The Automation Loop: Sensing and Controlling Underground Equipment

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Underground Shuttle Car Automation Goals

- The working face of an underground coal mine is a dynamic work area that exposes miners to numerous occupational hazards, including mobile equipment congestion
  - Coal dust, noise, whole body vibration, thermal stress
  - Heavy equipment
  - Roof & rib falls
  - Fatigue related accidents
- The goal of this project is to address these hazards by supporting the development of an autonomous shuttle car system
- Enhance and transform the role of the shuttle car operator
- Reduce risk to all miners at the working face.

Challenges

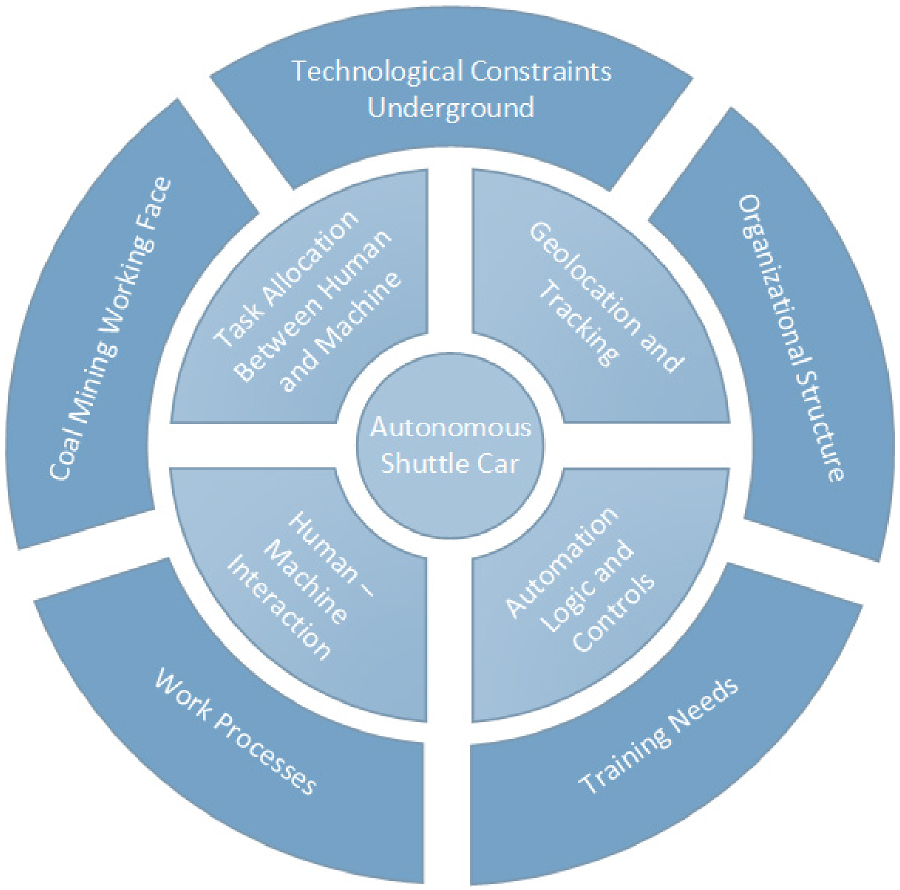
- GPS or similar localization technology NOT available
- Restrictions in communications
- Ever-changing environment
- Repetitive yet different tasks

Purpose of this Project

- This project involves multiple technical and ergonomic challenges:
  - Developing an accurate and reliable underground navigation system and methodology
  - Accounting for human factors related to the automation of certain tasks, evaluating the impact of an autonomous SC on the miners and work domain, and regulating human-machine interactions that allow remote control task allocation between human and machines
  - Designing, developing, and demonstrating a functional autonomous shuttle car

Approach

- Develop the framework for an accurate and reliable underground navigation system and methodology,
- Evaluate the impact of an autonomous haulage system on the miners and work domain as a whole including changing work processes and organizational structures, and
- Develop and demonstrate a functional prototype of the automated shuttle car haulage system.



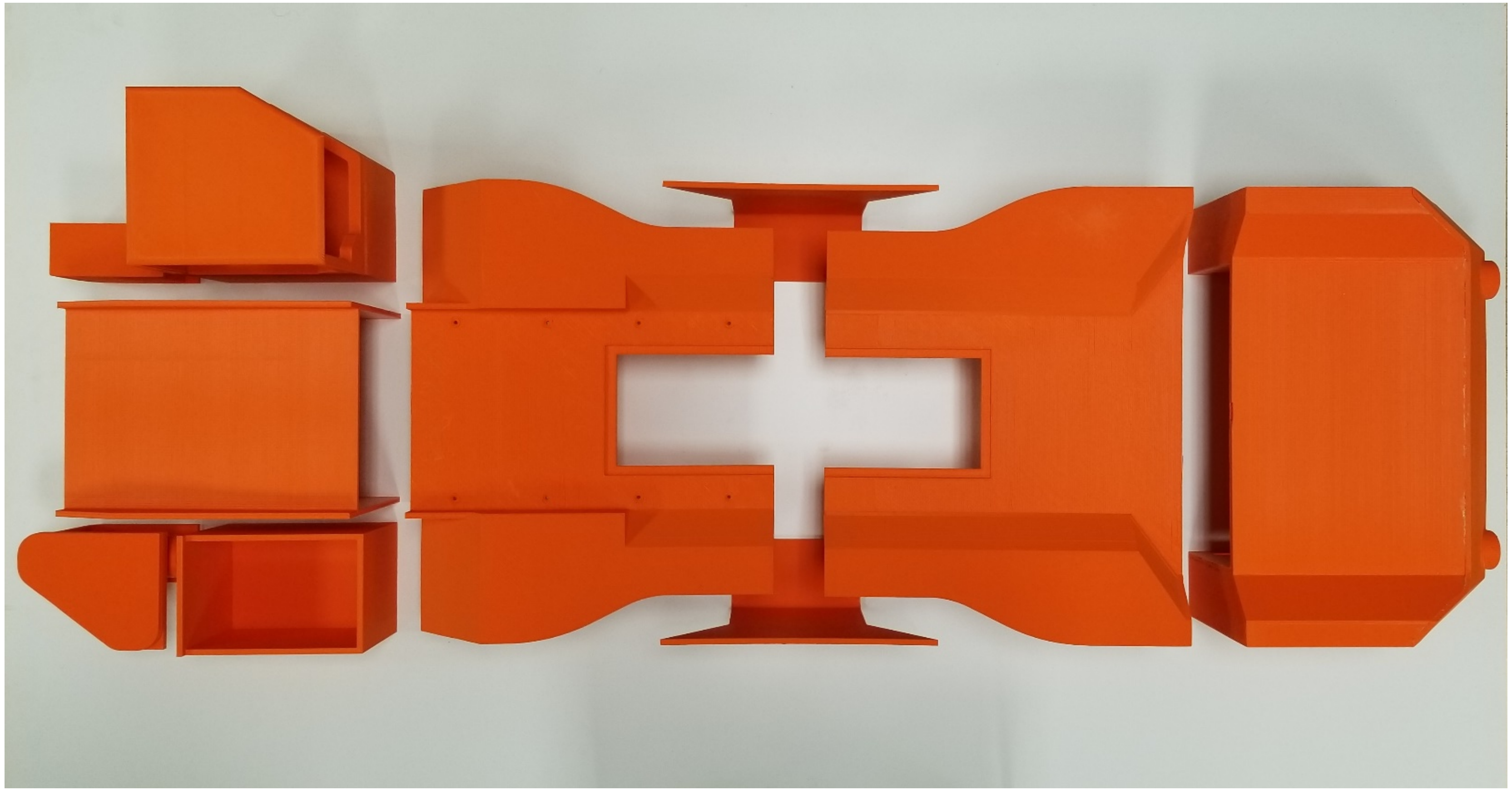
Lab-Scale Shuttle Car

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

Brushless DC Motor Controller

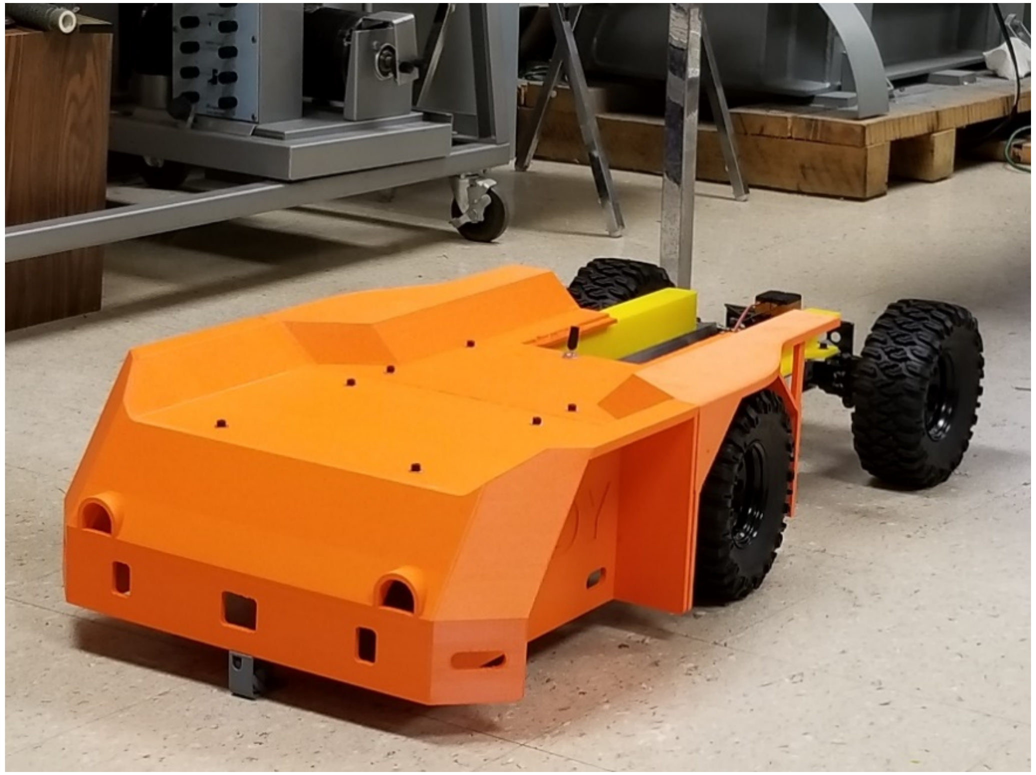
Shuttle Car Body

- 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



Lab-Scale Shuttle Car

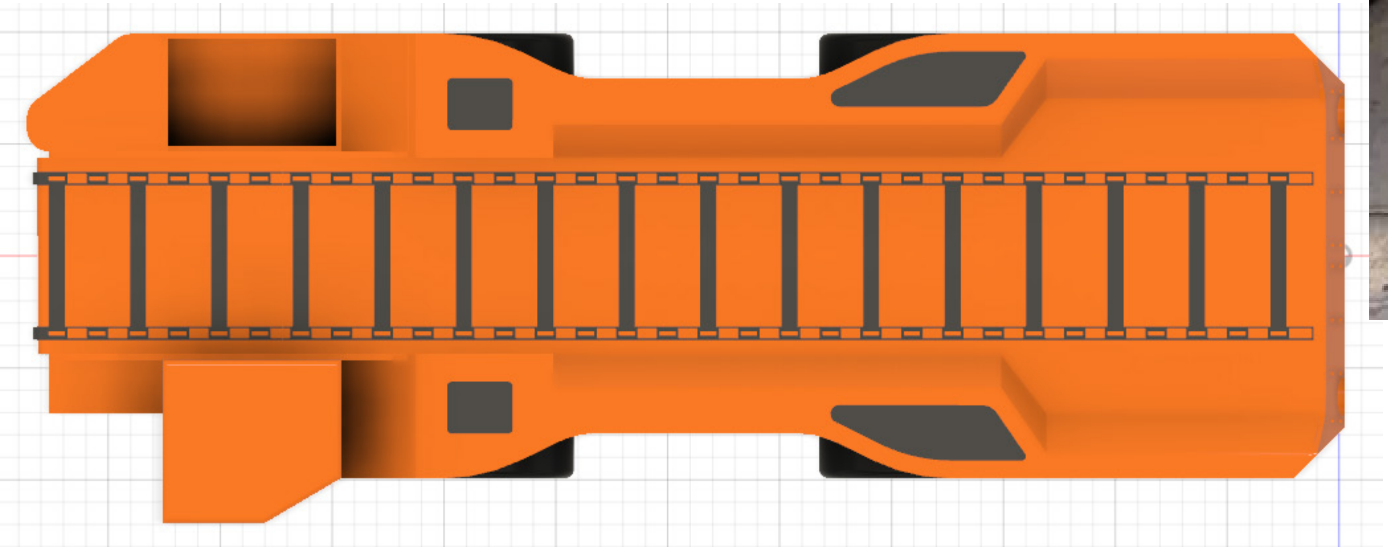
Discharge-End

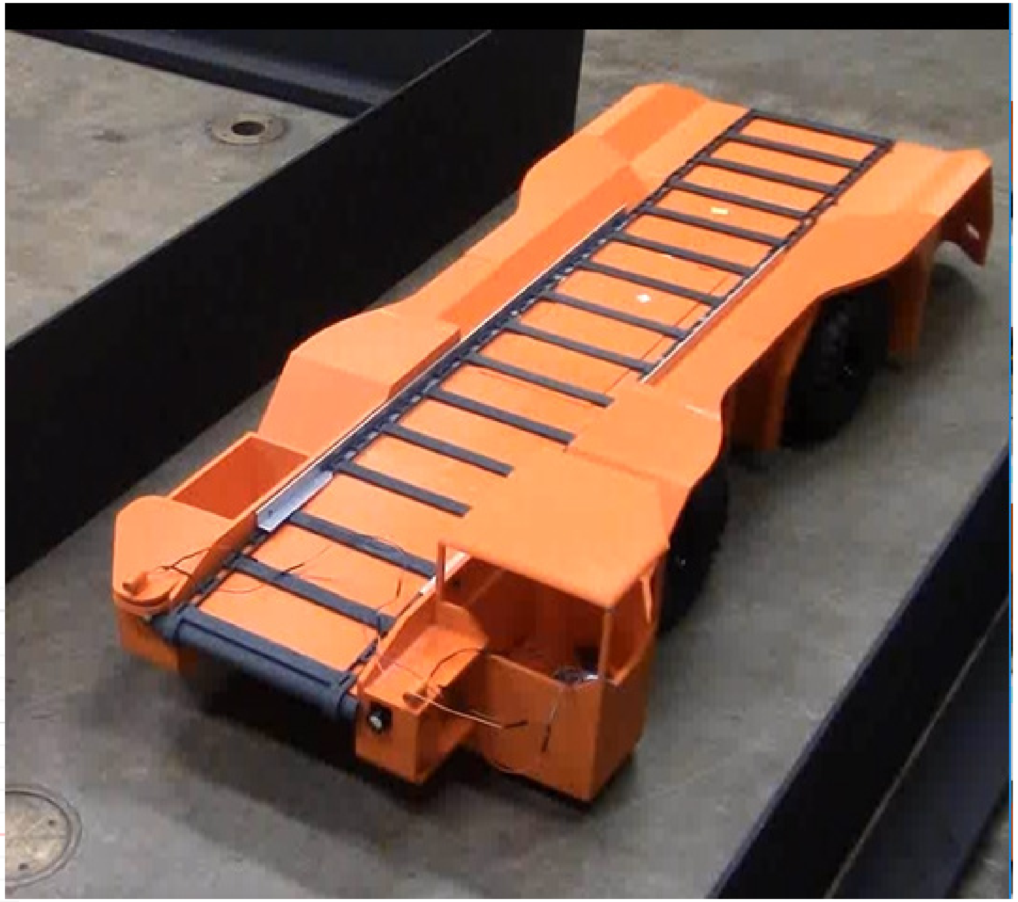


Load-End

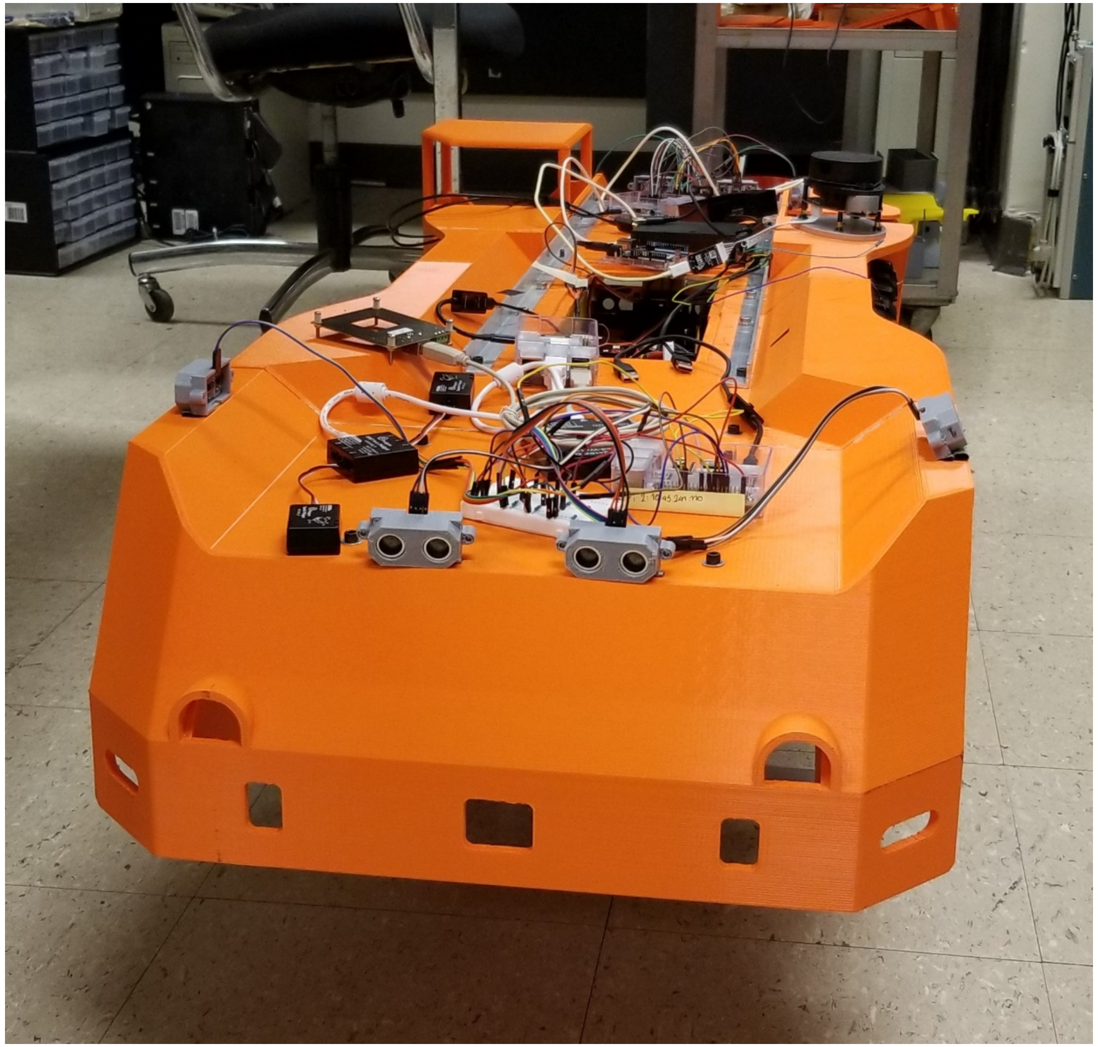
Lab-Scale Shuttle Car

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

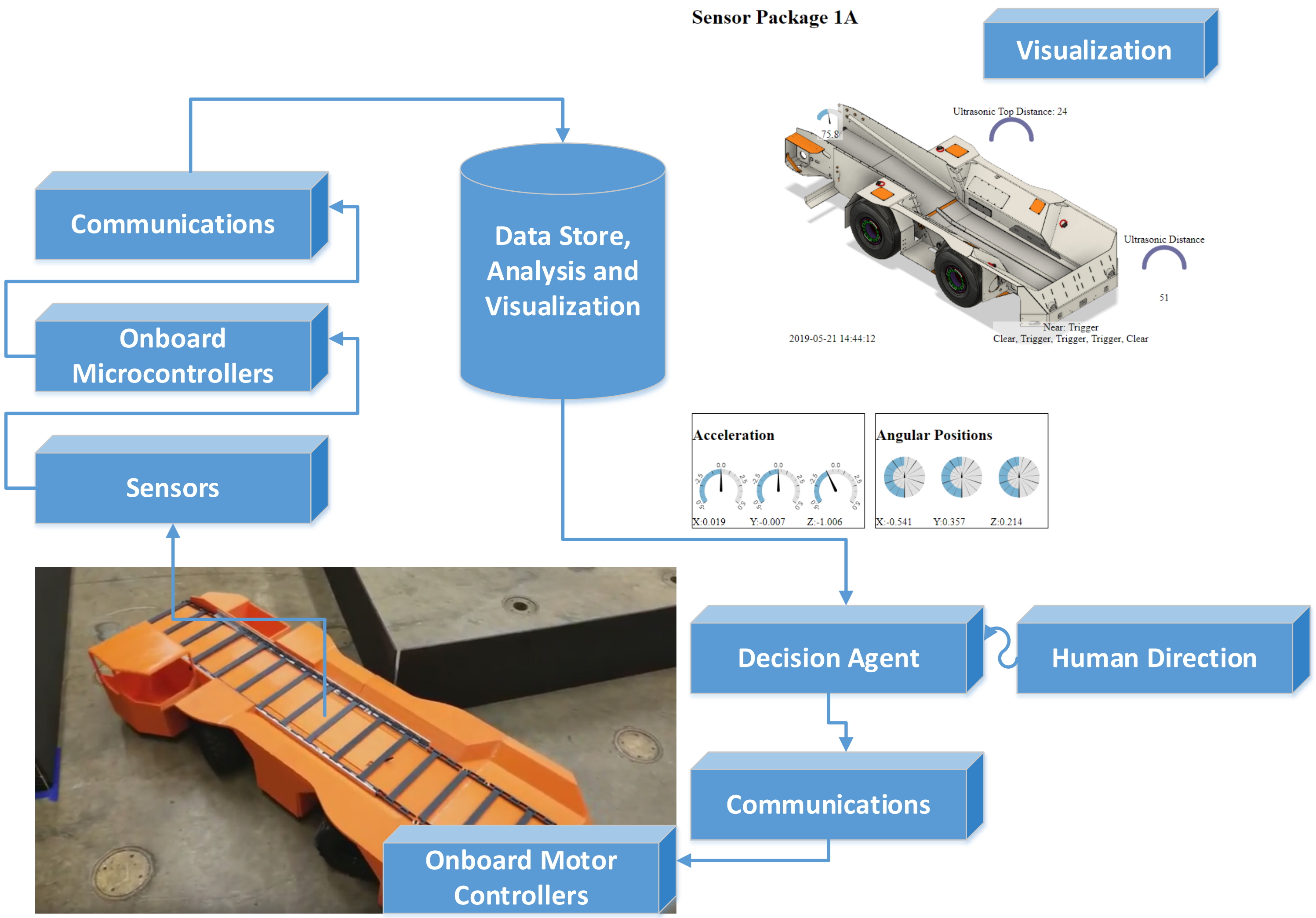




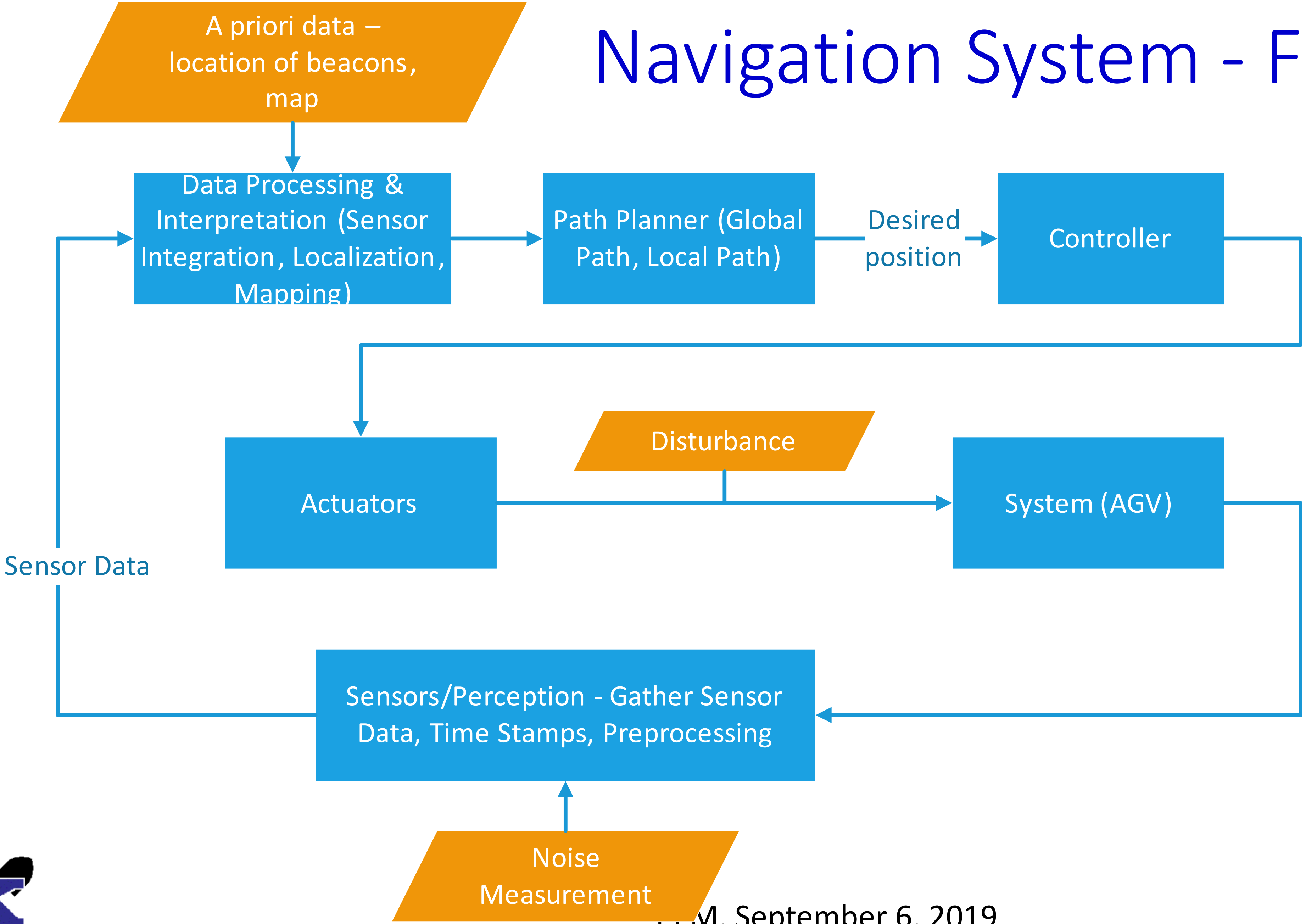
Lab-Scale Shuttle Car



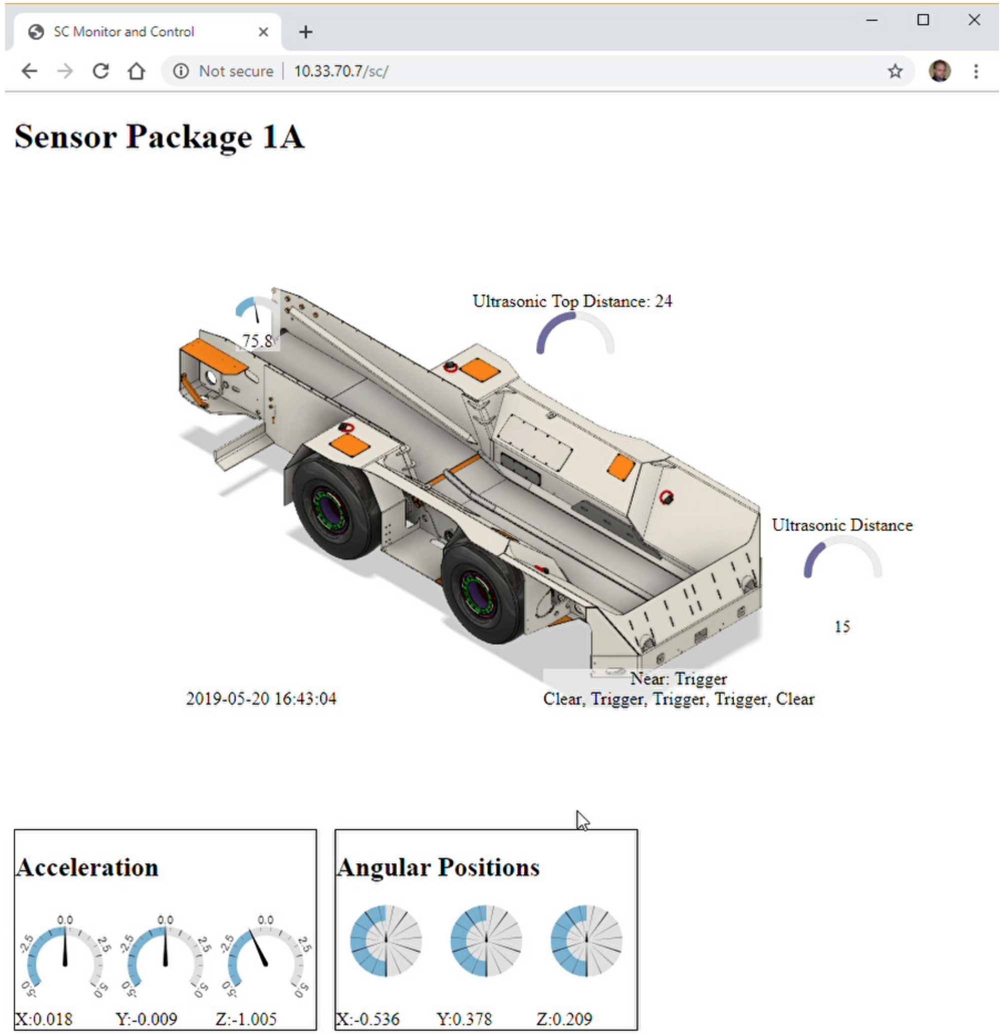
Navigation System - Data Management



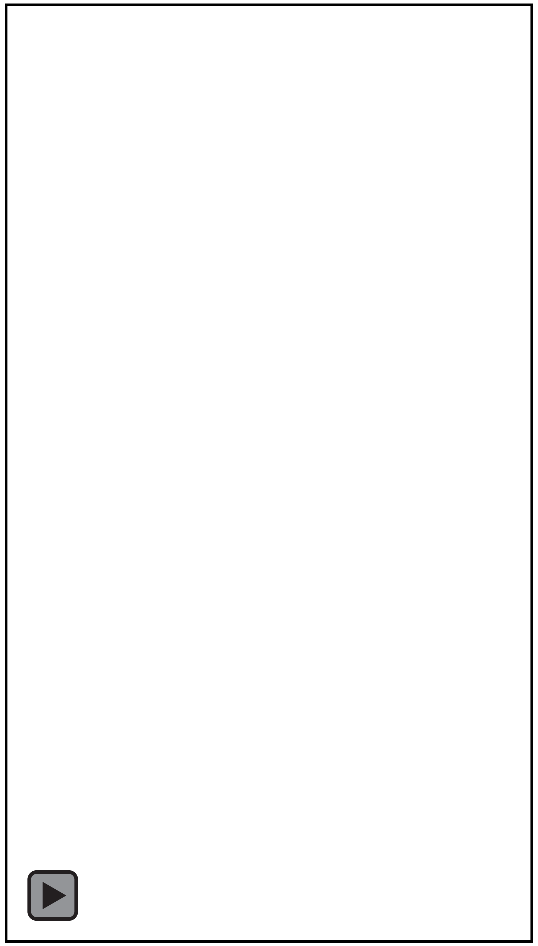
Navigation System - Flowchart



Navigation System – Data Visualization



Navigation System

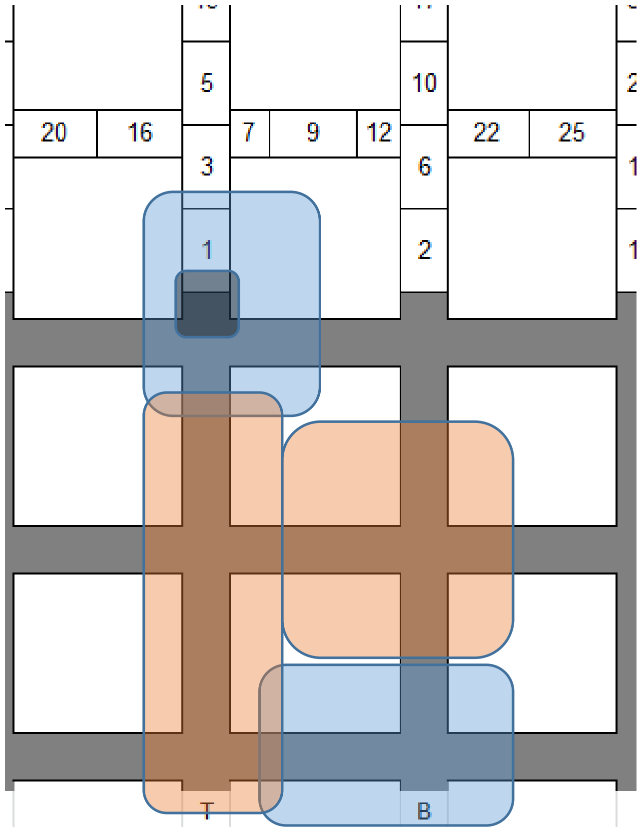


Underground Localization

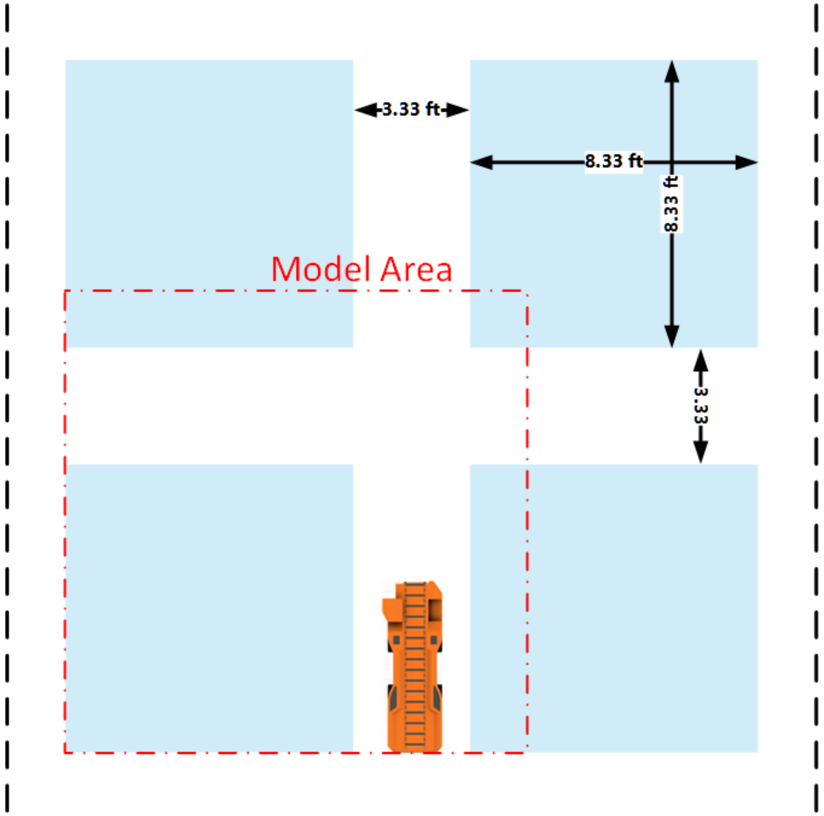
- Multiple localization techniques are currently available
  - Inertial Navigation System, laser, infrared, ultrasound, radio-based
- Existing device networks (communication or other infrastructure) can be used for localization
- Literature review indicated that vehicle-mounted beam-forming sensors (ultrasound, infrared, laser), which do not rely on additional infrastructure, deliver optimized localization efficiency, efficacy, and cost
- Such sensors can be easily integrated to provide robust mapping and proximity detection
- Integration with existing proximity detection systems is possible

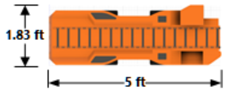
Localization Quality for the Task

- Unlike GPS based and many of the other underground autonomous systems, we are aiming for multiple zones of localization quality
- In places where the car will interact with other machines, or be near humans, the localization will need to be very accurate
- In places where the car is tramming, localization need not be as accurate



Scaled workings

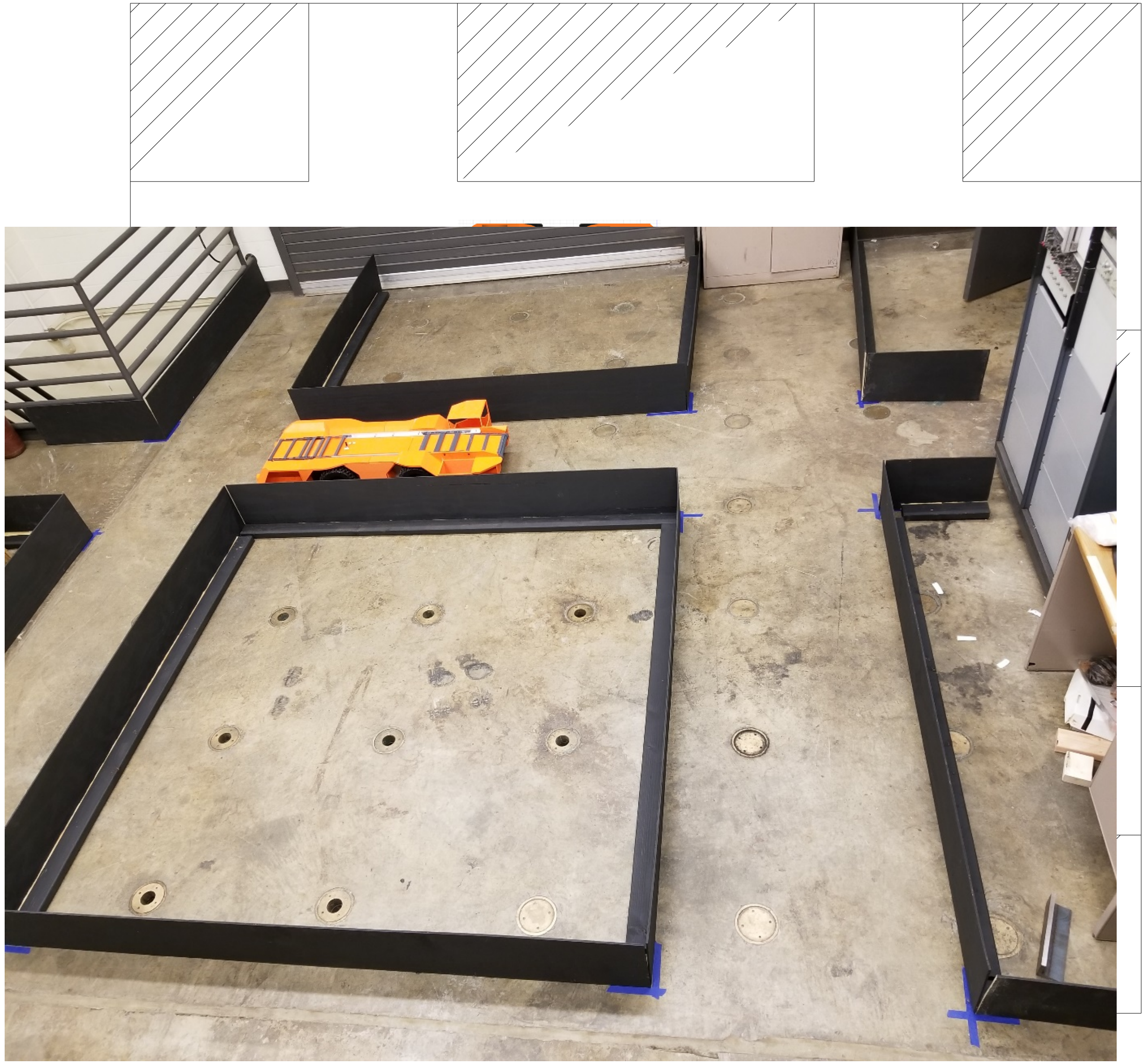




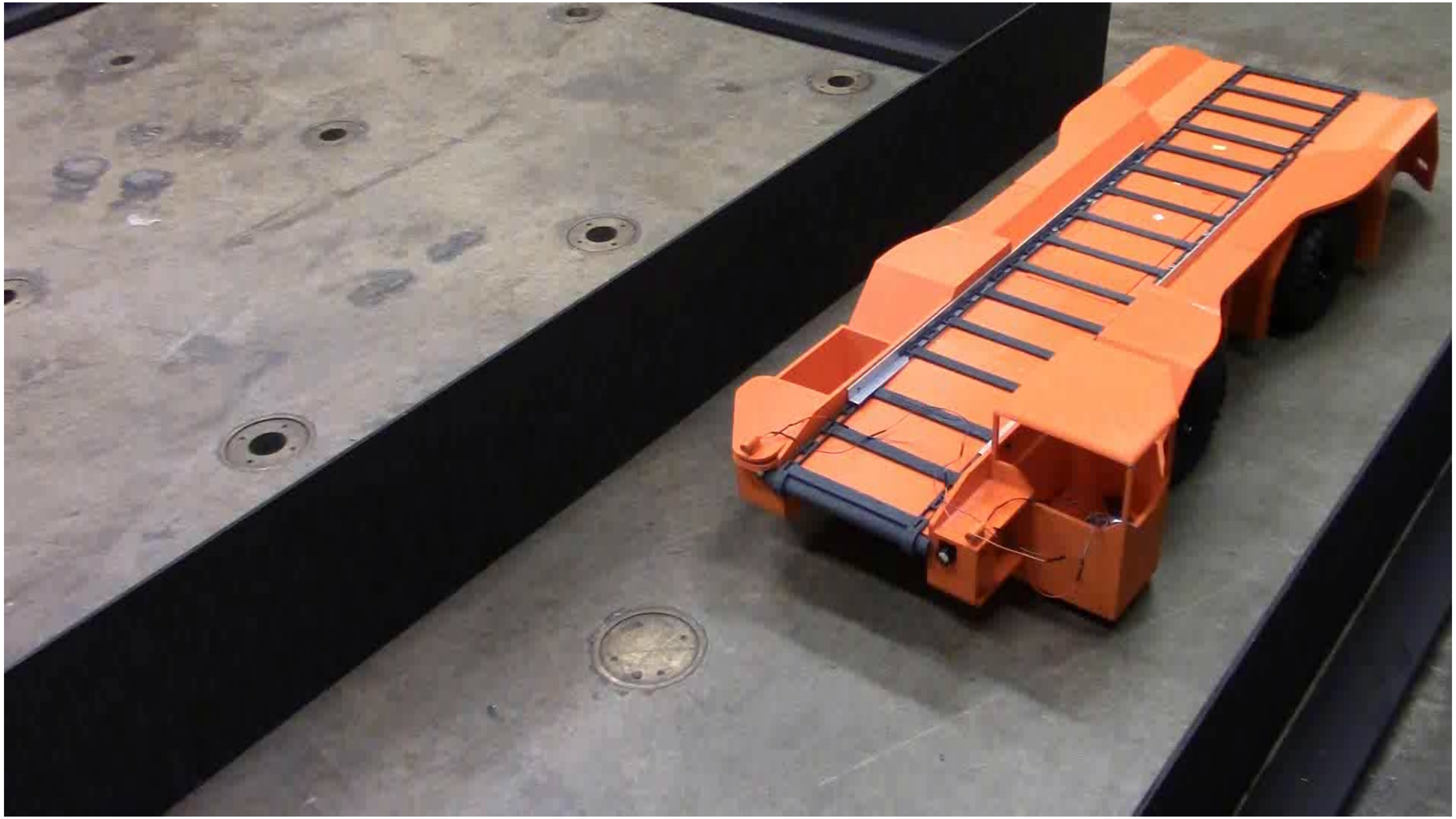
Track in the lab

Alternate Layouts

Allows for multiple paths

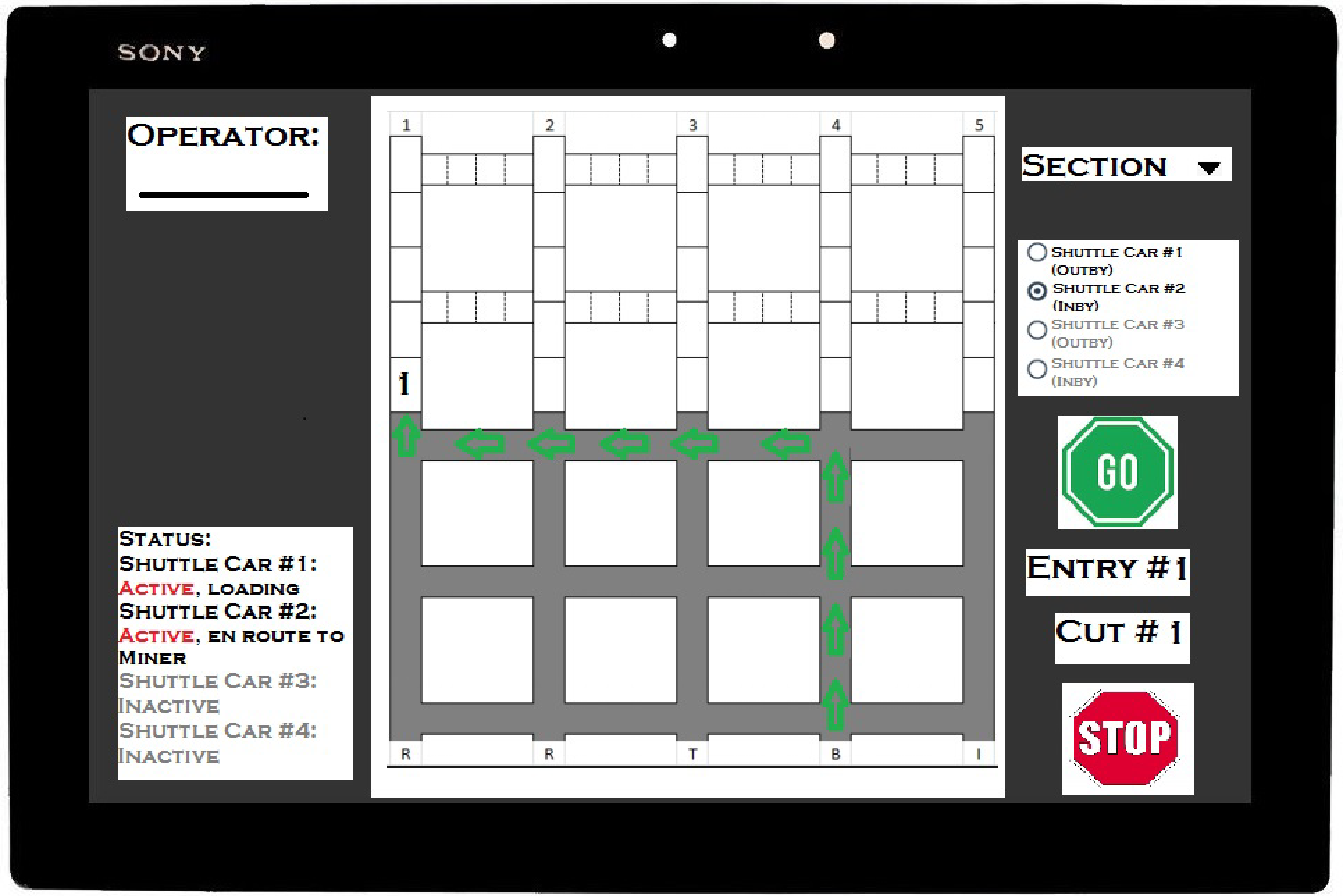


Shuttle Car – Video 1 – Remote Control



Shuttle Car – Video 2 – Autonomous Operation

Operator Tool Concept

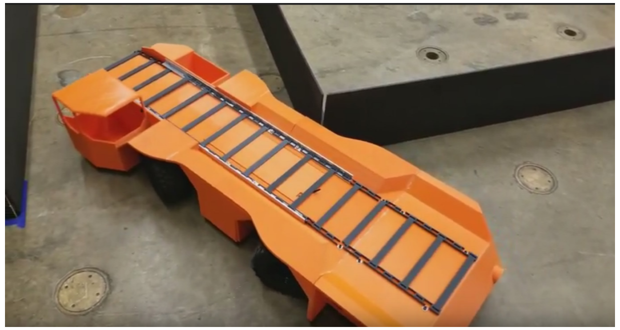


On-going Work

- Version 2 of the lab scale prototype nearly completed
- Continue to develop reliable navigation system
- Refine the data management system
- Evaluate performance of prototypes in the scaled mock mine
- Retrofit an actual shuttle car
- Demonstrate shuttle car operation at an underground mine

Shuttle Car Automation Preliminary Lessons

- Development is for demonstration not production
- Navigation without a map or GPS is feasible under regularity of terrain
- Consideration of human interaction with autonomous vehicles is critical



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