Next Generation Rail Systems using Artificial Intelligence and Machine Learning

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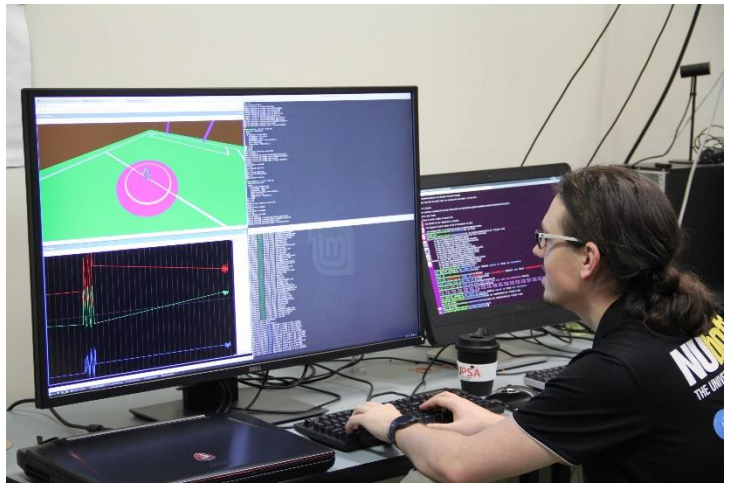
Protecting People and Assets

4Tel

Why talk about AI?

- 4Tel sponsor the University of Newcastle Robotics Laboratory to promote and capitalise on the development of AI and machine learning techniques for rail

- Our work is leading us into exciting applications in the rail industry



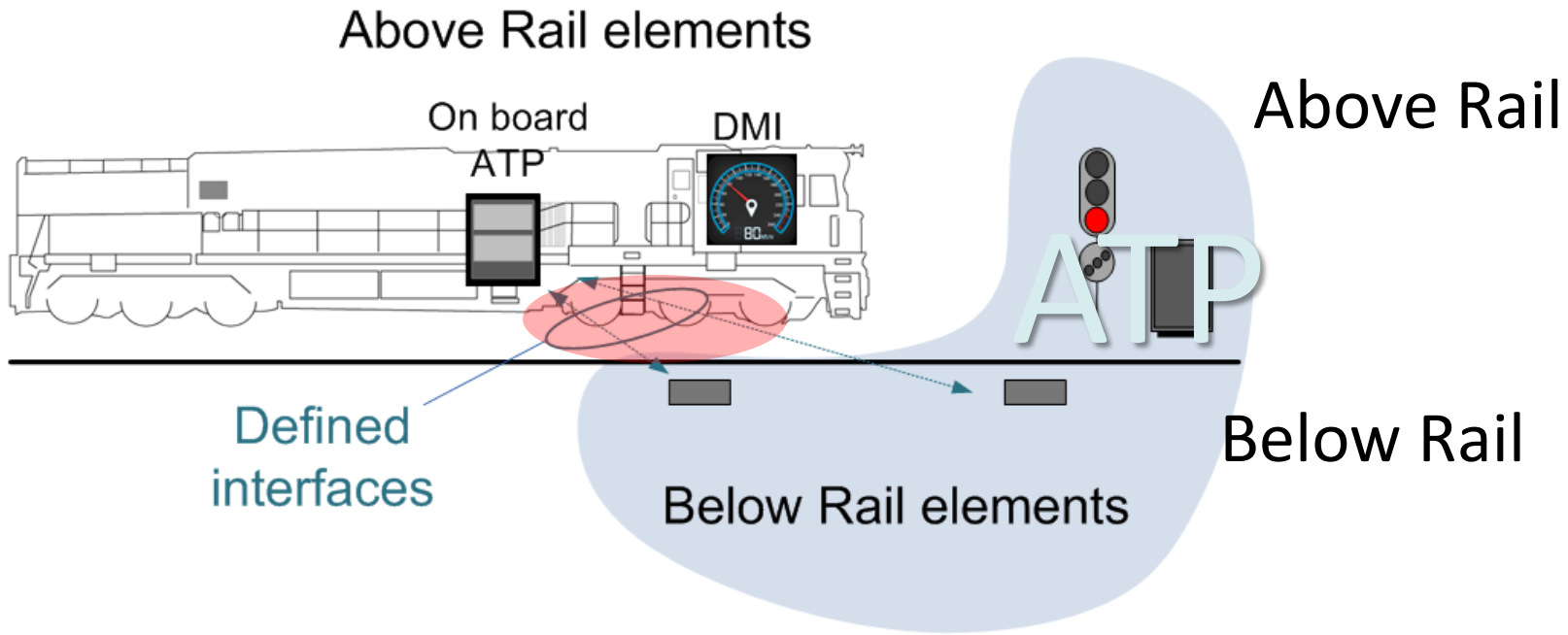
- We now have a full-time team working in this space

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

NU BOTS

Australia - Open Access Railways

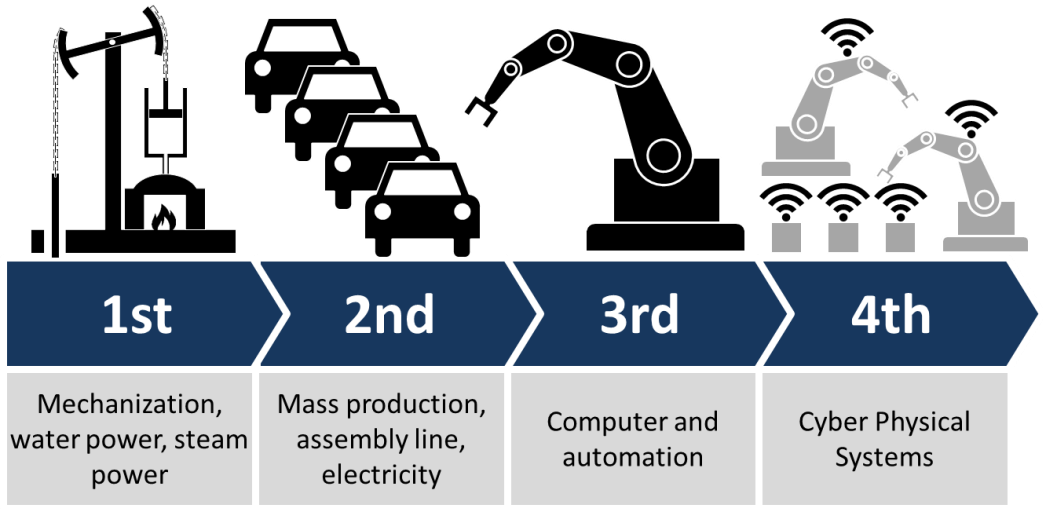
- Below Rail Maintainer: operate and maintain below rail network
- Above Rail Operator: Train operations (freight or passenger)
- Multiple railways may exist on the same railway corridor (e.g. Melb-Perth)
- Need to support proprietary below rail interfaces/control systems
- No end-to-end seamless ATP solution across rail corridors



Background

- Train operations continue to rely on train drivers, usually two drivers
- Automatic Train Protection (ATP) rollout progressing …….. Gradually
- Technology exists to protect against driver error
- Cost effective intermediate solutions exist that can provide an incremental safety improvement

RAIL 4.0 - 4th Industrial Revolution (4IR)



"Previous industrial revolutions liberated humankind from animal power, made mass production possible and brought digital capabilities to billions of people.

The Fourth Industrial Revolution is, however, fundamentally different. It is characterized by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human"

Source: Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum

What is Artificial Intelligence

- AI theory has been around since 1950s
- **Definition:** the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages

Five of the original participants in the 1956 Dartmouth Summer Research Project on AI. From left to right: Trenchard More, John McCarthy, Marvin Minsky, Oliver Selfridge, Ray Solomonoff. (Photo: © Dartmouth College)

Artificial Intelligence

Deep Neural Network

Deep Learning - provides the capability for a system to learn from large data sets, rather than follow pre-set rules which are insufficient in complex environments

Sample data

Deep Neural Networks

- Need to be trained, labelling of data sets can be time consuming
- Code base is much smaller than traditional computer processing
- Processor intensive – Hardware only recently became available (still to select groups) for real-time operation

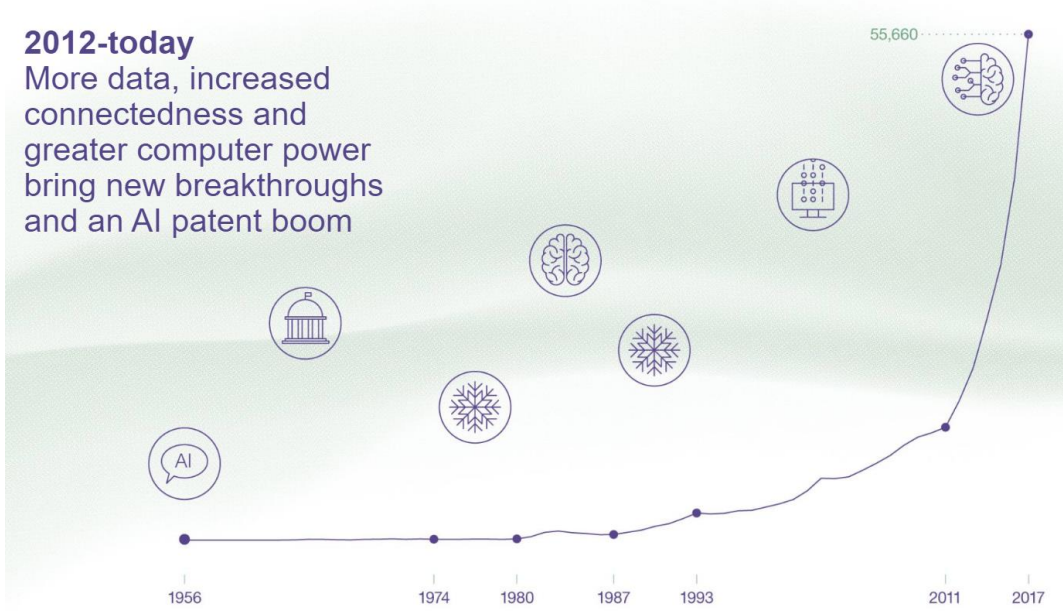
Research & Development

Car industry

- Autonomous driving market is expected to grow up to $173.1B by 2030.
- Level 4 Autonomy (no driver interaction), 2020
- Level 5 (no driver) after 2025
- From 2011 to 2017, Patents related to autonomous driving technologies have increased 330%, (compared to 16% across the board)

Rail Industry

- Much less…..



Rail Industry Challenges

- Creating the systems is only half the challenge
- The industry needs to understand what AI can do to help achieve better safety outcomes
- Agree on definitions; What is the difference between:
  - Unattended train
  - Robotic train
  - Autonomous train
  - Remote controlled train

Rio's remote control trains

AUSTRALASIA

Rio Tinto completes AutoHaul autonomous train project

5 January 2019

Rio Tinto runs 34 robot trains a day

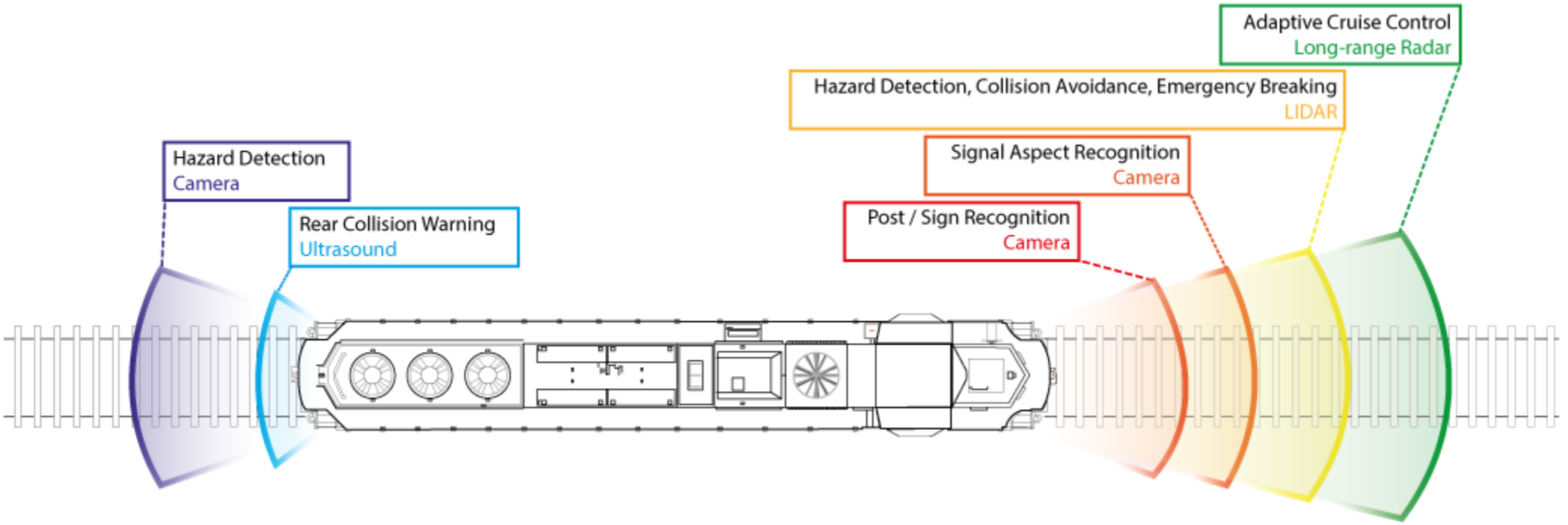
A Rail AI Processing Pipeline
Project HORUS

The rail environment is different to road environments.

Longer distance sensors & new algorithms are required to support rail operations.

HORUS brings operations, processing & sensors together

Multiple sensors types are available for all-weather conditions



The sensor data is integrated to create a digital virtualisation of the operating environment

Assessment of Driver Tasks & AI Equivalent (a sample)

Driver Task	AI Processing Task
Confirm train location	Location Assurance: Track kilometre & specific track
Call approaching signal	Identify approaching signal aspect
Situation Awareness	Look for people / objects / animals / vehicle in corridor Look for track defects

HORUS Locomotive Deep Learning Processing Pipeline

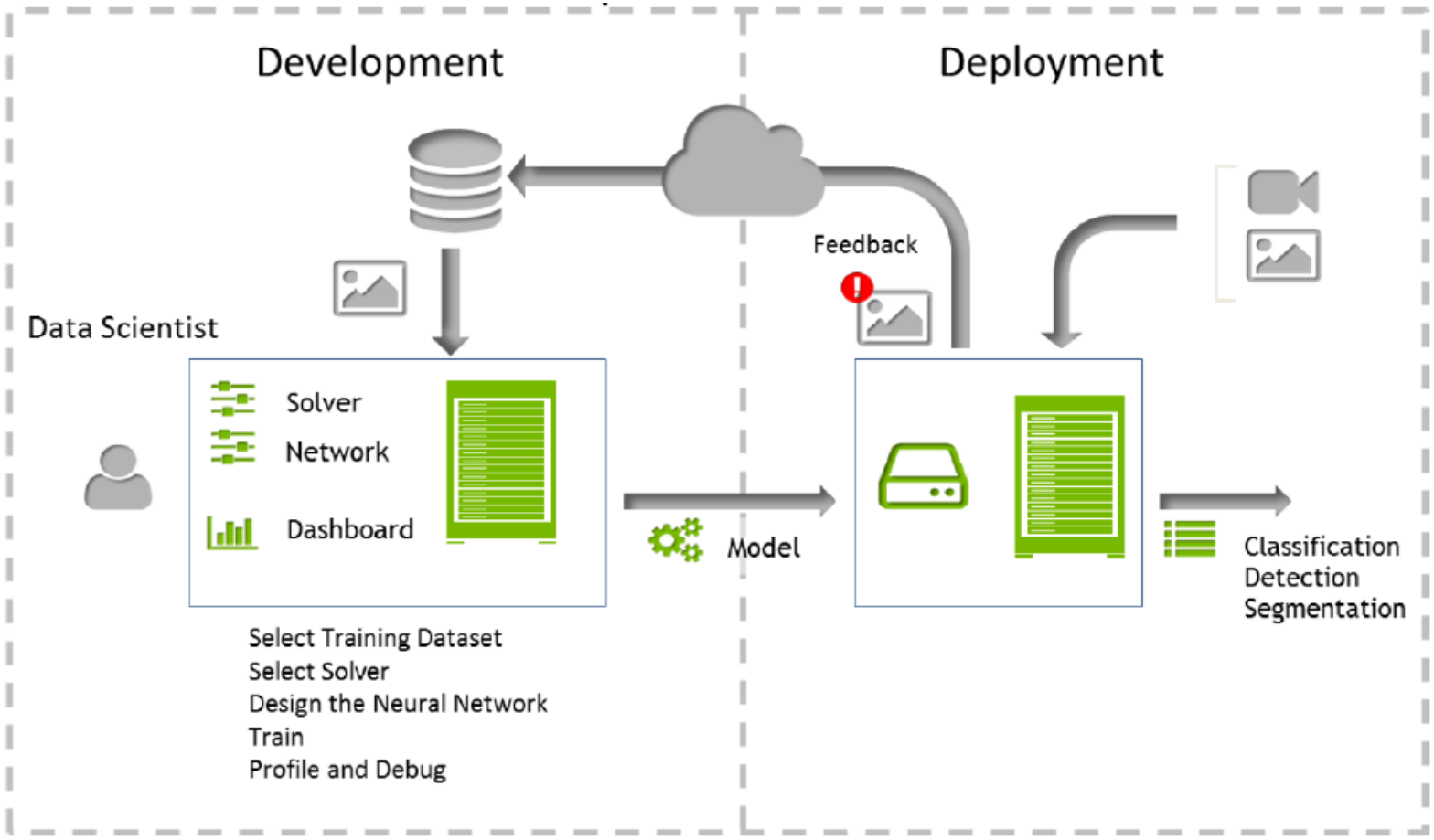
Requires a deep learning processing pipeline as appropriate to rail operations:

- **Detection**, which requires multiple sensor types applicable to rail
- **Localisation**, which requires visual, spatial and navigational data (GPS, inertial & odometer) data integration with known infrastructure
- **Awareness**, which interprets what is detected using machine learning
- **Dynamics**, which manages/checks actual operations against allowed operations
- **Monitoring**, which checks and reports on train running parameters

Artificial intelligence and machine learning provide the capability for an on-board system to autonomously identify objects and hazards, rather than simply act to pre-set rules which are insufficient in complex systems

HORUS Deep Learning Centre

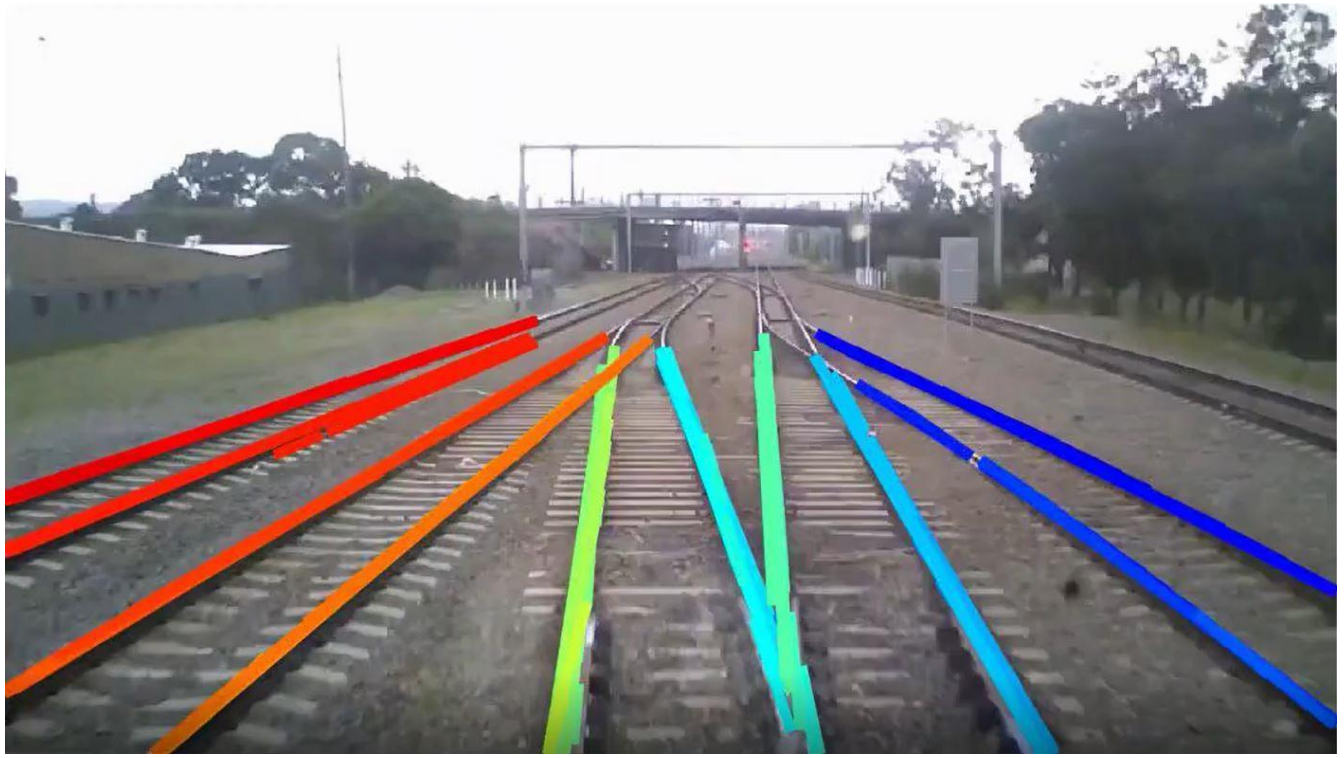
- Machine learning requires a good quality neural network computing centre
- Typically a large installation of GPU-based computers
- A Deep Learning Centre is actually a specialised super-computer
- Each depot will require a data service to upload as-run train video, and download updated master sequences into locos



Source: NVIDIA

Applying AI in rail

- GPS alone is not accurate enough to determine which track the train is on
- AI allow the discrete track to be identified



Location on the rail network is known

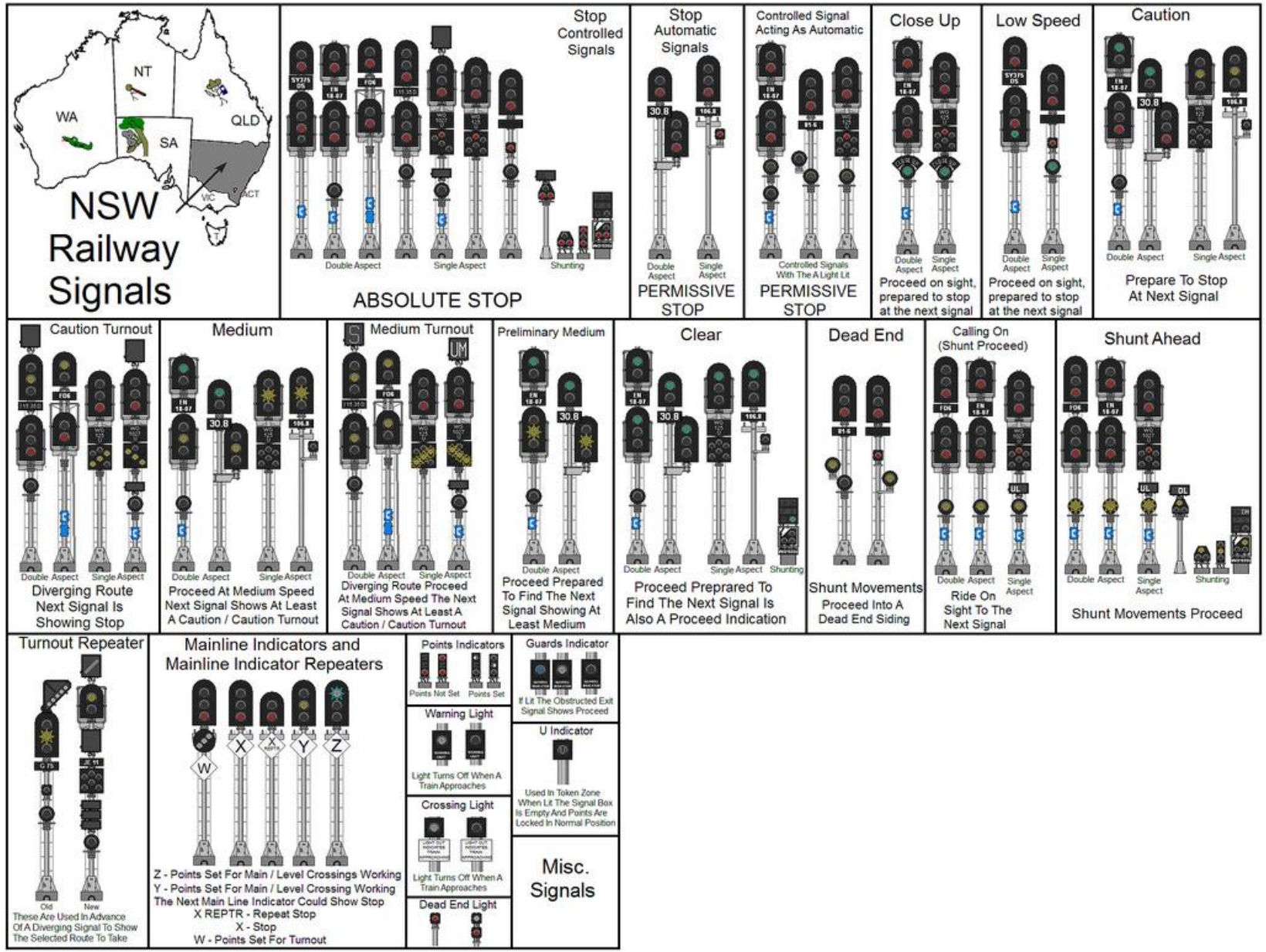
Locomotive AI

Signal and Sign recognition

- Signal Types, coloured light, train orders (different across states)
- Number of signs
- AI can identify different signs and signals
- AI continues to learn the differences

Standards

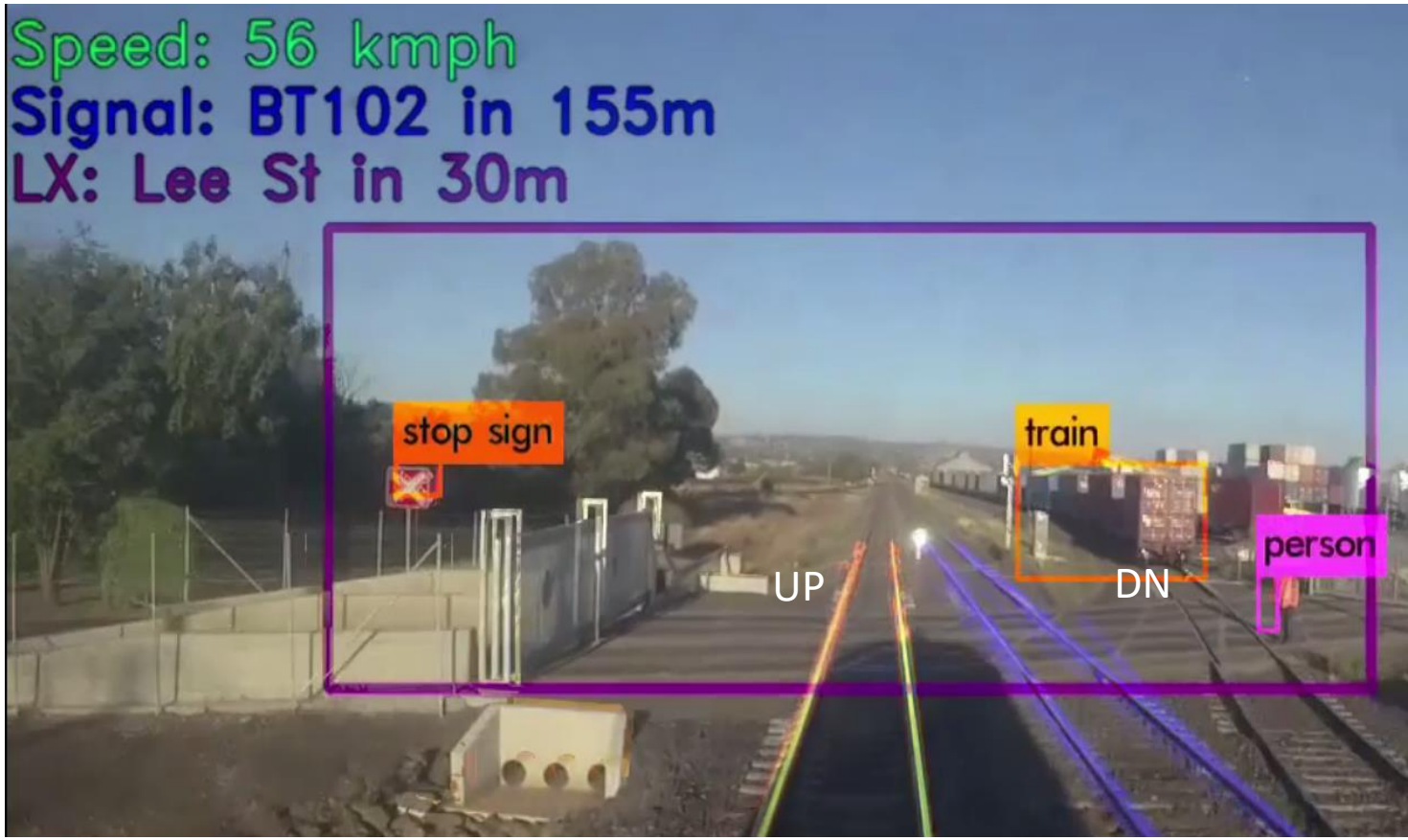
- Many “Standard” signals
- Imagine the international scene!



Horus Processing Pipeline

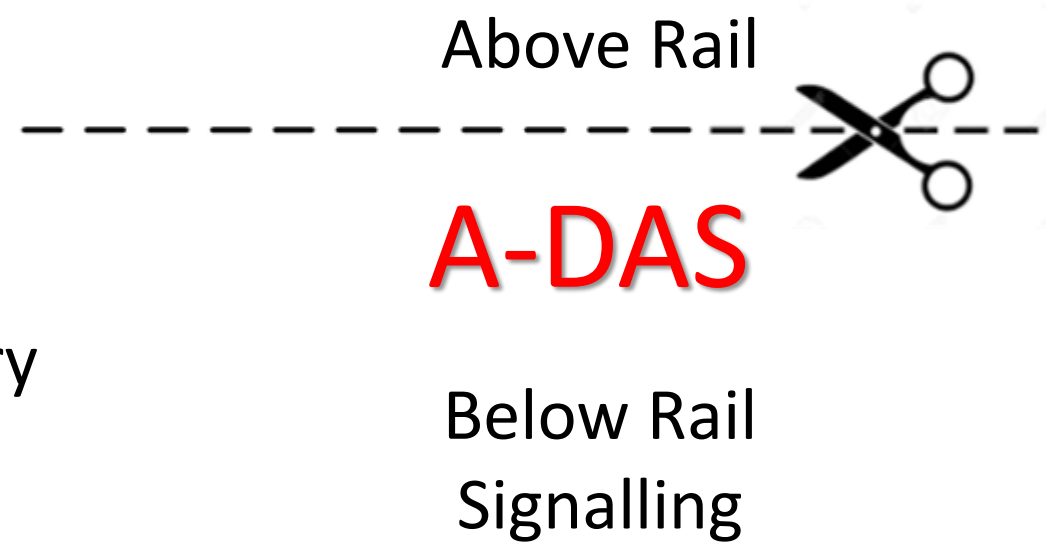
- All detected objects continuously checked against what is expected
- Computer vision can highlight unexpected objects: here a person
- Driver made aware by alarms and graphics
- Checked against Movement Authority track occupancy, and speed limits, with very high confidence

Level Crossing have a particular risk profile



Application of AI- Advanced Driver Advisory System

- Onboard real-time processing of routine driver tasks
- No below rail interfaces
- Improve safety and efficiency
- Automatic brake application
- A pragmatic intermediate solution for industry until national ATP solution is implemented

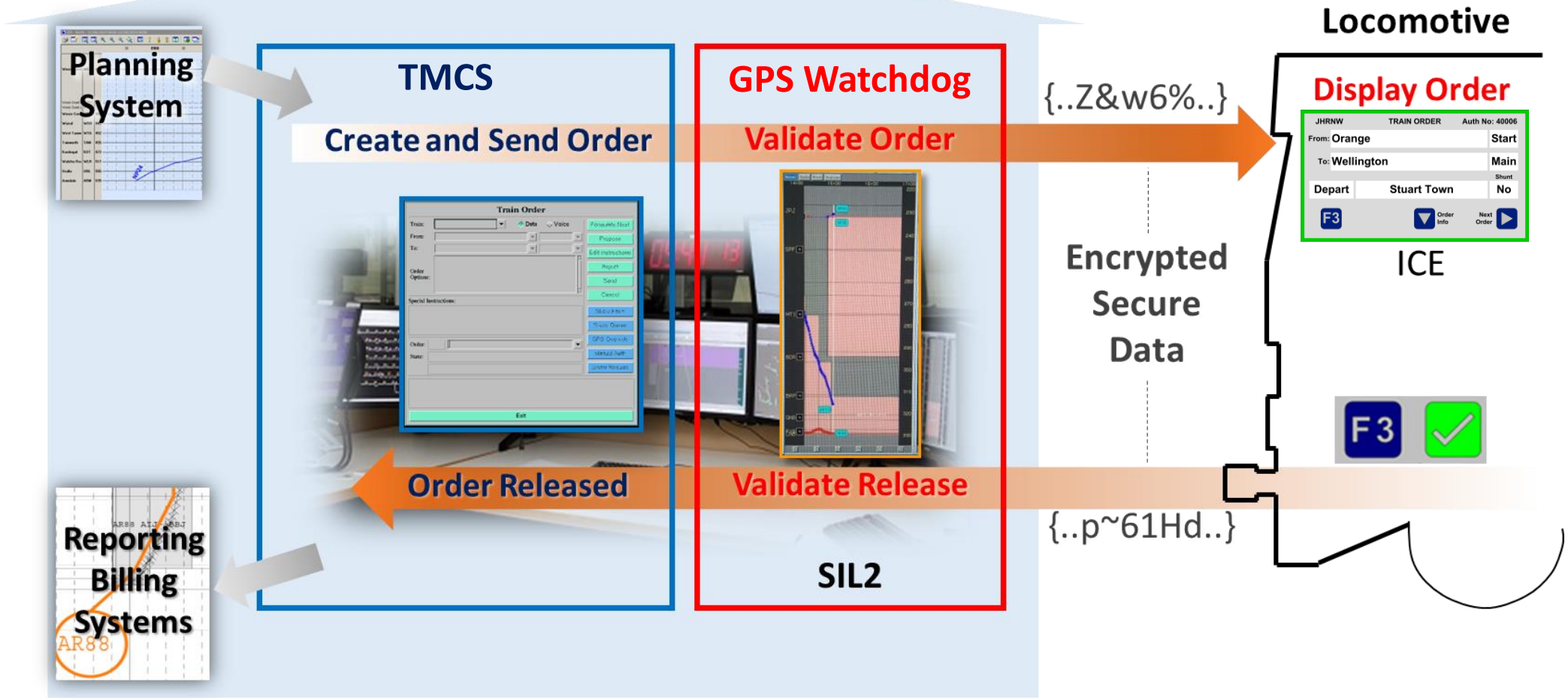


A-DAS

A never distracted, always alert, driver's assistant

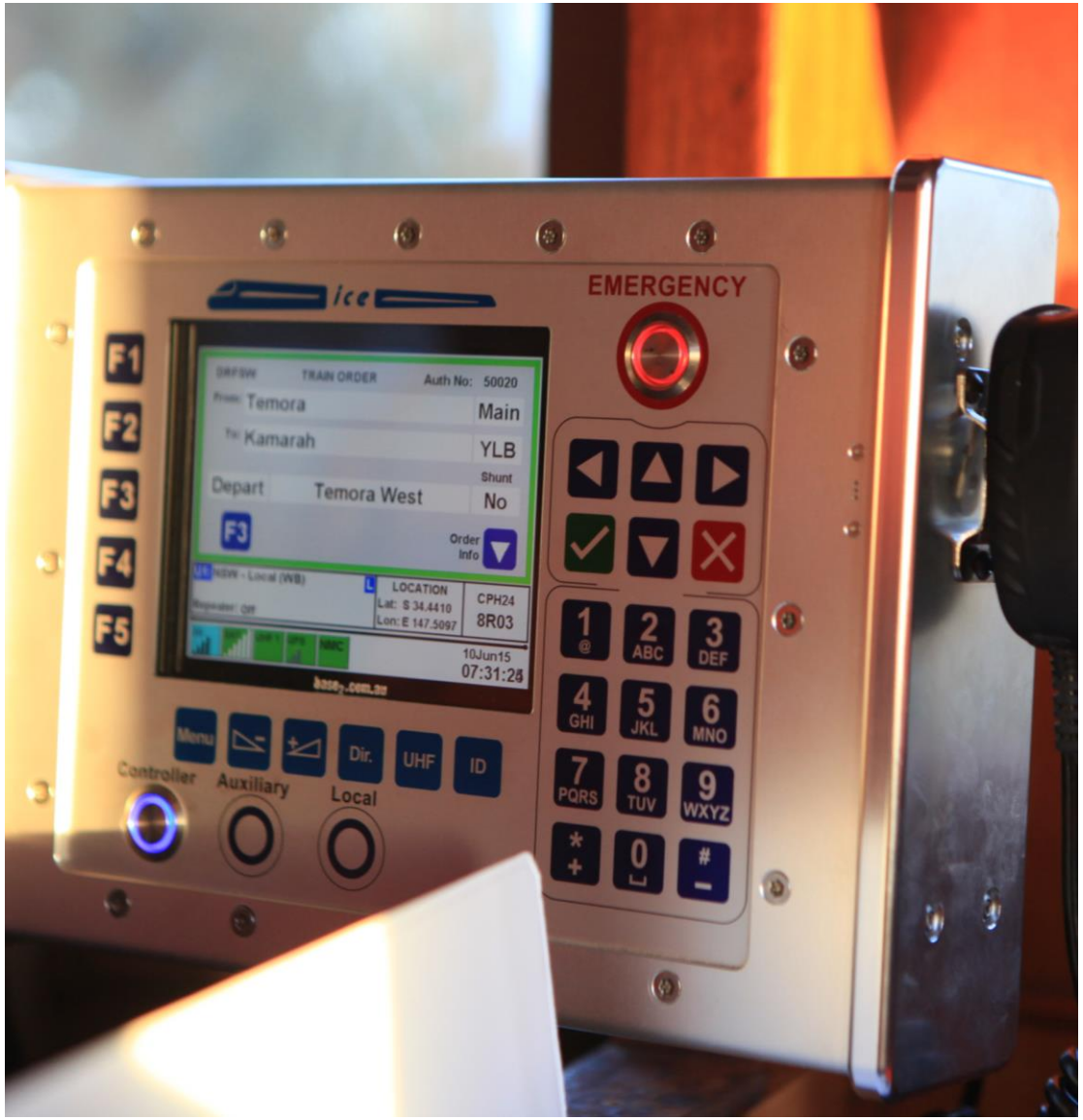
System Safety – Case study

- NSW Country Regional Network – Electronic Authorities



System Safety – Case study

- Electronic Authorities

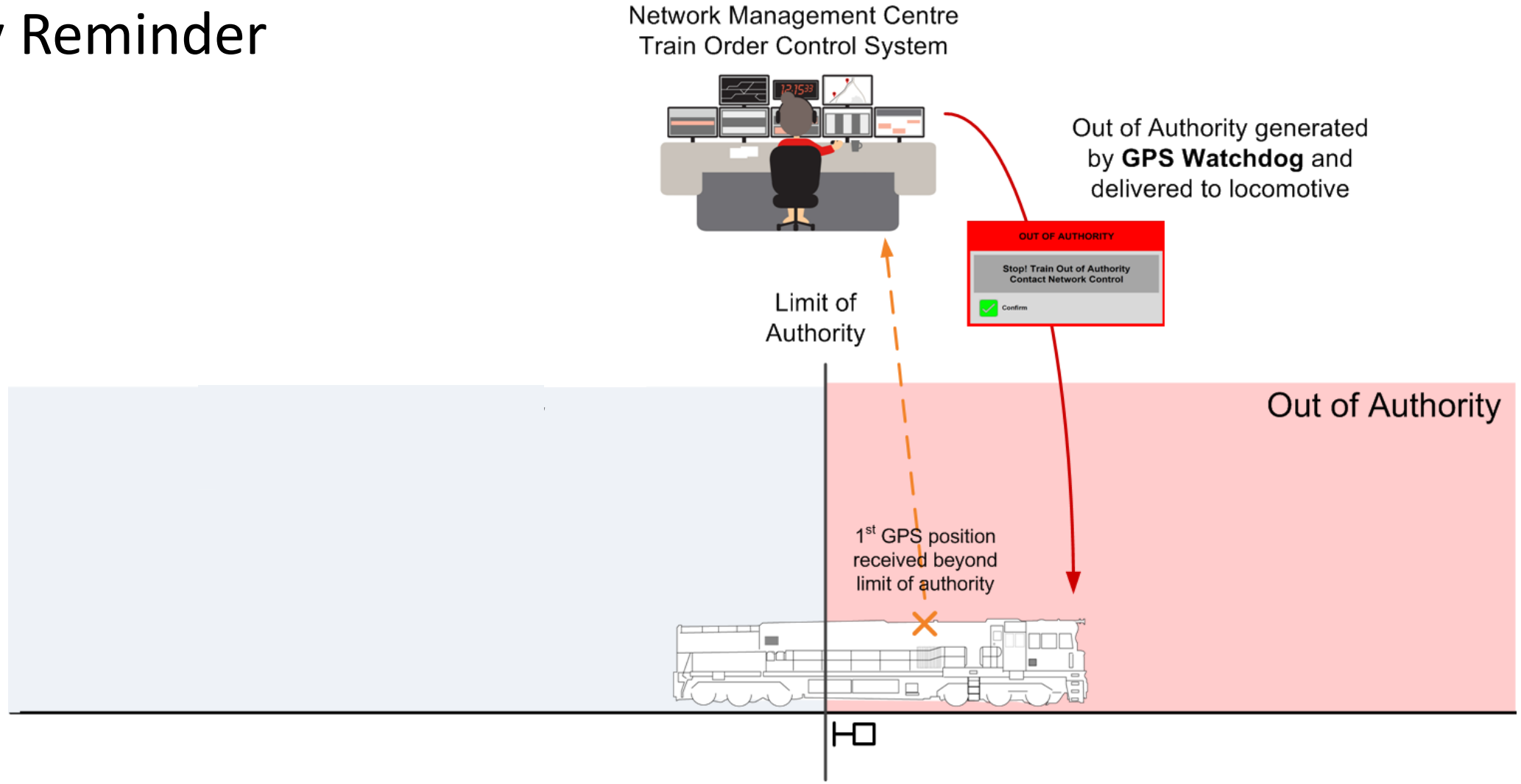


System Safety – Case study

- Out of Authority Alarm

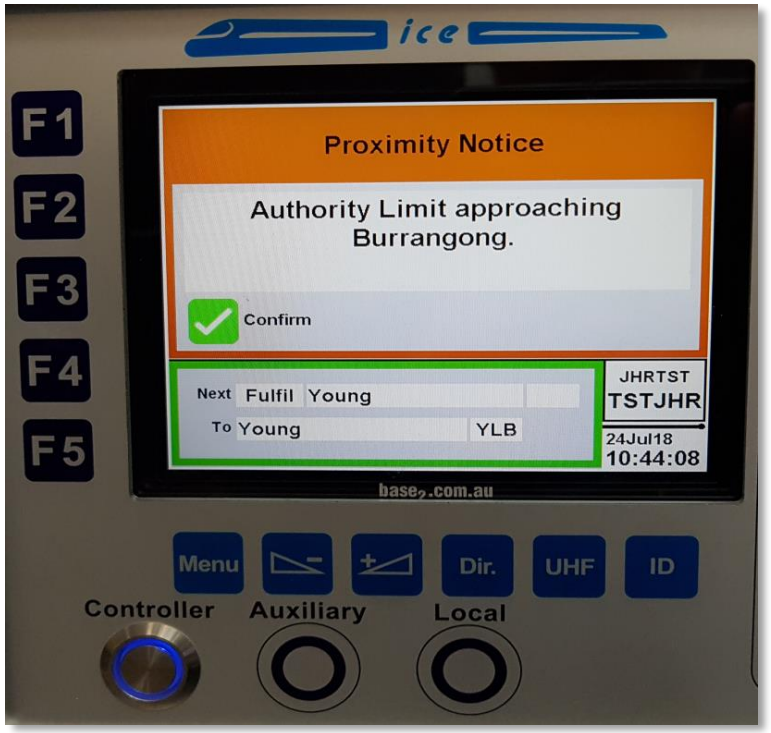
System Safety – Case study

Proximity Reminder



But it has no SIL!

- Proximity reminder is specifically targeted at the route cause of Out of Authority event – loss of situational awareness by the driver
- Proximity reminder system has no formal safety validation….
- Yet the impact on safety is significant
- Provided as a layer that complements existing controls
- Available across DIRN:
  - Stock on line
  - TSR
  - etc



AI-Based DAS Solution

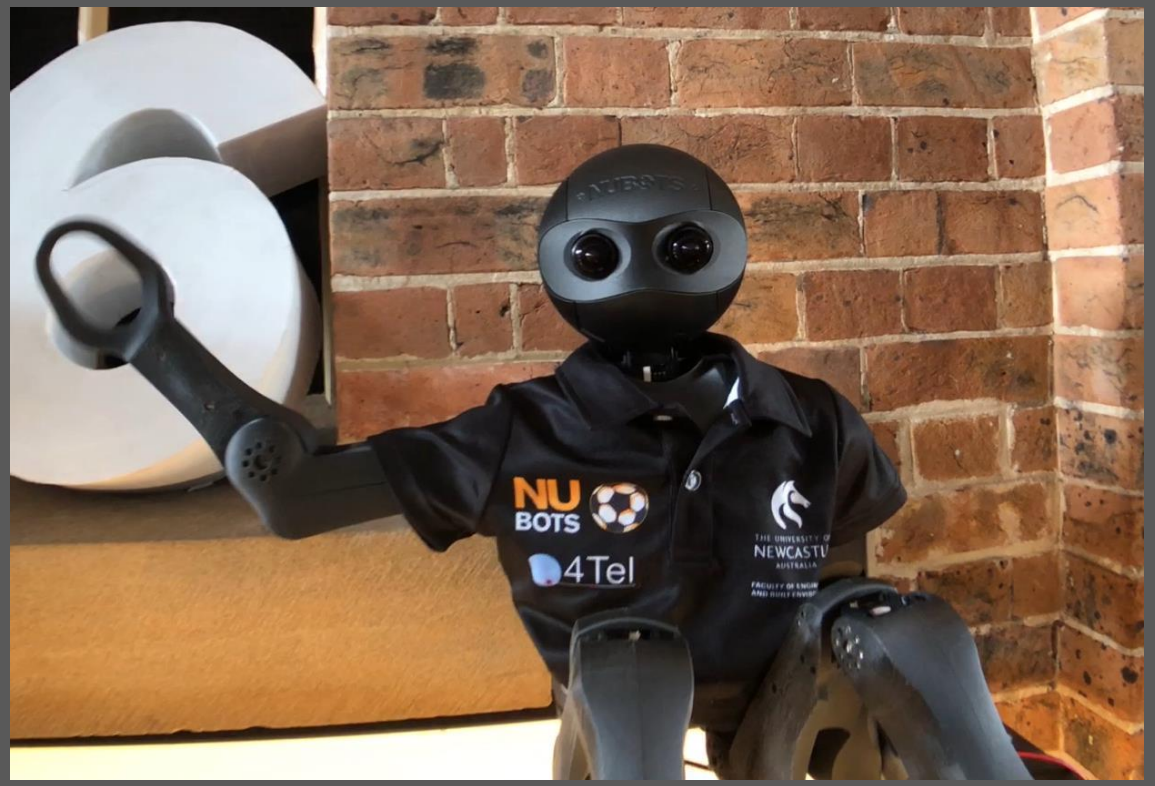
- Computer vision "…does not follow pre-defined rules"
- Driverless car industry:
  - Non deterministic neural networks processing massive data sets
  - Embracing ISO-26262 (an adaption of IEC-61508 for the automobile industry)
- Can protect against driver error & improve safety
- Can address key risk factor - loss of situational awareness
- Does not require complex above / below rail interface or trackside h/w
- SOFAIRP when compared with Driver-Only administrative controls?

Summary

“Can we be artificially safe?” …..Yes

- Future for rail technology is in software/data not hardware
- AI provides processing power not possible using traditional software techniques
- AI offers potential to improve safety and efficiency of rail operations
- Formal SIL certification is not necessarily the answer for AI
- Need to agree the process to certify an AI product

Thank you for your attention: any questions?



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