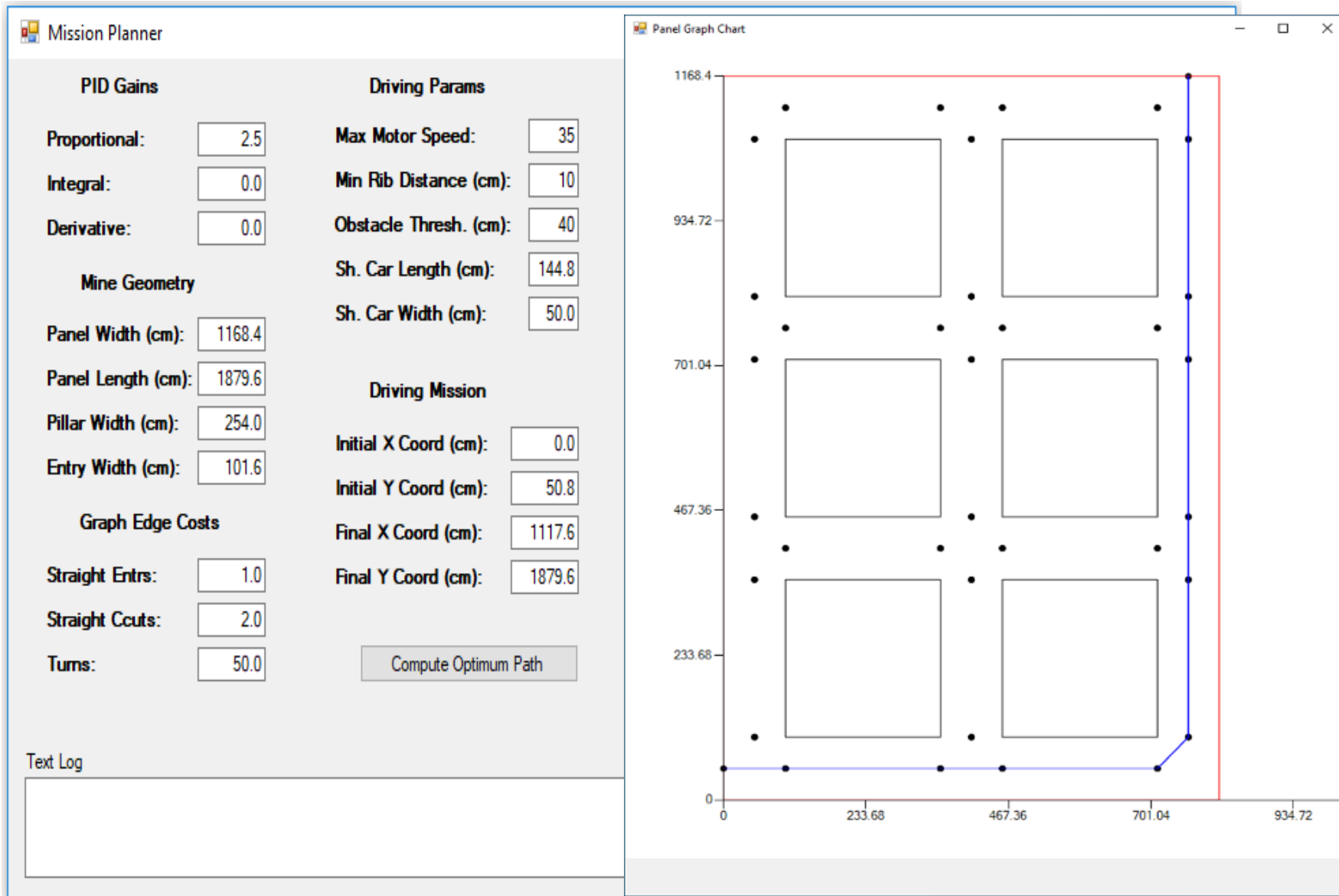


User Interface

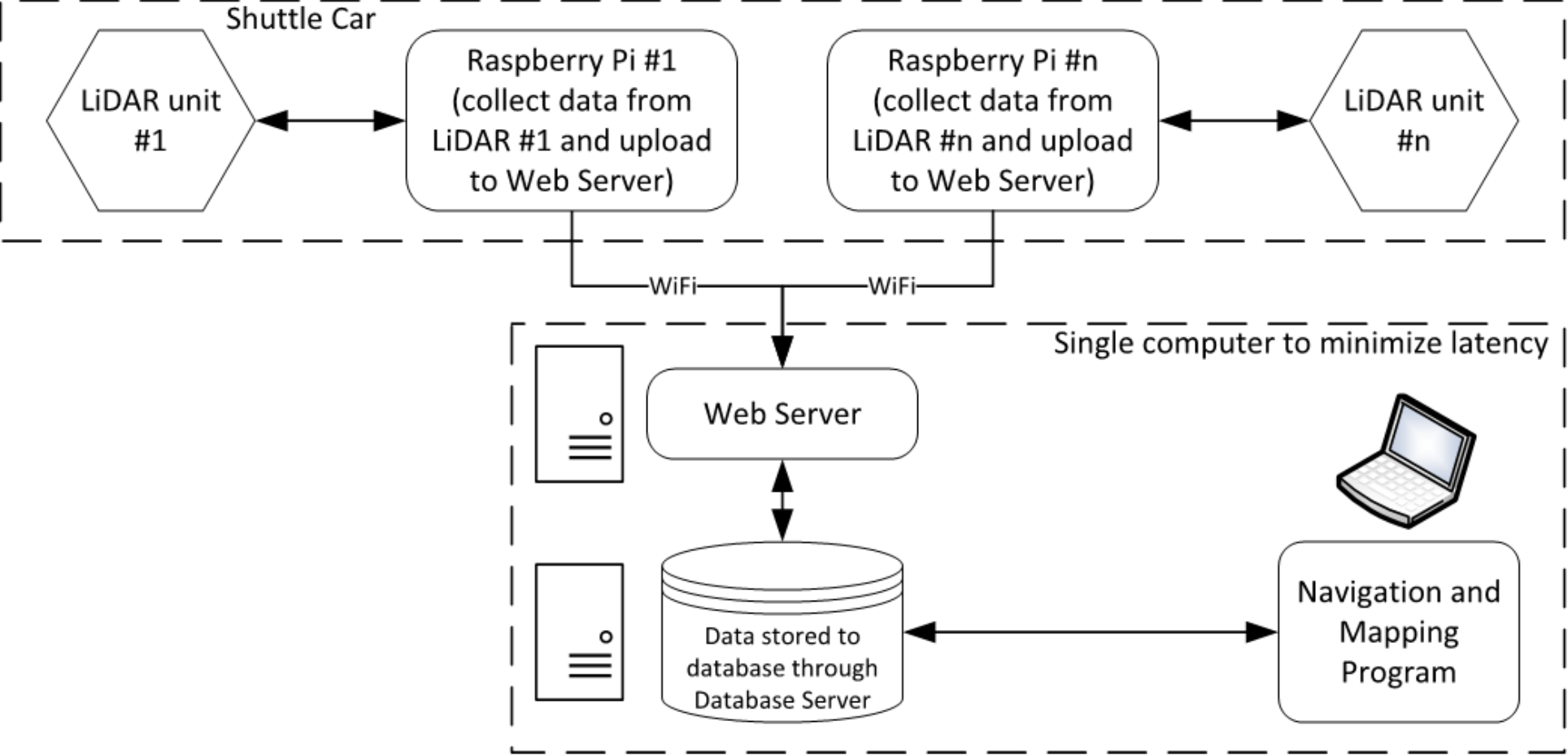
The screenshot displays the 'Shuttle Car GUI' window, which is organized into several functional panels:

- Driving Mode:** Includes buttons for 'Agent' and 'Human', with 'Human' currently selected.
- Safety Control Panel:** Features 'All Clear' and 'Emergency STOP' buttons, and a green circular indicator.
- Datastream Webservice IP:** Shows the IP address '10.33.70.246'.
- Arduino Serial Connection:** Contains a 'Ports' dropdown menu set to 'COM3', and buttons for 'Connect', 'Disconnect', and 'Refresh COMs'.
- Channels Manual Control:** Displays four vertical sliders labeled 'Ch 1' through 'Ch 4', each with a blue arrowhead and a '0' at the top.
- Additional Functions:** A vertical stack of buttons including 'Mission Planner', 'Manual Mission Planner', 'Sensor DataTable', 'Shuttle Car Health', 'Sensors Microcontrollers', and 'Mapping Tool'.
- Movement Control:** A complex section with:
 - Turn Angle:** A horizontal slider.
 - Tram Speed:** A horizontal slider.
 - Motor Ctrl:** Buttons for 'Move Inby', 'Stop', and 'Move Outby'.
 - Angle Ctrl:** Buttons for 'Turn Off Side', 'Zero Angle', and 'Turn Op Side'.
 - Time:** Input field with value '1'.
 - Mode:** Dropdown menu set to 'Centered'.
 - Target:** Input field with value '20'.
 - Steps:** Input field with value '1'.
 - Rib Side:** Dropdown menu set to 'Of_side'.
 - 90 Turn Ctrl:** Buttons for 'Inby', 'OpSide', 'Tight', 'Slow', 'Turn', 'Outby', 'OffSide', 'Wide', and 'Fast'.
 - Steps25:** Input field with value '15'.
 - Steps50:** Input field with value '7'.
- Command Queue:** A large empty text area for entering commands.
- Text Log:** A scrollable area showing the message: 'Shuttle Car GUI initialized. Driving mode is set to: Human'.
- History:** A large empty text area for recording events.
- Control Buttons:** A set of buttons at the bottom left including 'Play', 'Pause', 'Refresh', 'Clear', 'Save', and 'Load'.
- Clear History:** A button at the bottom right.

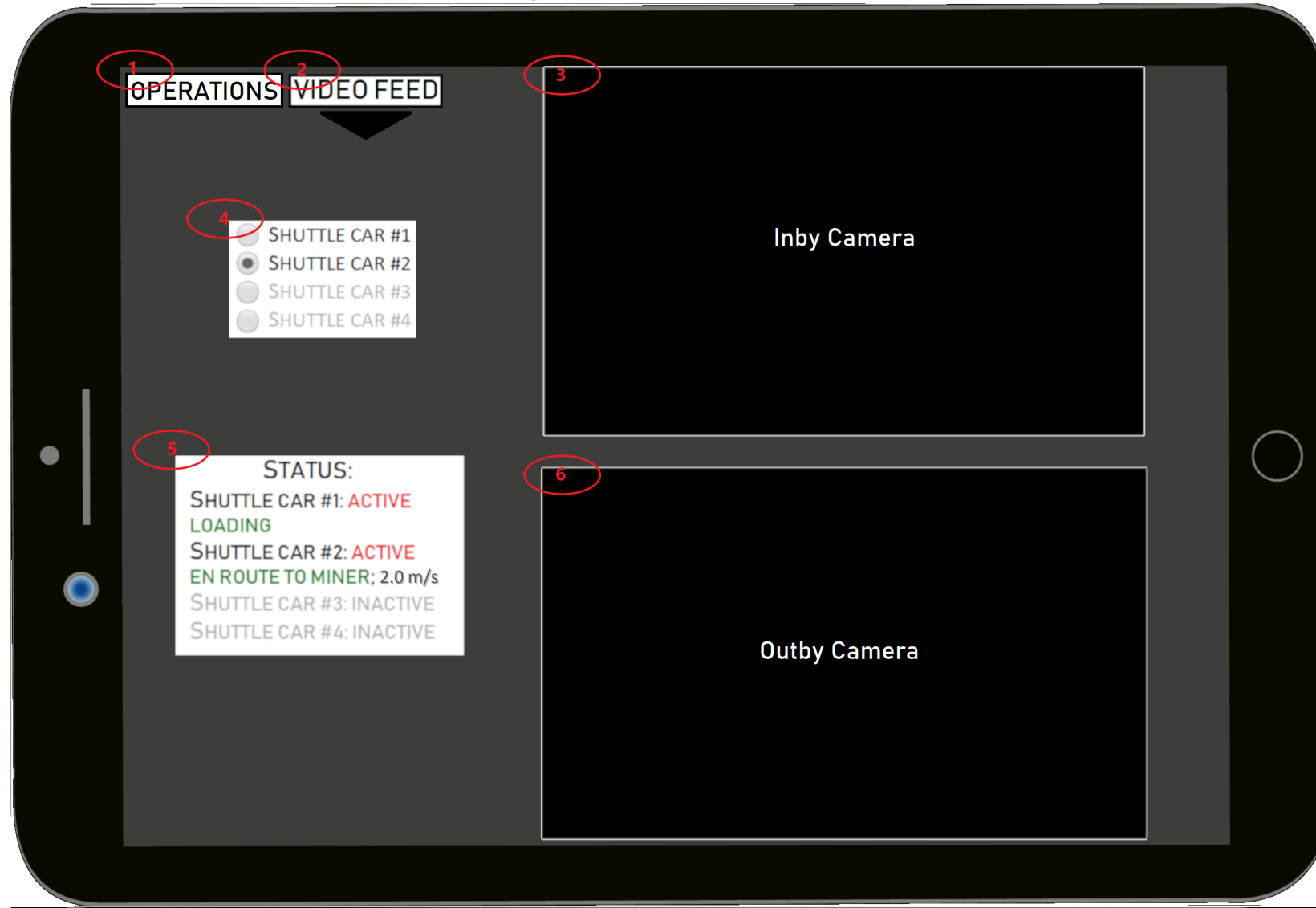




Navigation System - Data Management



Operator Tool Concept



On-going Work

- Continue to refine the navigation system
- Refine the data management system
- Evaluate performance of prototypes in the scaled mock mine
- Retrofit a full-scale shuttle car
- Demonstrate shuttle car operation at an underground mine





This presentation and study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

Industry support and help is greatly appreciated.

