Opportunities and Challenges for Autonomous Shuttle Car Operation in Underground Coal Mines

Zach Agioutantis, Joe Sottile, Steven Schafrik,

Vasilis Androulakis,

University of Kentucky, USA

Longwall USA, Pittsburgh, May 22, 2019

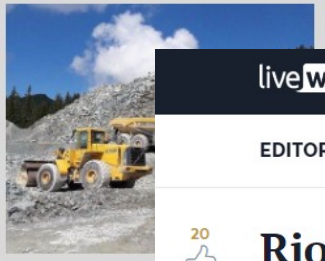
Outline

- Introduction
- Purpose of the Project
- Current Work
- Challenges
- Future Work

Mining Automation in the News

Humans Need Not Apply: Vale Iron Mine Goes Autonomous

Scott Tibballs - September 12th, 2018



Haulage trucks at the Brucutu mine will go autonomous in

Diversified mine
be 'manned' by a

In a Wednesday (S
Brucutu away fror

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 VALUI

20

SHARE

Rio Tinto's mining sector disruption

TIM GERRARD
Janus Henderson

When you pull up your car at a railway crossing in the Pilbara, yo
switch off the engine and get out to stretch your legs – you'll be w
while as wagon after wagon rumble by. While peace is restored s
ever short-lived as Asia's insatiable demand for iron ore means 3
need to make the journey from mine to port that day. Three locor
typically haul 240 wagons of processed iron ore, delivering 28,00
facilities in a single train load – day in, day out.

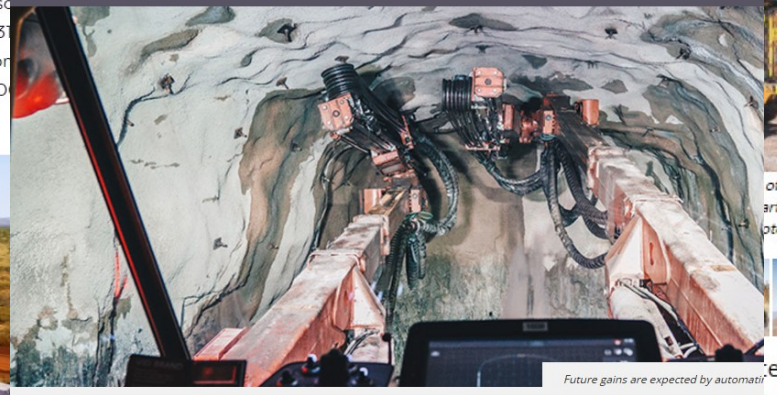
Mining Magazine

Webinars Events Online Exclusive

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 automati

Future Of Mining > Investment

"We are implementing a successful cocktail of electrification," he said.

11 April 2019

Innovation rush in the oil sands

Oil sands operators and suppliers alike are trying to find ways to reduce operations costs and cut emissions

By Alexandra Lopez-Pacheco | September 12, 2018

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

TUE SEPTEMBER 11, 2018 - WEST EDITION #19

AARON WITT – CEG CORRESPONDENT

of 400 tons — about the weight of 200 cars — roam
art of Caterpillar's Cat Command for Hauling system.
oto)

…es on earth, trucks hauling an upwards
…s — roam from pit to crusher with no
…aterpillar's **Cat Command for**
autonomous trucking.

Relate

ARIZONA
Technolog

NEXT ST

TEMPE'S
RIGHT TR

← PREV

AHWATU
PROGRES

Like P

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

CONNECT TWEET LINKEDIN COMMENT EMAIL MORE

Share your feedback to help improve our site experience!

POPULAR STORIES

High school principal dies after bone marrow donation

usatoday.com | 17 hours ago

WikiLeaks founder Julian Assange arrested, charged

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

Displacement ?

Long-Haul Driverless Trucking Would Displace Good-Paying Jobs

September 05, 2018 by Alan Adler, @AlanAdler

Driverless trucks could replace high-paying jobs. (Photo:

Autonomous trucks will displace good-paying, long-haul driving
paying delivery and port jobs, according to a new study.

Of 2.1 million trucking jobs in the U.S., 294,000 drivers on the na
threat from driverless technology, according to the UC Berkeley
Education and Working Partnerships USA report.

Getting trucks from factories or warehouses to autonomous tru

Presidential candidate says driverless trucks will cause 'mass riots'

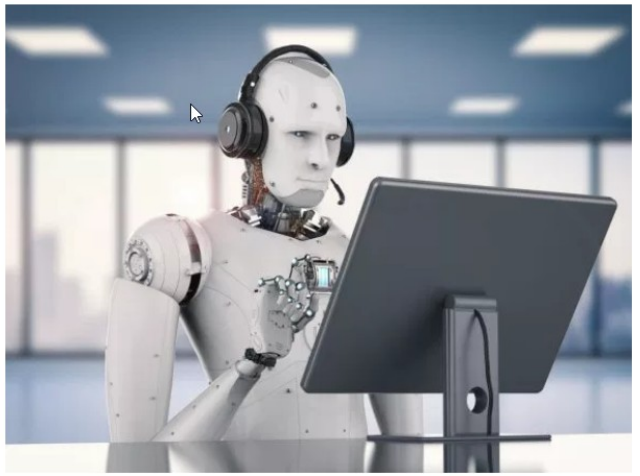
He predicts that truckers who lost their jobs to robots would "park their trucks across the highway and get their guns out."

By **Ashley** - March 18, 2019

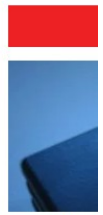
A Democratic presidential candidate is making headlines for his bold predictions about how he believes truck drivers will fight back violently if autonomous vehicles take away their jobs.

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.



New IBM tech
recognition t
hours

Google's new
phone calls, a

Mine Automation Future

- Underground is the growth
- Key factors
  - increasing need for worker safety
  - improvement in mining productivity
  - the reduction in operating costs

Astonishing Growth: Mining Automation Market 2019-2024 Company Share Analysis: Caterpillar, Sandvik, Atlas Copco, Komatsu, ABB, Hitachi, Hexagon, Rockwell, Micromine, Volvo Group, Trimble, Remote Control Technologies, Mine Site Technologies, and More

By Charles Dozier - April 11, 2019

Share on Facebook | Tweet on Twitter

Trending News

Mining Automation Market Competitive Landscape and Industry Expansion Strategies By 2026

Mining automation refers to highly efficient autonomous installation that enhances productivity and improves safety.

Misconceptions

Global Coal Handling Equipment Market in the Mining Industry, 2019-2023 - ResearchAndMarkets.com

March 22, 2019

Press release content from Business Wire. The AP news staff was not involved in its creation.

Click to copy

RELATED TOPICS

Business Wire
Business
Business Wire: Misc
Consumer affairs
Coal mining

DUB
Hand
repor
The c
regist
Coal
How
secto
the a
produ
extra
to inc
mine

Coal mining has traditionally been a labor-intensive industry. However, the growing competitiveness in the renewable energy sector and the emergence of substitutes for coal have accelerated the adoption of automation in coal mining to make mining productive and efficient. Furthermore, the share of coal extracted using the underground coal mining method continues to increase in the global coal mining industry. Underground coal mine workers are subject to increased safety risks than the

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

Studying Shuttle Car Automation

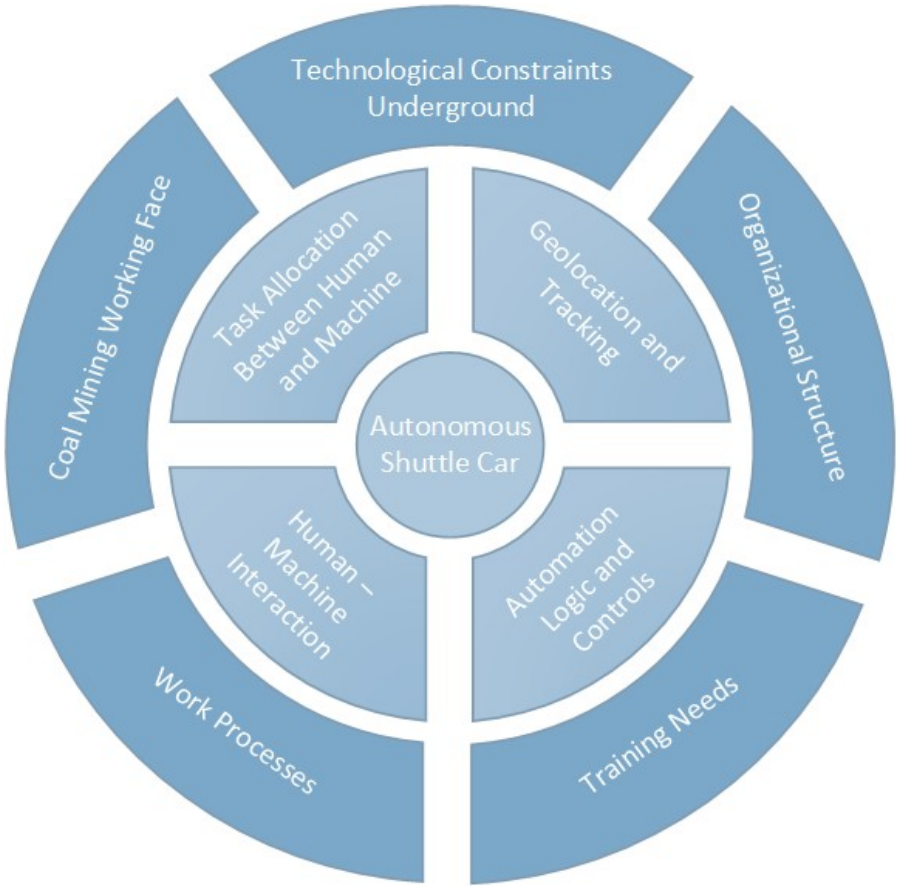
- Why Shuttle cars:
  - Much of the operation of the shuttle car underground is repetitive
  - Shuttle cars operate at a variety of speeds in a variety of areas
  - Shuttle cars are tethered
  - Shuttle car routes are generally predicable
  - Controls are straight forward
  - Most miners already know to avoid the path of a car

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

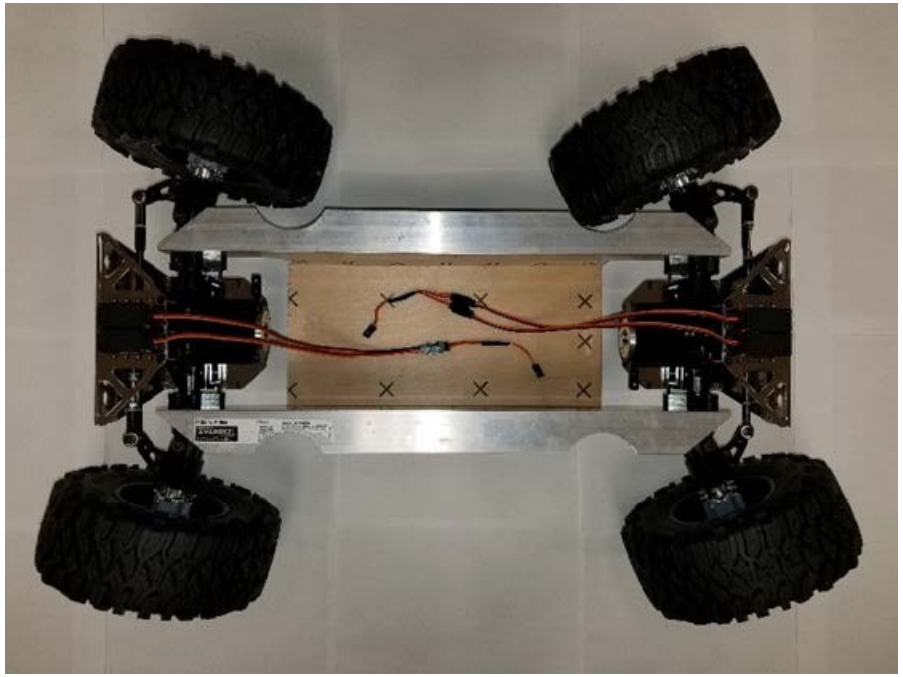
Approach

- 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.

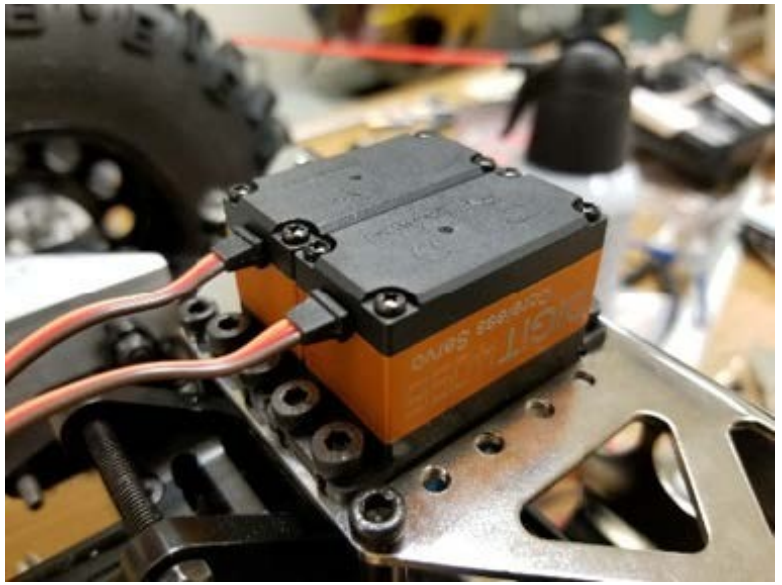


Lab-Scale Shuttle Car

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



Frame and Axles

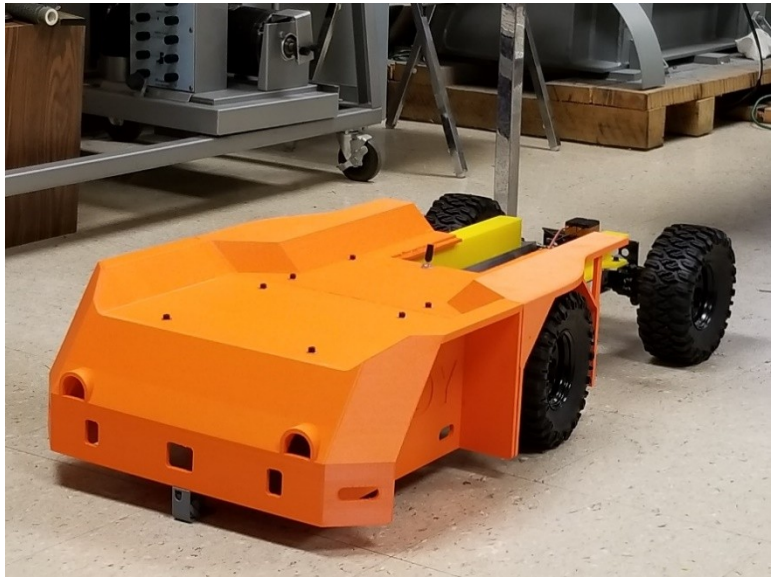


Steering Servo Motors

Lab-Scale Shuttle Car

- Body is based on Joy 10SC32B drawing provided by Komatsu Mining Corp.
- The scaled parts were printed on a Gigabot 3+ 3D printer

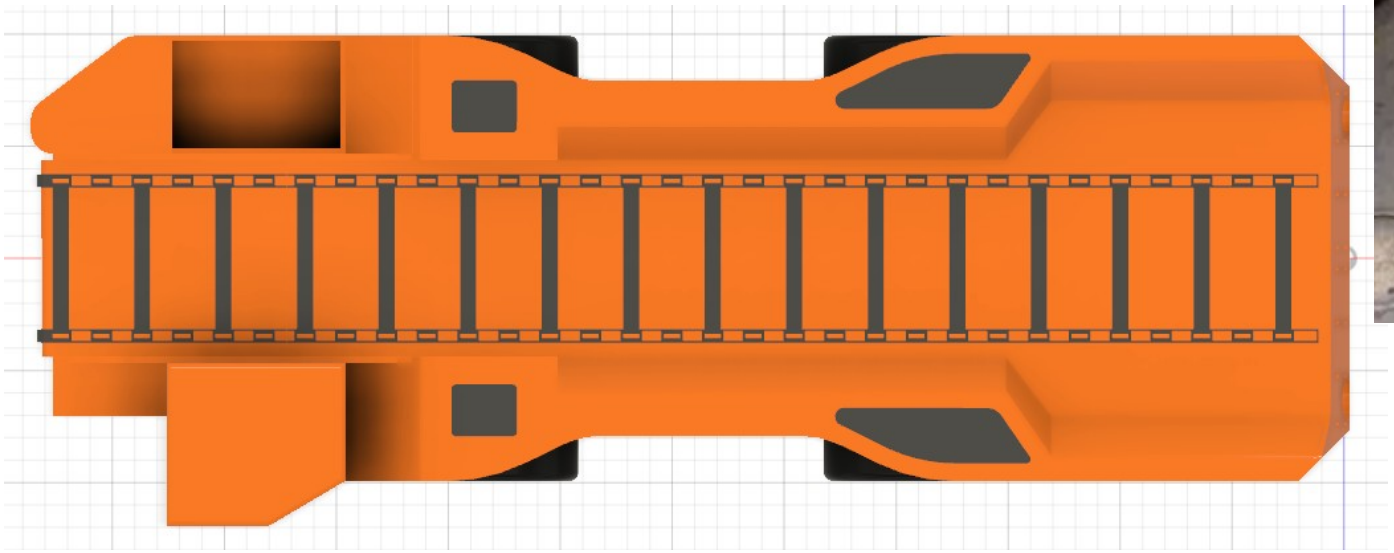
Discharge-End

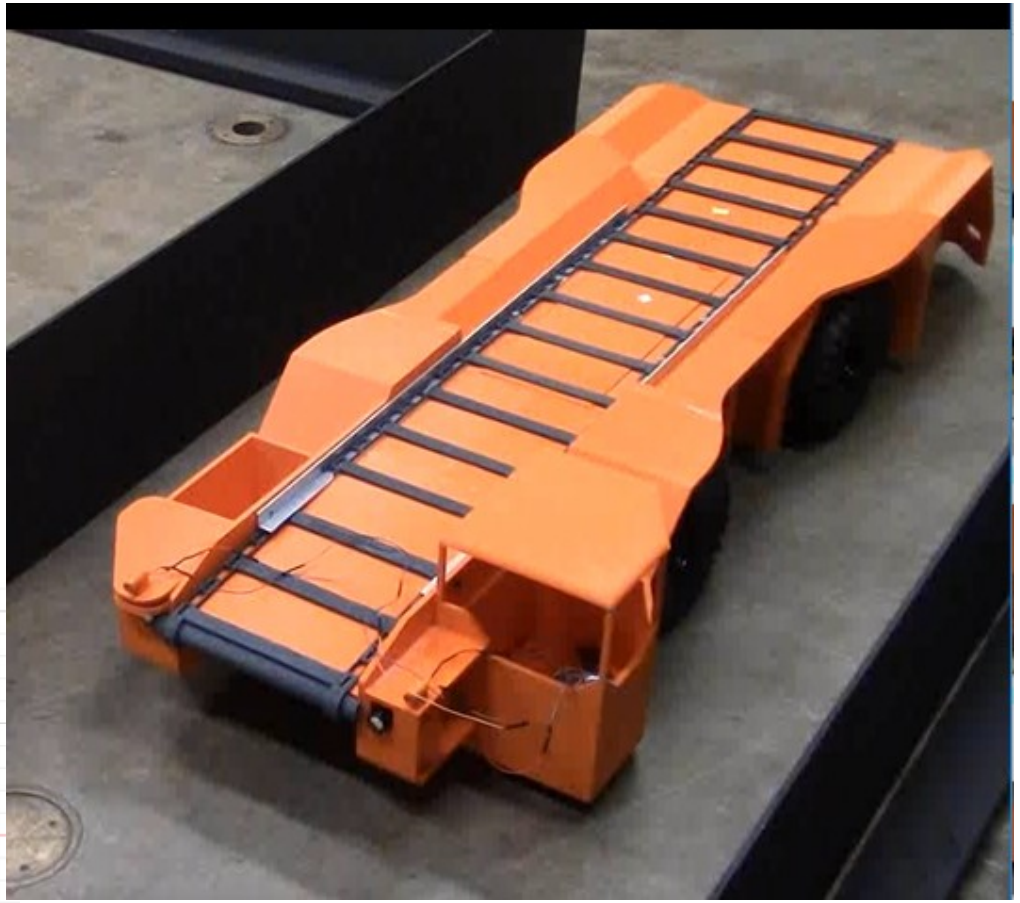


Bumper-End

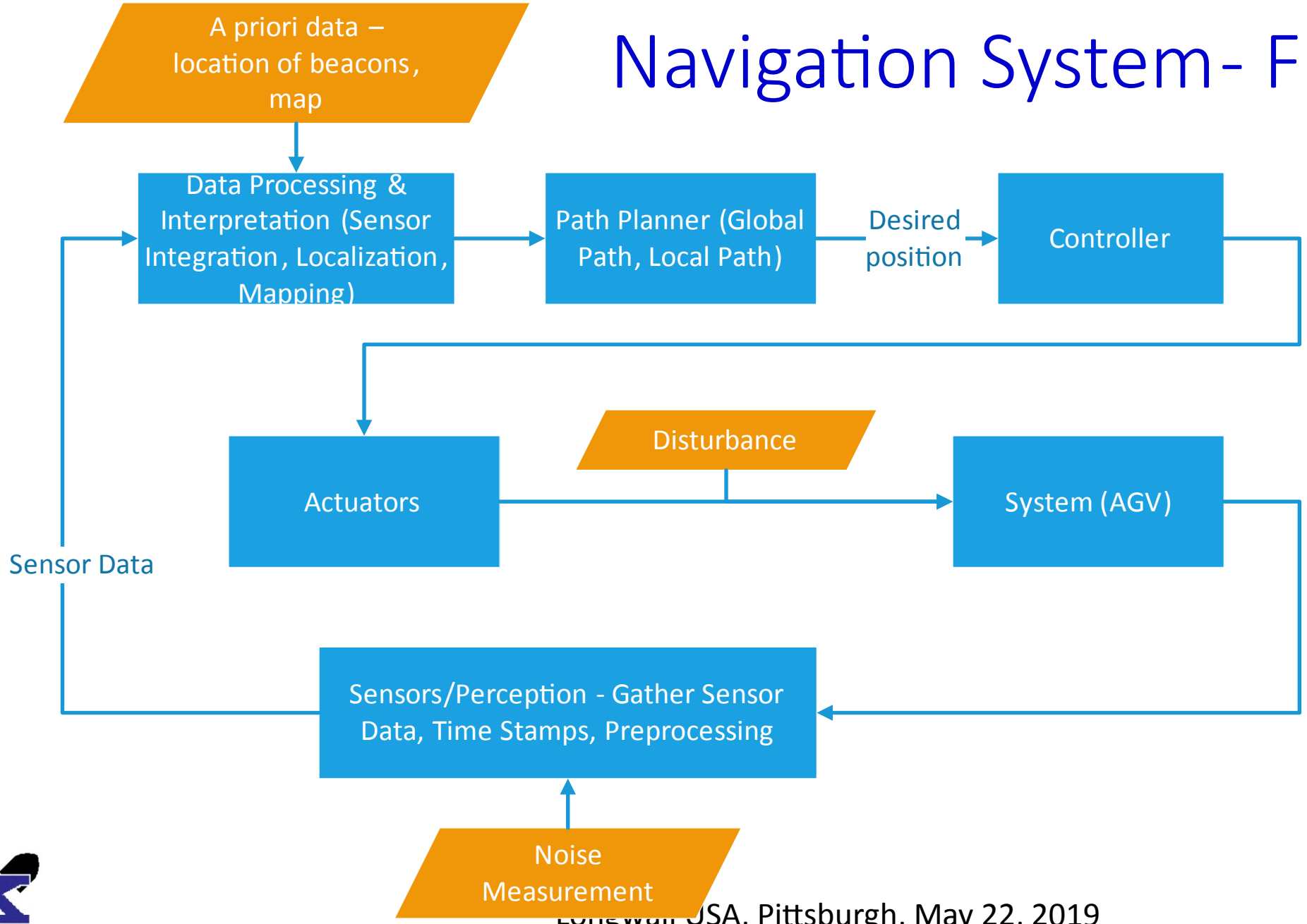
Lab-Scale Shuttle Car

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

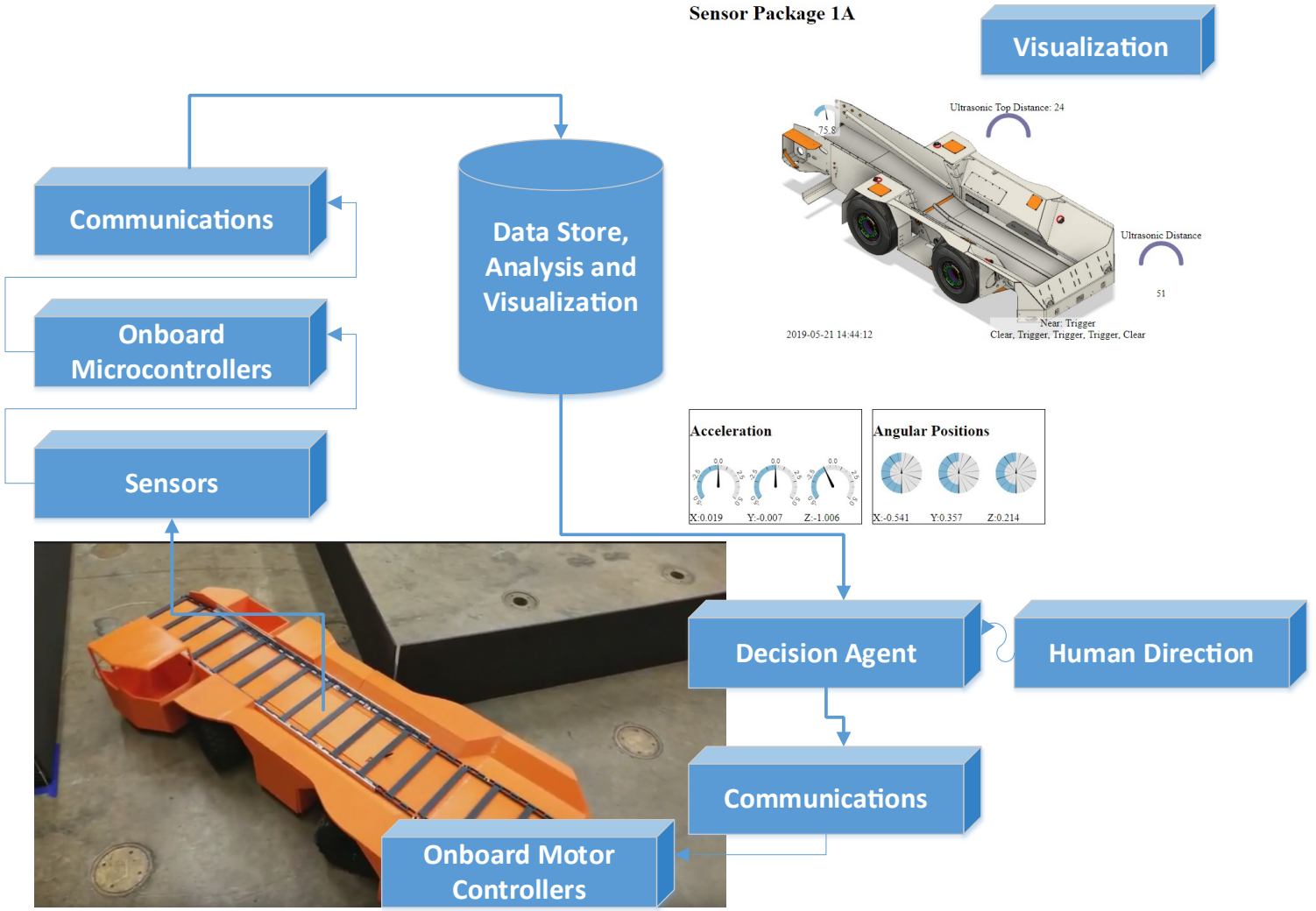




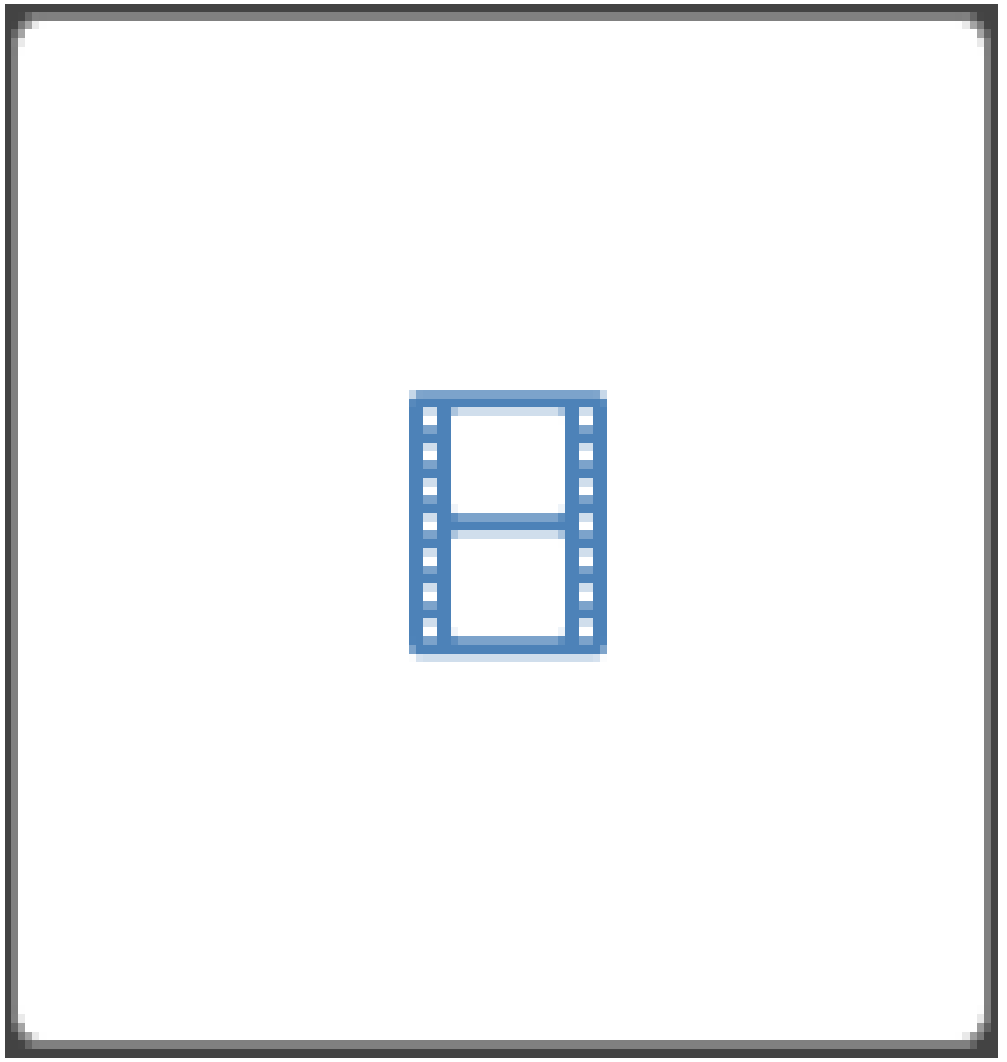
Navigation System- Flowchart



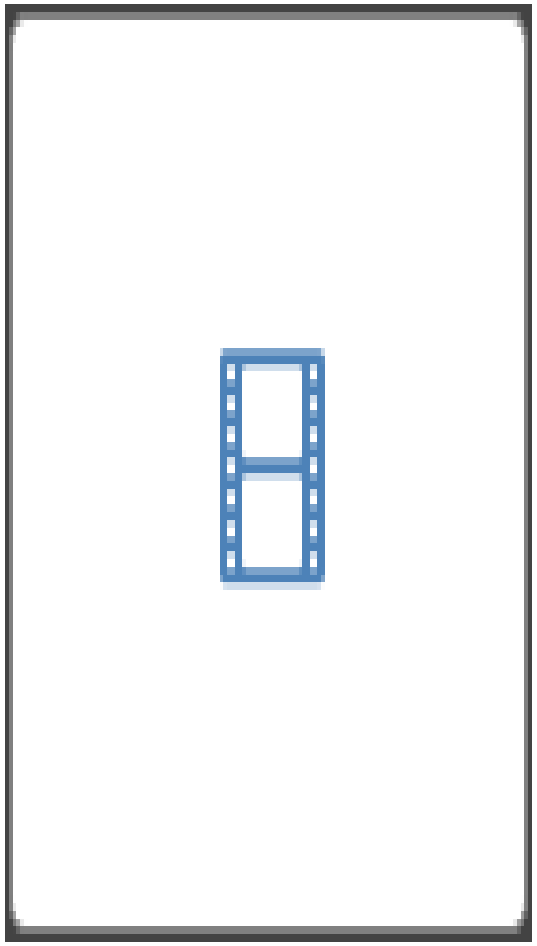
Navigation System- Data Management



Navigation System – Data Visualization



Navigation System – Simulink

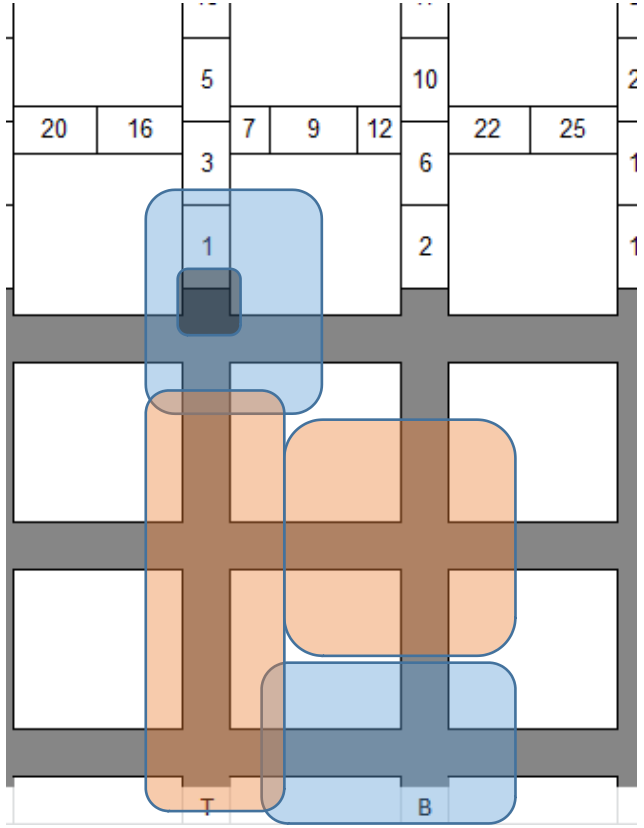


Underground Localization

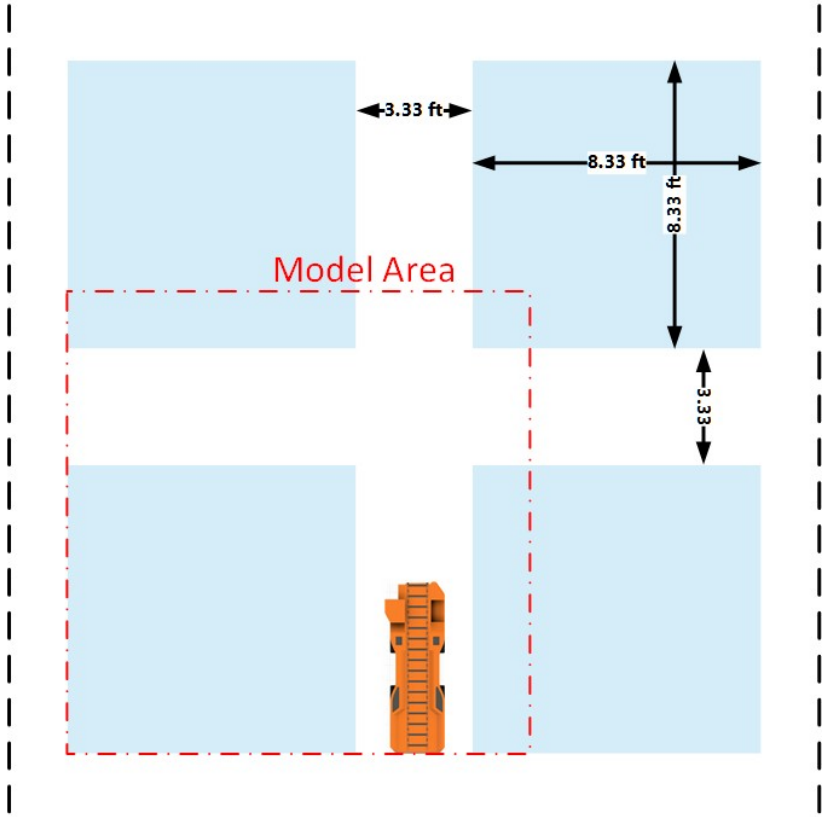
- Multiple localization techniques are currently available
  - Inertial Navigation System, laser, infrared, ultrasound, radio-based
- Existing device networks (communication or other infrastructure) can be used for localization
- Literature review indicated that vehicle-mounted beam-forming sensors (ultrasound, 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

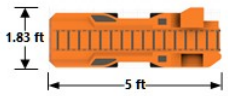
Localization Quality for the Task

- 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 on the scale of sub-inches
- In places where the car is tramming, localization needs to be in several inches to foot



Scaled workings



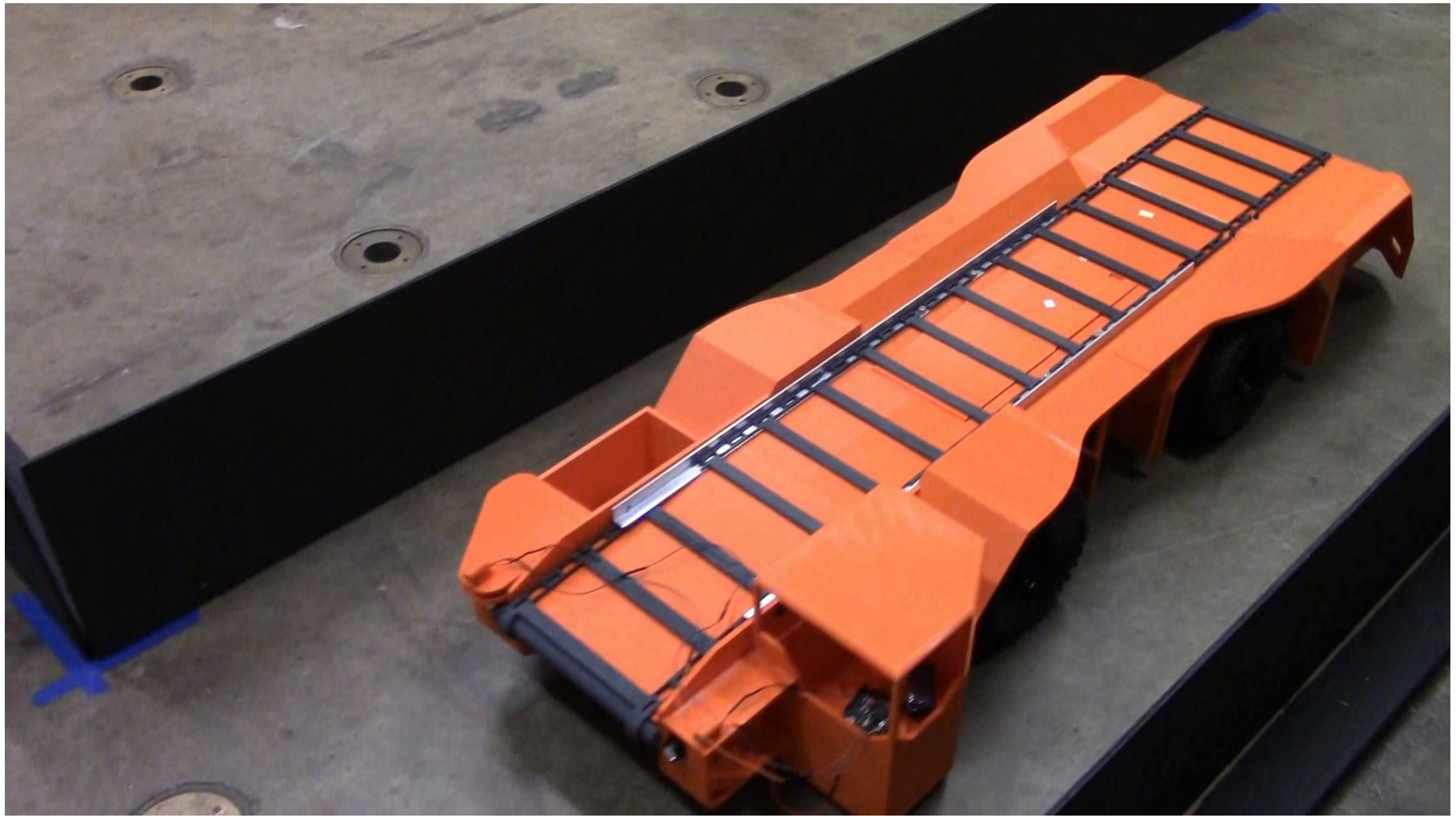


Track in the lab

Alternate Layouts

Allows for multiple paths

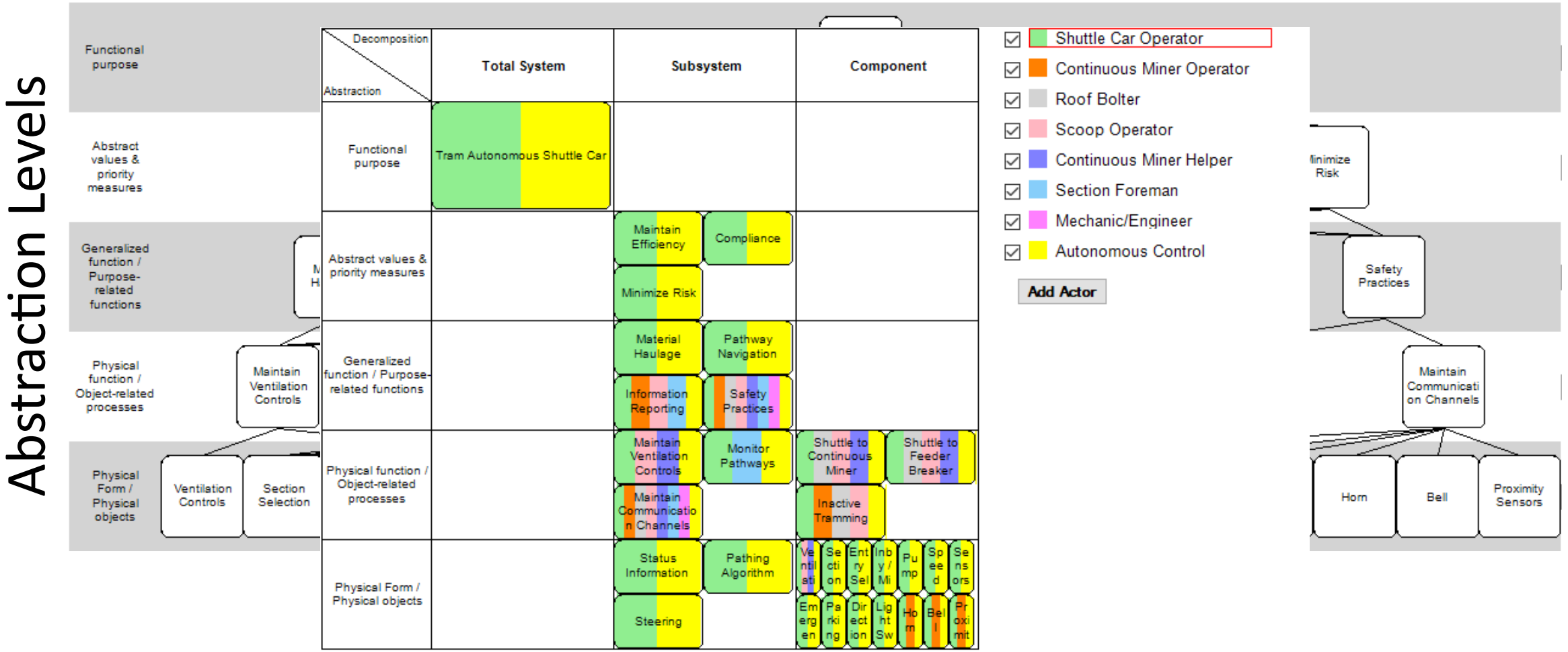
Shuttle Car- Video



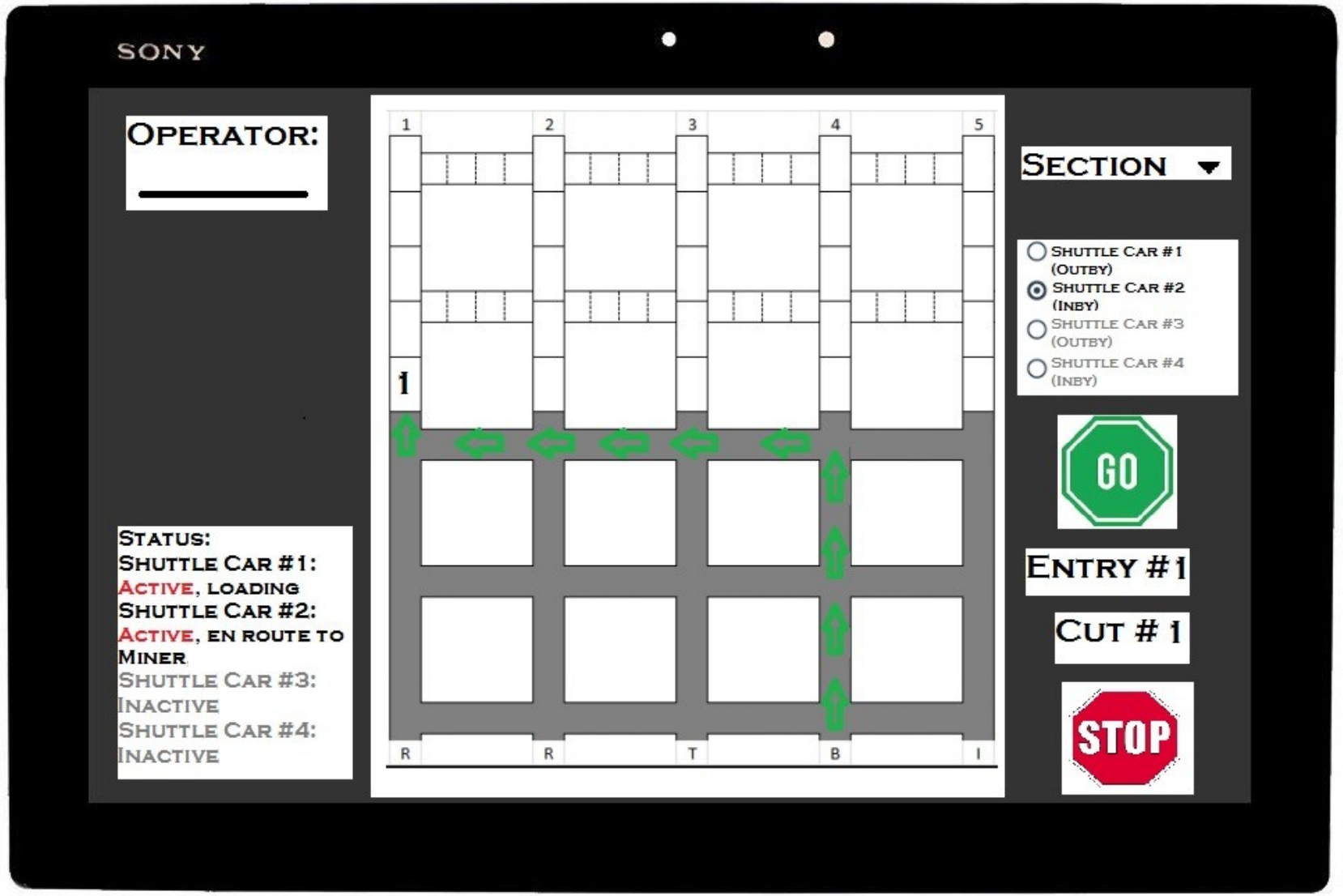
Restrictions & Challenges

- Continuous changing of mine layout
- Confined space
- Human-vehicle interactions
- Non-GPS environment & Line-of-Sight requirements
- Power cables
- Dust, humidity, ventilation curtains
- Robust mapping of the surroundings
  - Poor visibility conditions restrict vision
  - Computational cost
  - Compatibility of different sensors data

Results- CWA Automation

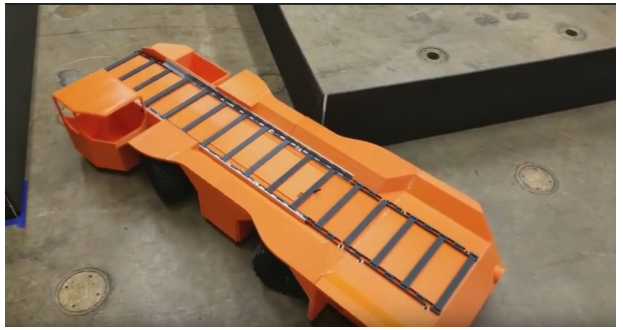


Operator Tool Concept



On-going Work

- 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
- Demostrate 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.