Practical integration of Automated Operation in Railways: A system of systems perspective

JOINT INSTITUTION SEMINAR:

PERMANENT WAY INSTITUTION (PWI)
INSTITUTION OF RAILWAY SIGNAL ENGINEERS (IRSE)
INSTITUTION OF MECHANICAL ENGINEERS (IMECHE)
INSTITUTION OF TECHNOLOGY (IET)

SEMINAR SESSION NOTES WRITTEN BY NETWORK RAIL YOUNG PWI MEMBERS:

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Madeleine is a recent Aerospace Engineering graduate who has joined Network Rail as a Graduate Engineer. She is also a Network Rail Diversity & Inclusion Champion and a PWI Ambassador. Madeleine has a great interest in remote condition monitoring and machine learning allowing for more predictive maintenance and something she wants to help implement in all disciplines on the railway. She is starting a Railway Engineering Masters at Leeds University this year.

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James pursued an MEng Civil Engineering at UCL. Awarded the ICE QUEST Scholarship with Network Rail, James completed four summer placements before joining Network Rail's Graduate Scheme. James led big data workstreams to improve design judgement for station wayfinding and completed carbon estimates for Network Rail's CP6 renewals forecasts. He currently manages slope stability across earthworks for Sussex route.

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PROGRAMME

BATCH 1

A systems perspective on the automated operation of railways (Professor Felix Schmid,University of Birmingham &Alexandra McGrath, VicTrack)

Operational concepts for automated railways (Piers Connor, Pasquire Associates)

Definitions, functional requirements and architectures (Tom Godfrey, ARUP)

Unattended Metro operation design: The Singapore perspective (Robert Cooke, Land Transit Authority, Singapore)

Sydney Metro's move from human driving to unattended operation (Steve Allday, ARCS (International))

Driver supervised automatic operation on Thameslink (Paul Booth, Network Rail)

Communications challenges of fully automatic railway operations (Tyson Moore, University of Birmingham)

Maintenance challenges of fully automatic railway operations (Kenneth Yuen, SMRT Corporation)

Fears and prejudices: The psychological impact of automation on staff and public (Eylem Thron, Ricardo Rail)

BATCH 2

Automation - beyond command and control (Stephen Barber, PWI)

Rolling stock challenges of attended and unattended automatic operation (Graham Neil, Transport for London)

Impacts of automatic train operation on track and infrastructure (Andy Vickerstaff, Transport for London)

Track access and automation of infrastructure inspection and maintenance (Gareth Evans, Network Rail)

Obstacle detection and avoidance of intrusions (Iain Flynn, Independent & David Milburn, WSP)

The right to differential speeds: ETCS, track cant and route availability (Professor Bridget Eickhoff, RSSB and University of Birmingham)

Ethics in designing software and algorithms for the automatic operation of railways (Professor Felix Schmid, University of Birmingham & Professor Rod Muttram, IRSE)

INTRODUCTION - Railway Automation is being increasingly deployed internationally and involves system wide collaboration between disciplines. It was therefore an ideal subject area for a number of Professional Engineering Institutions (PEIs) to collaborate in delivering a joint seminar and the original proposal for doing this was put forward by Daniel Woodland, the current President of the Institution of Railway Signalling Engineers. The following notes have been written by a number of young PWI members, all of whom currently work for Network Rail. One of the objectives of the seminar was to excite young engineers about the technological, organisational, behavioural and cultural issues that are involved in safely automating railway systems. To encourage this, ten young members from each participating Institution were given free delegate places to attend the seminar. These young delegates included the authors of these seminar notes and the PWI is grateful for the time they have spent producing them.

The joint PWI, IRSE, IMechE and IET online international seminar included two interactive live sessions to discuss two batches of recorded presentational content made available for delegates to view in advance.

Recorded content for Batch 1 largely related to the Command and Control discipline and focused on the requirements for automated railways, the challenges for stakeholders including passengers, and the impact on the railway system. The content for this was released for delegates to stream from the seminar website at the end of August 2020. This was followed by a live interactive Q&A session on 17 September 2020 discussing information given in the recorded presentations. The batch 1 live session was introduced by Monish Sengupta of the IRSE, chaired by Daniel Woodland, President of the IRSE and closed with concluding remarks by John Easton of the IET and the University of Birmingham (UoB).

Batch 2 recorded content was released in early September and focussed largely on interfacing disciplines, including covering risk controls, inspection, maintenance and the design ethics of Automated Train Operation (ATO). The second live Q&A session, on 8 October 2020, was introduced by John Edgley, President of the PWI, chaired by John Easton and closed with concluding remarks by Iain Flynn of the IMechE .

During the first live session, Monish set the tone of the seminars by quoting Bill Gates: 'The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency.' (Bill's second rule is that automation applied to an inefficient operation will magnify the inefficiency!)

The seminar presentations provided an insight into what ATO means, an analysis of Grade of Automation (GoA)1 to GoA4 systems (see the UITP definitions in Table 1) and a vision of what the future of automated railway technology looks like.

Grade of automation	Train operation	Description
GoA 0	On-sight	Driver control similar to a tram running in street traffic.
GoA 1	Manual	A train driver controls starting and stopping, operation of doors and handling of emergencies or sudden diversions.
GoA 2	Semi-automatic (STO)	Starting, running, and stopping are automated, but a driver operates the doors, drives the train if needed and handles emergencies. Many ATO systems are GoA 2.
GoA 3	Driverless (DTO)	Starting, running, and stopping are automated, but a train attendant operates the doors and drives the train in case of emergencies.
GoA 4	Unattended train operation (UTO)	Starting and stopping, operation of doors and handling of emergencies are all fully automated without any on-train staff.

Table 1: GoA level definitions.

A SYSTEMS PERSPECTIVE ON THE AUTOMATED OPERATION OF RAILWAYS

PROFESSOR FELIX SCHMID,UNIVERSITY OF BIRMINGHAM
ALEXANDRA MCGRATH, VICTRACK

Alex and Felix discussed how to adopt the principles of a system of systems approach to the Railway. Initially, Felix described a system as ‘an entity that exists in an environment’ which:

- is influenced by its environment;
- influences its environment;
- has a purpose;
- is a group of interacting and interrelated entities forming a unified whole;
- has spatial and temporal boundaries, and;
- has a set of principles and procedures.

He then defined a system of systems as:

- heterogeneous, interdependent systems networked for a common goal.

The railway system very much fits this definition.

Felix described how a system of systems is both complicated and complex and different elements decide how complicated or complex a system of systems is.

- Variability affects complication – weather, rail users, staff.
- Dispersion combines complication and complexity – multiple buildings, stations etc.

- Diversity affects complexity – various component types, variable asset life.
- Interdependency drives complexity and complication – timetables, wheel/rail interface.

The difference between complicated and complex systems was defined as follows:

- Complicated systems – can be controlled as they have predictable behaviour. Lists, databases and procedures.
- Complex systems – cannot be controlled, often constantly evolving, adapting and responding, and do not follow predictable behaviour.

Alex explained how complicated systems can follow the V-model of Validation and Verification through problem understanding, solution implementation, and maintenance over time. Whereas complex systems are better suited to the circular complex system adaptive cycle following reorganisation from rapid growth into conservation into system release (a shock to the system).

Alex explained that a system of complex systems cooperates more easily if the systems are similar in speed, scale, and family of activity. She showed how this applies to projects and asset management, considering the large difference in speed and scale. Alex explained how humans are well suited to complex systems due to their ability to learn and teach, reflect and remember, and predict and project. Due to the importance of humans, Alex explained, organisational identity is important to facilitate and consider when discussing systems.

Finally, Felix discussed how High Reliability Organisations (HROs) use these principles to build in resilience. Key attributes, as stated by Weick and Sutcliffe, of HROs include:

- preoccupation with failure;
- reluctance to simplify interpretations;
- sensitivity to operations;
- commitment to resilience, and;
- deference to expertise.

Working towards adopting these definitions and attributes (notably HROs) in the railway will enable progression towards a reliable service. Alex challenged delegates to apply these principles to the case studies shown in the rest of the conference and draw our own conclusion about a system of systems approach.

OPERATIONAL CONCEPTS FOR AUTOMATED RAILWAYS

PIERS CONNOR, PASQUIRE ASSOCIATES

Piers set the direction of his presentation by asking, ‘do we need changes in planning and operating practices?’, and his response of ‘yes’ was then developed throughout.

After defining an operational concept and what it should include, Piers discussed what is expected, versus what can realistically be achieved with an automated system.

He asked how you can improve the output, saying that it is important to understand where you are currently, what you want to achieve and what lessons have been learned from previous attempts in other projects. He explained options for mitigating risks and set out key questions to ask when analysing how well an automated system will operate in specific circumstances.

Clear communication between all disciplines at the start of planning automation of a line, as well as train-platform and train-train communication were highlighted because, if these are not given proper attention, they can limit how many trains can run on some sections of track. Piers portrayed this with tunnel ventilation issues and evacuation in an emergency (see Figure 1 on page 34).

Piers talked through case studies in people mover, metro, and heavy haul operating systems, reflecting on issues that have occurred and how this information can be integrated into future operational concepts to reduce the frequency of faults.

Piers summarised by reflecting on the original question and providing a guideline for how to approach changing the GoA (see Figure 2 on page 34) on a rail line. This covered staff engagement, in house expertise, relationships with suppliers, projected project development timescale and how long it will last. He rounded up by telling attendees to identify ‘known unknowns and unknown unknowns’.

DEFINITIONS, FUNCTIONAL REQUIREMENTS AND ARCHITECTURES

TOM GODFREY, ARUP

This presentation set out to cover the standards, history, architecture and Tom's own opinion on automatic railway projects.

Train automation started concurrently in America and Britain, making similar progress on people movers and mass transit since the 1960s. Metro systems have used ATO for more than 40 years, with 70 lines in 40 countries currently running with GoA 4, but we are now seeing this technology being integrated with mainline trains. This transition has taken so long due to added complications that come with mass passenger transport.

Tom compared different types of automated railway using different dimensions. This made it clear why mainline automation is taking the longest time to introduce, needing its own set of standards in the form of ATO subsets. He explained the original priorities of ATO and how it could look in the future.

He addressed ATO over European Train Control System (ETCS) architecture (see Figure 3 on page 33), explaining the different interfaces and how they communicate. Good communication is key to quality performance in elements such as precision stopping. Regarding the evolution of architecture, Tom envisioned that more intelligence will be allocated to the vehicle, reducing points for failure and potential errors in communication.

In his summary, Tom predicted the progress he expects to see over the next 10 years including ETCS growth and evolution, potential for hybrid systems, expansion of Connected Driver Advisory System (C-DAS), getting ATO adoption and benefits on mainlines, as well as the idea of making the vehicles more intelligent.

UNATTENDED METRO OPERATION DESIGN: THE SINGAPORE PERSPECTIVE

ROBERT COOKE, LAND TRANSPORT AUTHORITY, SINGAPORE

Robert introduced GoA4 systems used in Singapore including the rolling stock and the requirements of these systems. He identified the key drivers for having Mass Rapid Transit (MRT) & Light Rapid Transit (LRT) systems in operation, signifying the long-term benefits of increased reliability and the reduction of labour cost. Detailing the progression from GoA3 in 1987 to GoA4 in 2003, Robert highlighted that moving to GoA4 does not simply rely on reliable ATO.

Robert delved into the day-to-day processes.

- Automatic Train Supervision (ATS) ensures the trains are in running order and configures the running state.
- Automatic Train Protection (ATP) controls door opening and ATO ensures train is stopped in correct location.
- Dwell time = passenger exchange time + technical time.
- Current delays in technical time surround ATO communication with platform screen doors.
- Curved train profiles and sloped door bottoms reduce entrapment likelihood.
- Passengers queue and are fed real-time crowding information to increase boarding efficiency.
- Evacuation zones are built into the network for passenger initiated emergency evacuations.
- The train reports critical, non-critical and maintenance information during operation.
- At the end of the day the ATS communicates with the train maintenance facilities before stabling.

Robert described that for the future GoA4 incorporation on the Jurong Region Line 'Wet weather mode' and 'Availability of train-borne signalling equipment' are current developments.

To summarise, driverless systems are complex and involve disciplines from many multi-system functions. The limiting factor is how the system responds to failures and emergencies and by seeking innovative solutions, performance could lead to benefits in operation and safety.

SYDNEY METRO'S MOVE FROM HUMAN DRIVING TO UNATTENDED OPERATION

STEVE ALLDAY, ARCS (INTERNATIONAL)

Steve discussed the systems engineering challenges of introducing ATO into service the Sydney Metro in June 2019. He focused mainly on the second stage of the project which involved converting existing GoA1 commuter railway from Sydenham through to Bankstown to a GoA4 driverless metro.

The business requirement for the project was to provide greater connectivity into the city and alleviate existing traffic congestion. Steve described how the challenges of this project span the spectrum of time, logistics, design, integration, construction, assurance and innovation.

He also recognised how with automation's challenges come huge potential opportunities for the future.

From the outset he identified systems integration as the key activity necessary to complete the project successfully, taking lessons from the challenges witnessed on Crossrail in the UK. Consequently, a project-wide systems integrator has been introduced which provided benefits in risk reduction. Working groups under the review, and many cases control, of this systems integrator were introduced to undertake a variety of key roles in the project.

The Sydney Metro City & Southwest project and the Bankstown line conversion, systems-approach provide a case study and evidence other railways around the globe can apply. The success of this approach sets the way for other railways to enjoy the benefits that come with GoA4 railways sooner and in a cost-effective and efficient manner.

DRIVER SUPERVISED AUTOMATIC OPERATION ON THAMESLINK

PAUL BOOTH, NETWORK RAIL

Paul described the approach, process and systems involved in bringing GoA2 – Driver supervised ATO – to the central core of Thameslink to ensure high capacity.

Paul stated that the central core required 24 trains per hour (tph) maintaining 30mph. Using professional driver practices a maximum of 22-24 tph could be achieved. He explained that ETCS Level 2 was most appropriate to accommodate 30mph with a recovery margin, because of the established ATP connection. Level 2's continuous train-track comms via the Global System for Mobile Communication – Railways (GSM-R) permitted the ATO comms to be transmitted also. The system was designed with a cross-over zone after the transition points where ETCS or manual driving could occur.

Paul listed the key functions of ATO on Thameslink:

- full supervision only;
- follows the speed profile of the ATO stopping format and the ETCS profile;
- acts only on Packet 44 data transmission commands;
- uses geographic data stored on-board, and;
- opens doors automatically but doesn't shut them.

The Class 700 Electric Multiple Unit (EMU) was produced in advance of the European Union (EU) GoA2 specification (SUBSET-125), with two key differences:

- the Class 700 requires an on-board database, and;
- the Class 700 uses packet 44 rather than dedicated ATO packets.

The Class 700 driver's cab contains both ATO and ATP driver interfaces that change appearance depending on whether in Level NTC (National Train Control) or Level 2 zones.

The system was tested using simulations to ensure that the requirements were feasible and operable. The system was then repeatedly tested during dynamic testing.

Paul highlighted the key successes as:

- using realistic timescales;
- using a system and scenario-based approach;
- maintaining a strong engineering team that was increased as necessary, and;
- keeping a major focus on system integration throughout.

COMMUNICATIONS CHALLENGES OF FULLY AUTOMATIC RAILWAY OPERATIONS

TYSON MOORE, UNIVERSITY OF BIRMINGHAM

Having studied and worked in the telecommunications industry, Tyson brings industry knowledge of communication challenges to the implementation of ATO. Tyson highlighted that a telecoms system outage can be detrimental to safety-critical operations, as phone calls could be missed to emergency services. This human impact can be interpreted as similar to a system failure of railway signalling systems.

Legacy communication systems (such as coded track circuits) were characterised by data links designed to be low-capacity, continuous and short range. In contrast, a mainline ATO system is built on top of ETCS using existing GSM-R communication links for data exchange that require a higher capacity and longer range.

Consequently, the challenges of ATO implementation are defined in four areas.

1. Regulatory challenge – radio frequencies are part of a finite resource with safety-critical communications prioritised to specific bandwidths.
2. Implementation – installing resilient wireless communication systems into underground or surface railways that are susceptible to interference from the built environment.
3. Operational challenges - In the rare instances of complete ATO system loss, troubleshooting and recovery can be difficult because of the wide variety of potential causes (e.g. power failures). To combat this, ATO systems use complementary train detection technology such as axle counters to provide a 'sanity check' on the position of trains.
4. Lifecycle challenges – the system's end of life is not controlled by the designer but could be due to the availability in the future of spare and new parts to maintain and upgrade the system. Additionally, upgrade programmes will have to consider the need to maintain the incumbent system whilst introducing the new system.

MAINTENANCE CHALLENGES OF FULLY AUTOMATIC RAILWAY OPERATIONS

KENNETH YUEN, SMRT CORPORATION

Kenneth Yuen discussed the maintenance challenges encountered on two in-service SMRT driverless lines. These lines are fully operational, running on GoA4, and consist of the Circle Line (CCL) and the Bukit Panjang Light Rail Transit (BPLRT).

The first requirement for maintenance is ensuring fast incident response times. Kenneth highlighted how important it is to plan and strategically deploy the teams and equipment spares throughout the line to achieve this. Additional systems such as CCTV, Intercom, Platform Edge Doors (PEDs) and track intrusion detection place greater demand on maintenance teams. This means it is essential that additional manpower resources with the required technical knowledge are available to maintain these systems.

Kenneth then described how, despite the trains being fully automatic, they must be drivable in manual mode to cater for malfunction, sweep train operation, shunting of train or when staff are on the emergency walkway. Therefore, staff still need to maintain their driving competency.

Using the example of a station ATO failure (see Figure 4 on page 35) Kenneth demonstrated how incidents are managed.

1. The central control receives an alarm informing them of a failure check.
2. If the station ATO status is unhealthy they send maintenance staff to resolve the fault.
3. Meanwhile, staff are instructed to manually drive the train between affected stations.

With increased grade of automation comes a greater complexity of interconnection between different systems. This means cybersecurity must respond to the greater risk of cyber-attack. Kenneth explained that maintenance staff are trained to understand the importance of cybersecurity and ensure security procedures are followed.

FEARS AND PREJUDICES: THE PSYCHOLOGICAL IMPACT OF AUTOMATION ON STAFF AND PUBLIC

EYLEM THRON, RICARDO RAIL

Eylem discussed the benefits and challenges of railway automation considering the impact of humans involved: signallers, drivers, station staff and passengers, comparing these impacts to those experienced during automation in other industries.

Eylem highlighted the key benefits of automation systems, such as automatic route setting (ARS) and European Railway Traffic Management System (ERTMS), including predictable running times, energy optimisation, lower costs and reduced human error. These improve the overall customer experience and reduces the signaller workload.

However, questions arise with automated systems as the lack of train staff leaves the passengers to react when there is a fault or an emergency scenario, causing them anxiety. Another problem that occurs without staff is the limit of accessibility for disabled passengers. These factors could result in trains being used less often.

Automation systems are also apparent in stations. Self-service ticket machines are widespread across the world and in 30 years stations may be completely unmanned. This gives more responsibility to the passengers to check their own tickets and navigate through the station. This could cause problems for tourists interchanging at stations.

Eylem also suggested that collaboration between industries such as rail, automotive and aerospace is important to successfully implement automation systems. This presentation highlighted the problems that need to be addressed to ensure the railway remains passenger friendly, safe and reliable as automation systems are developed.

AUTOMATION - BEYOND COMMAND AND CONTROL

STEPHEN BARBER, PWI

Stephen identified two examples where the introduction of automated operation brought established risk control regimes into question, highlighting the critical importance of managing the interface between different engineering disciplines.

Stephen began by suggesting that instead of the introduction of ATO technology increasing passenger capacity and train efficiency, the opposite result may occur if risks at discipline interfaces are not properly considered.

Speed control through junctions is an example of one of the risks. Permanent way determines the speed generally according to passenger comfort criteria (as “comfort speed” is always lower than safe speed) whereas Command and Control focusses primarily on safety. If this difference in approach is not well communicated or considered, then the speed through a junction will be slower than optimal, reducing train running capacity and efficiency. Changes to the system must be accompanied by an understanding of existing risks and controls (even unwritten/informal ones), their structure and the implication of a change.

GoA4 is a train operating system with completely ‘unmanned’ operation. This removes the driver from the carriage; however, in non-automated railways, the driver is currently required to alert on track risks such as flooding, obstructions and vegetation. The cost to retrofit monitoring systems that identify these risks is substantial, so the whole infrastructure may need to be upgraded.

This presentation provided an insightful reminder that while technology promises to deliver increased capacity, it is essential that at the interface between disciplines, dialogue must be open to enable these works to deliver an improvement.

ROLLING STOCK CHALLENGES OF ATTENDED AND UNATTENDED AUTOMATIC OPERATION

GRAHAM NEIL, TRANSPORT FOR LONDON

Graham described the challenges London Underground experienced when considering the introduction of unattended automatic operation.

Initially, Graham discussed what automation replaces: the driver, the signaller, the line controller and the depot shunter. In introducing automation, the train-centric approach must be rethought fundamentally into a railway-centric system as the train becomes a subsystem of the signalling system.

Graham identified the rolling stock challenges, notably transition from front end driving to equipment located in any position under GoA3/4 systems. Under fully automated systems, there are multiple requirements of the operator function that must be automated, and others which must be remote controlled from the line control system, notably emergency train isolation. He also identified the number of detectors required to establish the correct action in the event of different fire cases. Additionally, minimal driving equipment must be kept on the train with remote control access available for control centre operation in the event of train recovery. Graham identified how these challenges increase the complexity of retrofitting existing rolling stock as decisions are required on how much of the stock’s original systems should be removed, disconnected, or retained.

Graham then discussed operational challenges, including passenger alarm activations at the platform-train interface. These would require passenger alarm system decisions to be built into the system, introduction of platform edge doors, visual and audible warnings for closing doors and increased CCTV to monitor the platform edge and the door closure. Once these challenges are overcome, multiple automation benefits can be gained.

IMPACTS OF AUTOMATIC TRAIN OPERATION ON TRACK AND INFRASTRUCTURE

ANDY VICKERSTAFF, TRANSPORT FOR LONDON

Andy reflected on how ATO has impacted the maintenance requirements on London Underground's track infrastructure. He related in some detail each impact back to the theory of wheel-rail forces causing track defects, such as thermally induced squats, rolling contact fatigue and constant frequency corrugations.

He explained that a combination of capacity demand and legacy design issues led to the introduction of ATO on London Underground's network. With ATO first commissioned on the Victoria Line in 1968. To give context on the drivers for introducing ATO, he explained that small radius, deep tube tunnels meant you can't operate bigger trains. Lines historically mirroring London's road network led to high curvature on platforms. Longer trains would require platforms to be extended. Faster trains with greater accelerating/braking would have some impact on increasing capacity, but there is little to gain due to the short distances between stations and speed limiting curvature.

Introducing ATO has allowed more trains to run, at the expense of requiring increased train loading on the network. An example is the 45% tonnage increase between Farringdon and Barbican from 2011 to 2018. An impact of the increased tonnages is the number of broken rails, especially where there is bull-head rail. The lower capacity in the smaller bull head rail section causes the rail to deteriorate faster against the increased tonnages. From 2010-2020, 108 out of 127 broken rails were due to bull-head rail instead of flat-bottom, despite bull-head rail comprising only around 40% of the network.

TRACK ACCESS AND AUTOMATION OF INFRASTRUCTURE INSPECTION AND MAINTENANCE

GARETH EVANS, NETWORK RAIL

In this session, Gareth showcased latest developments and gave an insight into the future of automated infrastructure inspection and maintenance, including the use of autonomous plant and how access to work on the railway is changing due to the wider adoption of automation.

Gareth addressed the benefits of automation, asking, 'why automate?'

He grouped Network Rail's progress and developments of automation within the 3 pillars of Automated Intelligent Systems (AIS):

a) smart data collection (better quality information);
b) autonomous planning and inspection (predicting instead of reacting), and;
c) autonomous robotics for planning and maintenance (staff safety and improved productivity).

Key current developments include:

- plain line pattern recognition (PLPR);
- train-borne ultrasound inspection of rail;
- measurement of dynamic track stiffness;
- expansion in scope of the track decision support tool;
- introduction of fixed sensors and fibre optic acoustic sensing, and;
- autonomous inspection and repair practices.

He highlighted key challenges such as:

- data security;
- access to information systems;
- futureproofing;
- training and competency;
- climate change, and;
- compliance with the common safety method (CSM).

Gareth strongly emphasised that all railway asset disciplines across the network need to engage in the development of automation to enable a safe and effective automated system.

In summary, Gareth provided a thorough and exciting overview into what Network Rail is currently doing to enable and develop automation within the railway environment, significantly noting that we need to create a system that can support historical assets while being prepared for the challenges of tomorrow.

OBSTACLE DETECTION AND AVOIDANCE OF INTRUSIONS

IAIN FLYNN, INDEPENDENT
DAVID MILBURN, WSP

Iain and David addressed the biggest hurdles facing obstacle detection and avoidance of intrusions.

Iain declared that safely implementing ATO (GoA3/4) is not a train control problem. Whilst it might be expected that trains and signalling posed the largest problems to overcome, due to the maturity of the train control technology, the greatest complication is obstacle detection and avoidance. GoA3/4 systems function well and face less challenges to implementation on railways that are never at-grade or passenger carrying.

Iain singled out the passenger-train interface and the complication of platform edge screen doors (PSDs) having to cope with a variety of trains as their doors won't all match up at the same point on the platform. Some innovative solutions were covered such as mechanical lifting barriers. The first half of the presentation was closed by analysing human factors relating to risks such as error in simple tasks eg watching for obstructions.

David Milburn addressed potential solutions to Iain's proposed issues. He provided a breakdown of how to safeguard trains based on the GoA level and discussed the differences between automatic versus autonomous systems in relation to deterministic and non-deterministic outputs on the network. He explained the ETCS example and development, talking through the process of the autonomous system model. Finally, David explored the benefits of artificial intelligence (AI) based enhanced driver advisory systems.

In summary, when moving from a deterministic to stochastic model, where we must expect the unexpected, progress must only be measured by a betterment to the current human role.

THE RIGHT TO DIFFERENTIAL SPEEDS: ETCS, TRACK CANT AND ROUTE AVAILABILITY

PROFESSOR BRIDGET EICKHOFF,
RSSB AND UNIVERSITY OF BIRMINGHAM

Bridget's presentation focused on the use of differential speeds on the railway and how they are dealt with during the transfer into using the ETCS system. Firstly, she stated the benefits of using differential speeds: ability to manage safety, optimising performance and capacity, protection of infrastructure assets and management of interfaces such as signal sighting.

Bridget discussed the different types of differential speeds, which mainly depend on the type of train, for example freight or passenger as well as tilting trains and high-speed trains. It is also important to consider the safe speed of the train which is calculated using several factors including load capacity of bridges, track condition and geometry, electrification equipment and level crossings.

This leads onto some of the problems within the differential speed system. Some differential speeds are not updated after a track renewal which leaves lengths of track with unnecessary differential speeds. Bridget also highlighted the lack of consistency in implementing differential speeds across the railway network and discussed work currently underway to resolve it.

Bridget discussed the limited range of differential speeds provided by ETCS, touching on; braking performance, cant deficiency, and loading for underline structures. Bridget concluded that ETCS must continue to be developed if it is to replace the current arrangements for implementing differential speeds, and that review of the current system is itself critical to successful ETCS implementation.

ETHICS IN DESIGNING SOFTWARE AND ALGORITHMS FOR THE AUTOMATIC OPERATION OF RAILWAYS

PROFESSOR FELIX SCHMID, UNIVERSITY OF BIRMINGHAM
PROFESSOR ROD MUTTRAM, IRSE

The history of automation has multiple examples of poor human interface and risk management since the first automated railway was implemented on the London Underground's Victoria Line in 1968. Notable failure examples include those at Purley in 1988, and at Southall in 1997 which were respectively due to the driver's "reflex" cancellation of repeated automatic warning system (AWS) alerts, and failure and isolation of the AWS system coupled with a lapse in driver attention.

Rod and Felix provided poignant learning points from two automated system designs. The 737 Max, an example of 'whole-system' failure, and the Swiss Railway Violet Aspect's incorrect adoption of 2-channel safety principle resulting in over-reliance on correct driver decisions.

For the implementation of ATO on mainline railways, Rod explained the importance of not forgetting the 'Irony of Automation' – that it results in the deskilling of humans. The design stage is vital to proper ATO implementation, considering the following factors:

- network age and maturity;
- interfacing ATP systems;
- 'open' or 'closed' system;
- organisation and culture, and;
- human factors – competence maintenance, heavy/low workload, distractions, and legal consequences.

There are many human interface interactions to consider and removing the driver from the situation entirely may not bring the reliability expected. The driver is involved in many nuanced decisions that raise many ethical questions. "Trains can't steer", Felix stated, therefore on 'open' systems, such as mainlines, the ethical decisions come at the design stage.

Rod described the Institution of Electrical and Electronic Engineers' (IEEE) ethically aligned design framework pillars, notably the first pillar considering 'Universal Human Values' (no system should prioritise one group) and the third pillar considering 'Technical Dependability'. The IEEE has also produced eight principles for ATO design which are supported by the P7000 series of standards for the design and development of autonomous and intelligent systems.

SUMMARY

The joint seminar was a success. It included a total of 17 recorded online presentations and was attended by well over 200 delegates from all over the world (only 38% of delegates were from the UK). Automated operations and maintenance is the next major step for many railway systems, with benefits in risk reduction, increased performance, increased capacity and cost saving. However, understanding the limitations and implementation challenges of automation is paramount in maintaining the railway's resilience and safety. The seminar raised a number of important questions.

- Will automation provide the savings and improvements anticipated?
- How are human performance and wellbeing affected by automated systems?
- Do we fully understand the risks that increase under ATO?
- What makes mainline ATO harder than automation of metro operation?
- Is sufficient effort being applied to successfully implement automation on the railway and to realise its true benefits?
- When can we expect fully functioning automated train operation on mainlines?
- How does ATO impact rolling stock and the infrastructure?
- Are the operational and risk interrelationships between ATO and all interfacing asset groups comprehensively understood and defined?

With ATO functioning on metro systems and planned for mainline trains across Europe in the coming years, it is an exciting time to be working on the railway. This seminar outlined and explained the challenges that need to be overcome as automation progresses. ATO introduces new risks; organisationally, practically, ergonomically, and across railway sub-system boundaries. Safety must, therefore, remain forefront at all stages of ATO implementation.

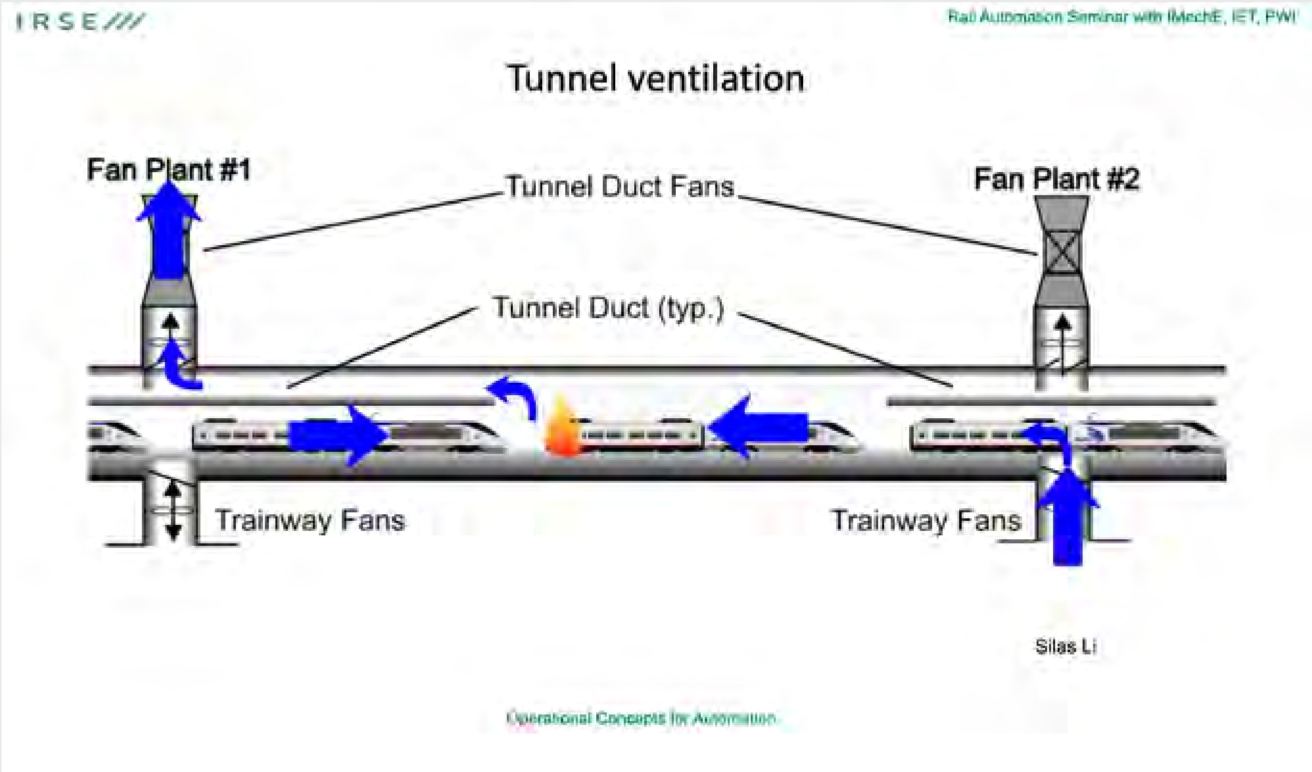

Figure 1: Tunnel ventilation during train evacuation.

OPERATIONAL CONCEPTS FOR AUTOMATED RAILWAYS - PIERS CONNOR, PASQUIRE ASSOCIATES

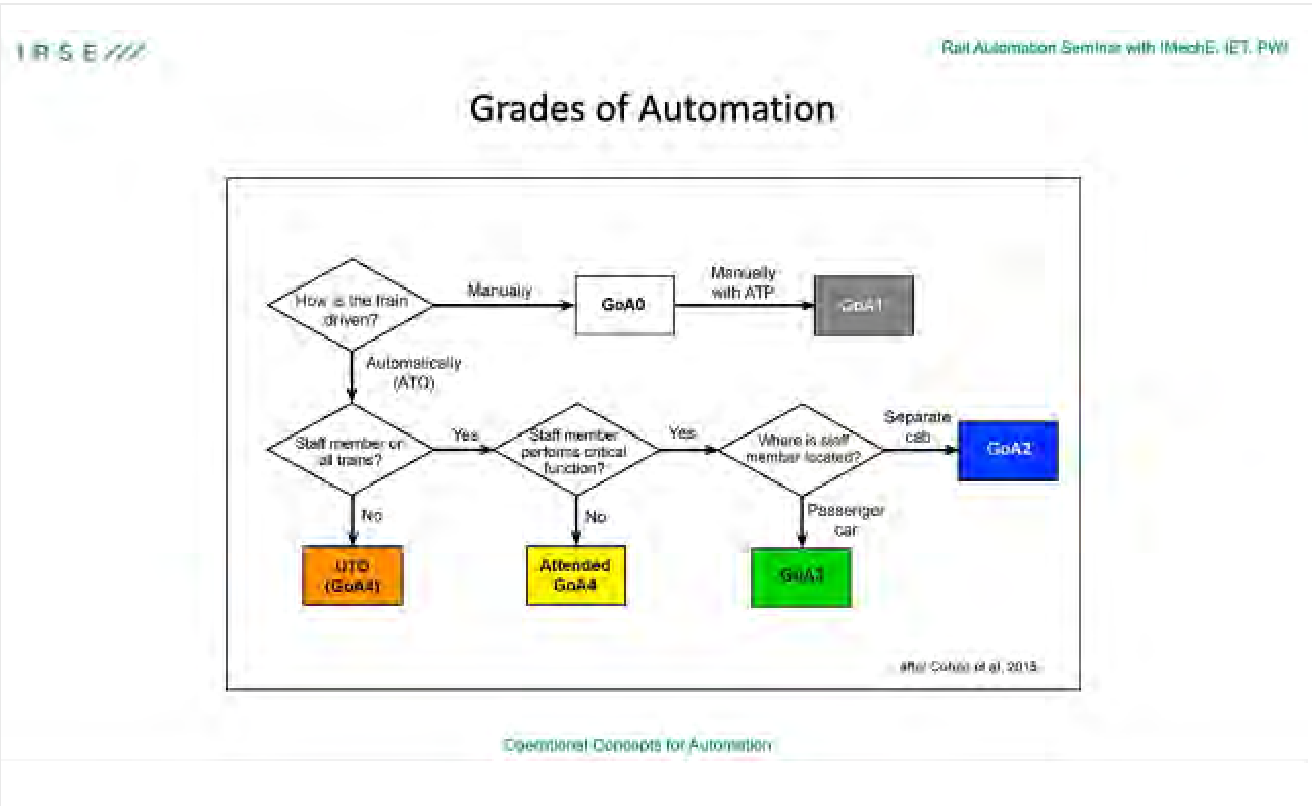

Figure 2: Flow chart establishing the Grade of Operation implemented.

OPERATIONAL CONCEPTS FOR AUTOMATED RAILWAYS - PIERS CONNOR, PASQUIRE ASSOCIATES

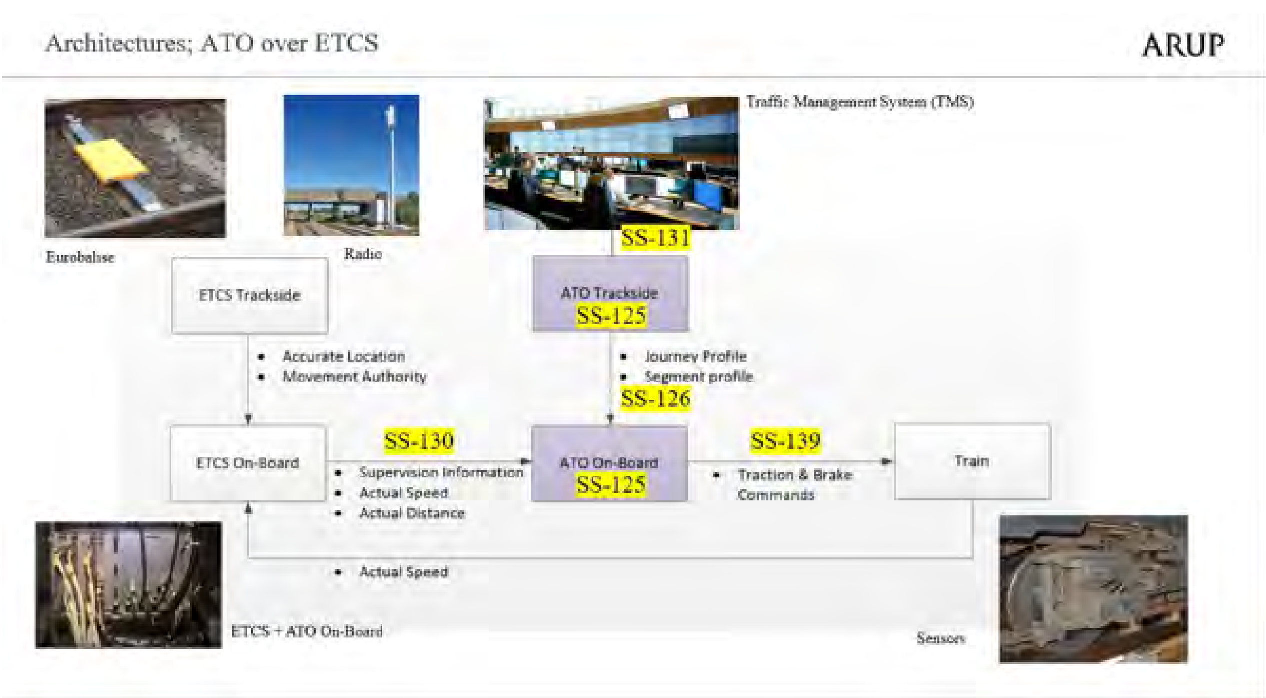

Figure 3: Automatic Train Operation under European Train Control System.

DEFINITIONS, FUNCTIONAL REQUIREMENTS AND ARCHITECTURES - TOM GODFREY, ARUP

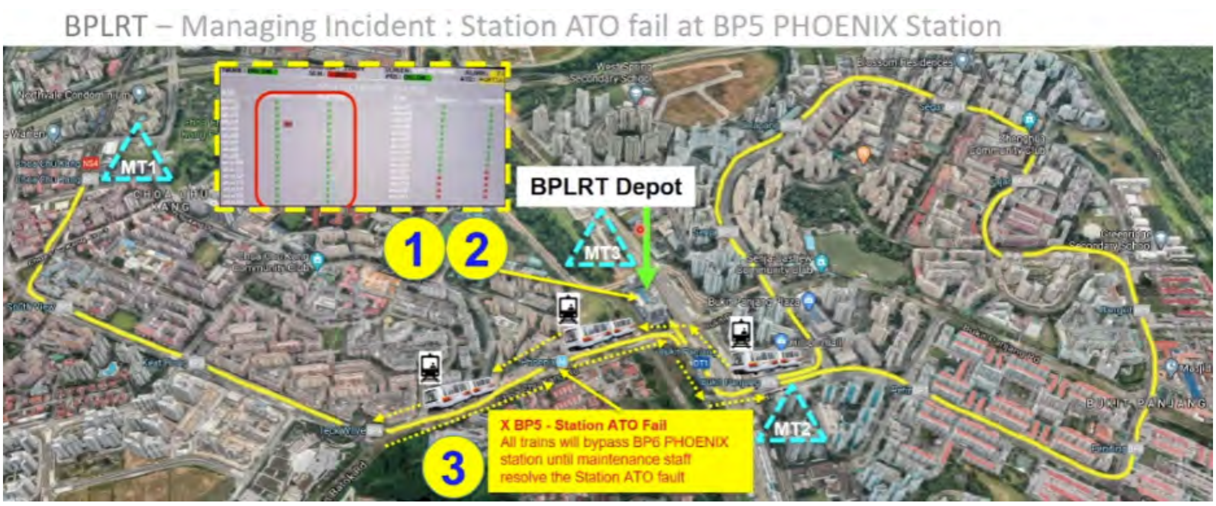

Figure 4: Example response to an ATO failure incident.

MAINTENANCE CHALLENGES OF FULLY AUTOMATIC RAILWAY OPERATIONS - KENNETH YUEN, SMRT CORPORATION

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