Autonomous Shuttle Car Research

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Acknowledgements

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We have had huge amount of help from our industry partners and this work cannot be done without their support

Introduction

- When you find yourself doing the same thing over and over again, there's an opportunity to train a computer to do that activity
- The mining industry has a long history of automation
- There's a lot of opportunity and activity in mine automation

Automation in the News

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Humans Need Not Apply: Vale Iron Mine Goes Autonomous

Scott Tibballs - September 12th, 2018

Haulage trucks at the Brucutu mine will go autonomous in 2019, after six years of research into the viability of the project returned positive economics.

Diversified miner Vale (NYSE:VALE) has announced that its Brucutu iron mine in Minas Gerais w be 'manned' by autonomous hauling trucks by the end of next year.

In a Wednesday (September 12) release, the company detailed plans to transition the hauling fleet at Brucutu away from 'traditionally operated vehicles' to become fully autonomous

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

20

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Rio Tinto's mining sector disruption

TIM GERRARD
Janus Henderson

19th August, 2018

When you pull up your car at a railway crossing in the Pilbara, you can afford to switch off the engine and get out to stretch your legs – you'll be waiting for quite a while as wagon after wagon rumble by. While peace is restored soon enough, it's only ever short-lived as Asia's insatiable demand for iron ore means 31 more trains will need to make the journey from mine to port that day. Three locomotive engines typically haul 240 wagons of processed iron ore, delivering 28,000. tonnes to the port facilities in a single train load – day in, day out.

Automation in the News

"The future is here."

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)

The future is here. 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.

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Automation in the News

7 SEPTEMBER 2018 COMMENT

Automated truck upgrades will cut costs at Australia's iron ore mines

By **GlobalData Energy**

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Rio Tinto, which is responsible for up to 40% of Australia's iron ore production, has gradually expanded its AHS truck fleet, increasing it to 95 as of the end of 2017, with plans to increase further to around 150 trucks by 2020. Credit: Courtesy of Rio Tinto/Christian Sprogoe Photography

Automation in Australia's mining industry began with the successful implementation of Komatsu's Automatic Hauling System (AHS) at Rio Tinto's Pilbara iron ore operations in 2008. During that year, the compan deployed five AHS trucks. Rio Tinto, which is responsible for up to 40% o Australia's iron ore production, has gradually expanded its AHS truck fleet, increasing it to 95 as of the end of 2017, with plans to increase

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

Komatsu has worked with Suncor since 2013 to adapt the OEM's autonomous haulage systems to the Alberta oil sands. Courtesy of Komatsu

Dozens of emerging technologies for almost every facet of oil sands production could be paving the way for solutions to the most significant environmental and operational challenges faced today. In fact, according to a study by the Canadian Energy Research Institute (CERI), these emerging technologies are establishing a foundation for the industry to reduce its operational costs by 40 per cent and its emissions by up to 80 per cent. There is an innovation rush in Alberta's oil sands and the impacts could be far reaching.

It’s not all good news

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

Long-Haul Driverless Trucking Would Displace Good-Paying Jobs

September 05, 2018 by Alan Adler, @AlanAdler

Driverless trucks could replace high-paying jobs. (Photo: Jerry Hirsch/Trucks.com)

Autonomous trucks will displace good-paying, long-haul driving jobs, replacing them with low-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 nation's highways face the greatest threat from driverless technology, according to the UC Berkeley Center for Labor Research and Education and Working Partnerships USA report.

Getting trucks from factories or warehouses to autonomous truck ports on the outskirts of cities

Underground is not left out

Australian Mining

Home | News | Features | Oil & Gas | Mine Map | Events | Resources | Magazine

Sandvik positions mining companies for underground automation

September 11, 2018 | Features, News | Australian Mining

Total underground automation is becoming a reality. Sandvik is working with Australia's Resolute Mining to introduce the technology in West Africa. Australian Mining *writes.*

Resolute Mining's Syama underground operation in Mali.

Sandvik continues to bolster its underground automation capabilities with updated equipment and systems.

The original equipment manufacturer (OEM) has accelerated its development into an automation-ready company as these projects have become economically possible for mining companies

Sandvik has established its '3 Pillar Framework' for automation, which provides efficient monitoring and accurate reporting of data, smart management systems and intelligent machines equipped with systems like AutoMine and OptiMine.

It has also released a range of new machines – the i-series – that support the move of mining companies into an underground automation environment.

Latest News

- Collaboration and communication at MICROMINE's Regional Manager's Week
- Rio Tinto Amrun export facility wins civil construction award
- Lithium Australia cathode performance to be tested by Chinese battery makers
- Kalium Lakes in talks with Australian Government for NAIF potash funding

Sandvik has taken a major step towards its underground automation vision this year through a relationship with Australian-based gold company, Resolute Mining.

5 SEPTEMBER 2018 ANALYSIS

Could 5G be the key to unlocking autonomy in deep mines?

By **Molly Lempriere**

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Volvo Construction Equipment is partnering with mobile operator Telia to pilot 5G mobile tech, giving mining an exponential boost in data transfer capabilities. How promising is that extra G and could it unlock the next generation of autonomous vehicles?

As autonomous fleets expand in size and the number of connected devices at mine sites increase, more will be needed. This is where 5G comes in. Credit: Courtesy of Volvo

Over the last few years, automation in the mining sector has boomed. In particular, automated vehicles like trucks, which allow efficient haulage almost 24/7, are now a common sight in the mines of Rio Tinto, BHP and others. Secure, reliable communication with

MOST READ

1. **Vale to automate iron ore mine to improve safety and production**
2. The five largest coal-producing states in the US
3. Glencore share price hit after lawsuits over dealings with Israeli billionaire Dan Gertler

Mine Automation Future

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

MINING AUTOMATION MARKET 2023 – MARKET SIZE, SHARE, TRENDS ANALYSIS AND GROWTH FORECAST

September 12, 2018 Maria Martinez Uncategorized Comments Off

Mining Automation Market 2018 research report is a proven source of information which offers a telescopic view of the current **market trends, situations, opportunities and status.** Both established and new players in the Mining Automation industry can use this report for complete understanding of the market.

"The mining automation market has been segmented on the basis of technique, workflow, type, and geography.Key factors such as the increasing need for worker safety, the growing requirement improvement in mining productivity, and the reduction in operating costs are driving the market growth. The underground mining technique held the largest share of the mining automation market in 2017 owing to the major minerals found under the earthâ□□s crust, which are explored, collected, and later on processed. Since working in underground mines is considered extremely hazardous, the need for advanced automated mining equipment is more for underground mining techniques. To safeguard mine workers, automated systems have been deployed at a huge rate in underground mines, which

Common Components

- All these projects have common technical characteristics
  - Communication in abundance
  - High reliance on GPS or similar localization technology
  - Isolation
- All these project have common non-technical characteristics
  - Remote FIFO operations
  - High Capital Expenditures
  - Mostly companies with remote operations experience
  - Favorable regulatory environment

Underground Shuttle 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

- 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.

Advantages of Studying Shuttle Car Automation

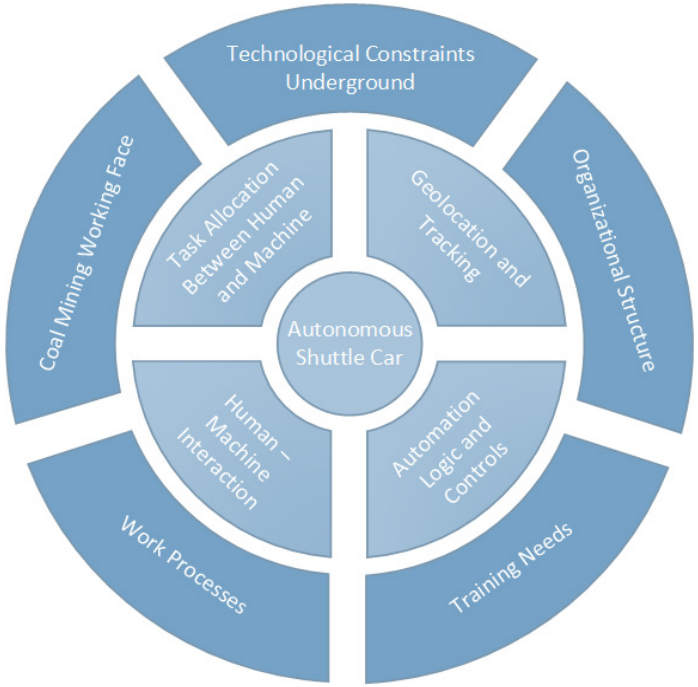
- Why Shuttle cars:
  - Much of the operation of the shuttle car underground is repetitive
  - Shuttle cars operate at a variety of speeds in a variety of areas
  - Shuttle cars are tethered
  - Shuttle car routes are generally predicable
  - Controls are straight forward
  - Most miners already know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

Challenges

- 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
  - Designing developing and demonstrating a functional autonomous shuttle car

Approach

1. Develop the framework for an accurate and reliable underground navigation system and methodology,
2. 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
3. Develop and demonstrate a functional prototype of the automated shuttle car haulage system.



Academic Team

- University of Kentucky
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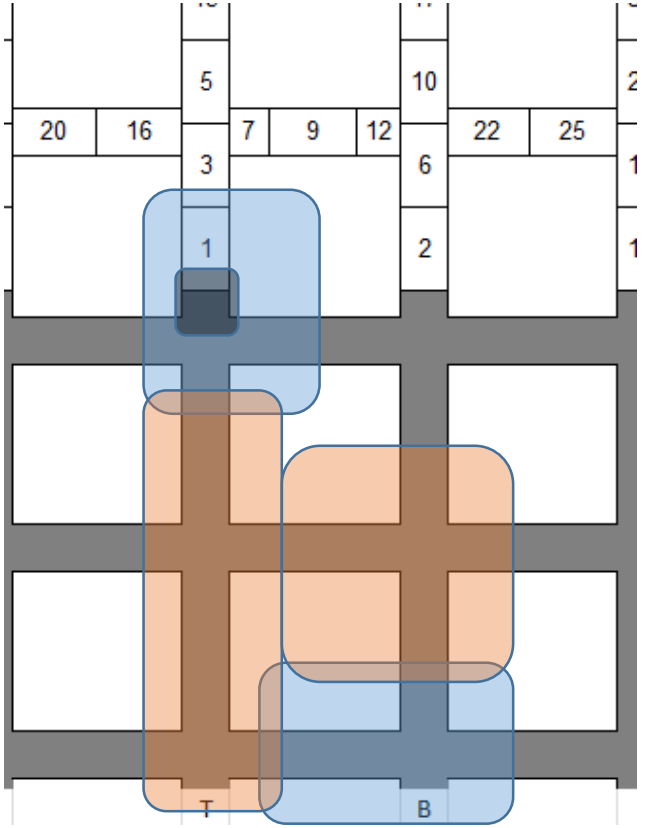
- Virginia Tech
  - Virginia Center for Coal and Energy Research (VCCER)
    - Eddy Jong (VT PI)
    - Charles Schlosser
  - Virginia Tech Transportation Institute (VTTI)
    - Rich Hanowski
    - ~~Johan Engstrom~~ (just left for Waymo)
    - Andrew Miller

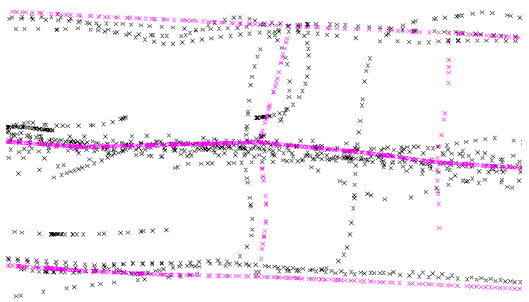
Underground Localization

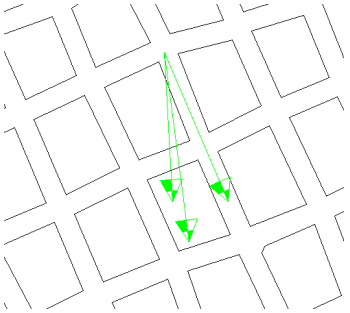
- Multiple localization techniques are currently available
  - Inertial Navigation System, laser, infrared, ultrasound, radio-based
- Existing device networks (communication or other infrastructure) can be used for localization
- Literature review indicated that vehicle-mounted beam-forming sensors (ultrasound,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



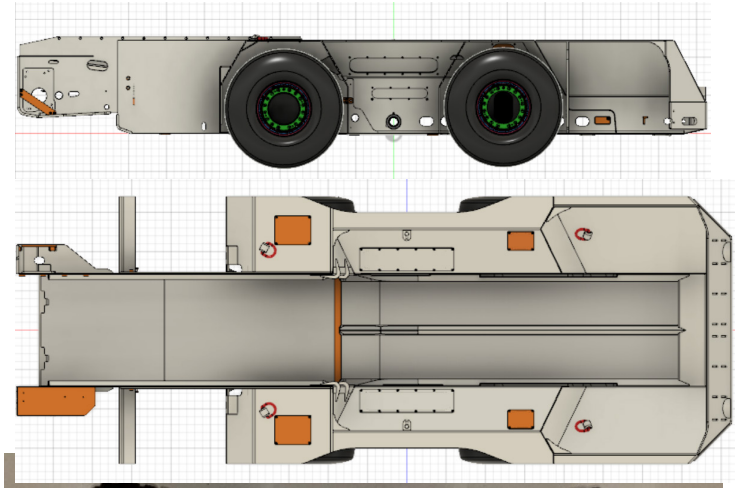


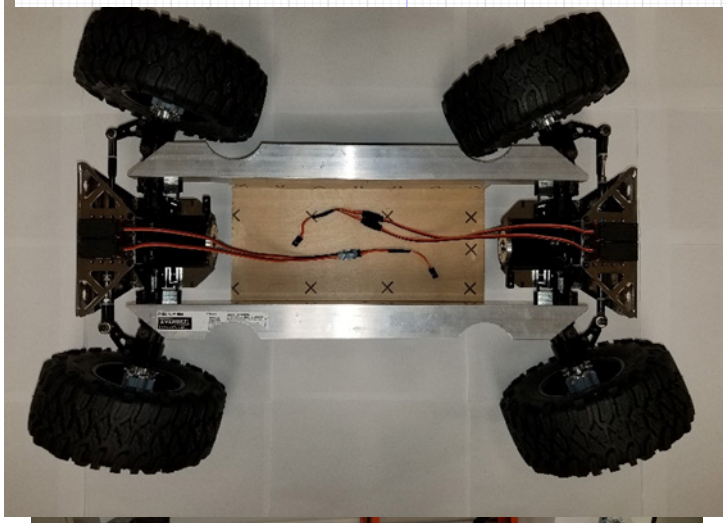


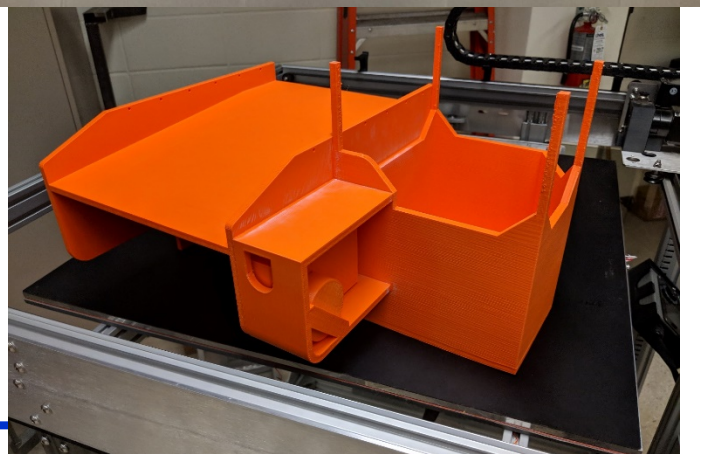
Scale Models

- Joy 10SC32B provided by Komatsu Mining Corp. is being used to establish the relevant dimensional ratios and shuttle car body details for the small-scale prototype
- Sourcing motors strong and small and slow enough has been a challenge
- Internals are completed, body is being printed

- https://www.youtube.com/watch?v=7B9S-Xz40F4







Autonomous Decisions

- We have defined several different states for the shuttle car
- For each state, there are activities for the machine to perform
- When the actions are completed, then sensor reads and potentially input from a human will be required
  - Dispatcher from the feeder
  - Miner operator while loading

- Software simulation is complete, being modified for this particular project
- Processing is done as an expert system, not a learning network like most other automation projects

Cognitive Work Analysis (CWA)

- Defines a work-centered framework for the analysis of complex sociotechnical systems, such as a coal mine
- Addresses all levels, from the general work domain and organization, to specific activities/tasks (e.g., the individual worker)
- Results serve as the basis for integrating new functions and technologies
- Provides for a holistic approach that accounts for several dimensions simultaneously

Cognitive Work Analysis (CWA)

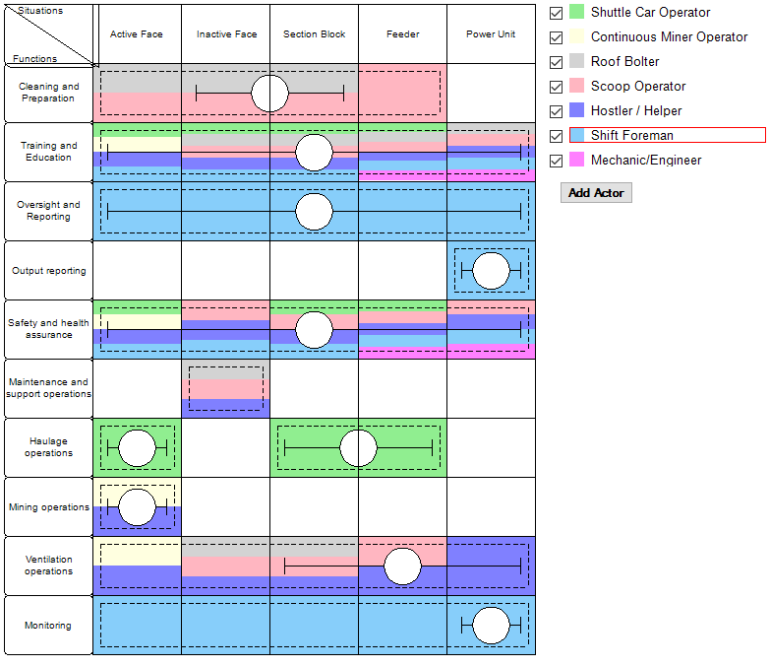
- Focuses analytic on human work activities to design a system that work harmoniously with workers by examining:
  1. The work human do,
  2. Their behavior,
  3. The context in which they work, and
  4. The reasons for their actions
  - Investigates the work domain in-context to design a system in the environment being investigated

CWA - Autonomous Shuttle Car

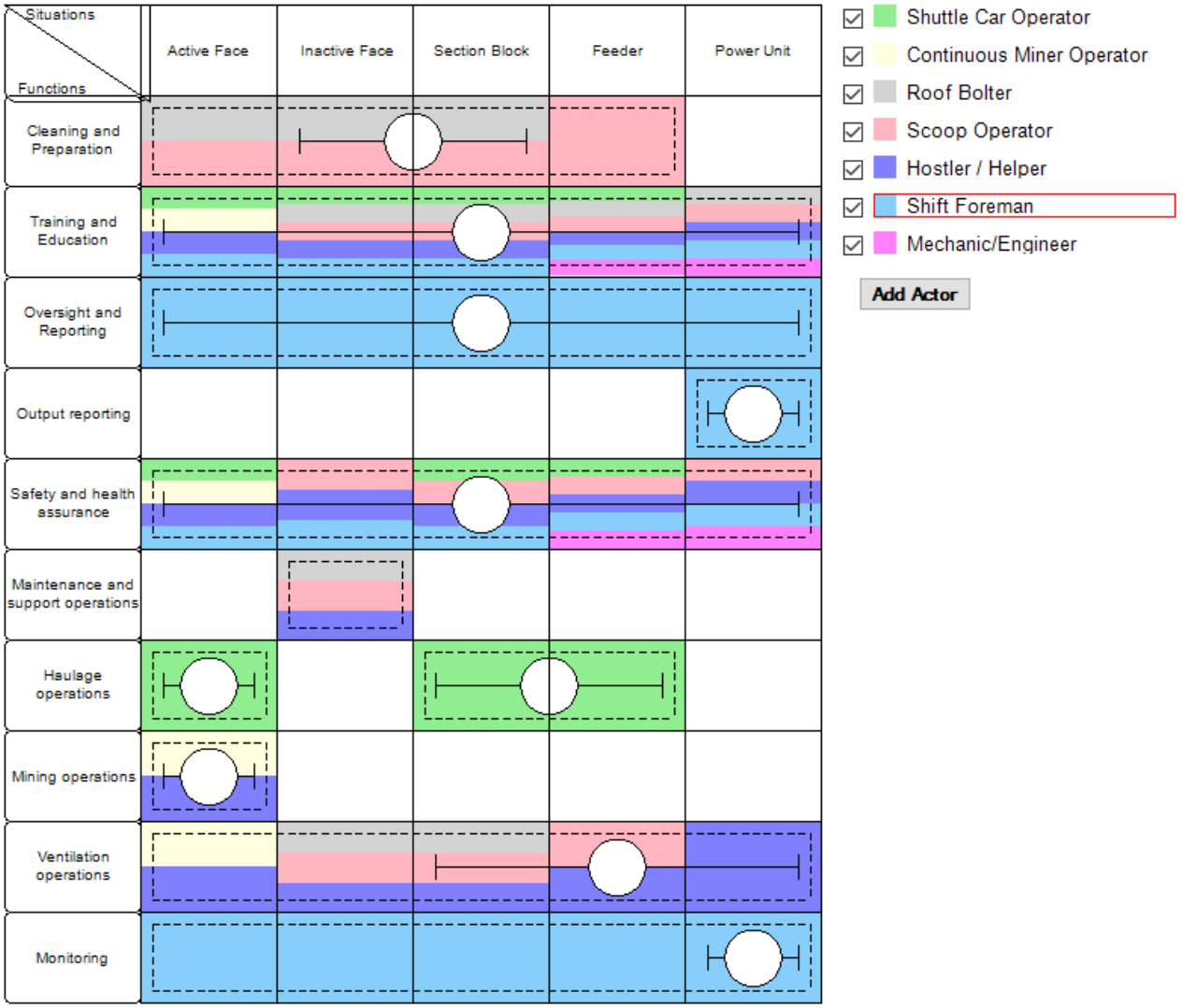
- Detailed representation of underground personnel roles and interactions in areas that regularly intersect with shuttle car operations
- Identifies areas that may need to be replaced by additional autonomous systems after disrupting shuttle car operations
- Outlines the human roles that will be affected with the introduction of an autonomous shuttle car system
- Helps drive both the required system components and worker task adaptations needed to integration an autonomous haulage system

Contextual Activity Template

- Describes the responsible personnel for a function grouped by the location in which the activity is performed



Contextual Activity Template



Conclusions, for now

- This is ongoing work with results and demonstration available around the corner
- Publications on the CWA results are in the pipeline and will be in press soon
- This is the first of many presentations like this one, talking about our approach and bringing in feedback

- Many barriers exist for bringing this to production at the mine
- Autonomous machines must communicate to the human around them, what they are doing and why they are doing it
- Existing “wireless” communications, like cap lamp signals will be very difficult to implement – just because it’s hard doesn’t mean it’s impossible

Go Cats!