The KEY TO SUCCESS
I have been lucky enough to visit a number of IRSE sections recently, including in Australia (of course), Singapore, Thailand, South Africa and Hong Kong. Those of you who follow the IRSE Twitter feed will have seen updates and photos from each visit.

It was a particular honour to attend the inaugural meeting of the new Thai section that occurred at the end of July. The new section has strong industry support and also has close links to Kasetsart University. It was particularly encouraging to see the age profile of both the local committee and the audience with by far the majority qualifying as Younger Members.

The visit to Hong Kong had a particular significance as this was the first occasion where a Presidential series paper has been delivered outside the UK. This taps into a theme of the IRSE strategy, of making the Presidential programme more accessible to a greater range of our membership. A video was taken so we also hope to get that onto the website in the near future.

When I meet with the local committee members and industry representatives I always try to get an understanding of the industry that the IRSE aims to serve, and the key issues facing them. I also try and discuss the IRSE strategy, and test its relevance to each local section.

So far the news is good, in so far as the various elements of our strategy seem well targeted. Tackling the skills gap features prominently. There is a clear need for helping to educate and develop a new generation of engineers, and upskill existing practitioners with the most recent technologies. Providing high quality and relevant papers and events remains core to what we do. This issue of IRSE NEWS contains many examples but its something we have to keep working at.

Another consistent theme is the need to facilitate connections between our local sections. There is a great interest in what other sections are doing, and accessing the papers and presentations that their activities generate. We have some ideas for that too.

It’s good to see we seem to have the right ideas. It’s the follow through that is essential now and we will continue keep you updated via IRSE NEWS.

Charles Page, President
The evolution of signalling technologies in Hong Kong

Philip Wong Wai Ming
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This paper, the first of this year’s Presidential Programme, was presented on 26 August in Hong Kong. It was the first occasion on which such a paper has been presented outside the UK. In it, Philip Wong explains the evolution of signalling technology in main line, suburban and mass transit applications in this unique territory.

Introduction

The railways in Hong Kong have been operating for more than one hundred years. Throughout the years signalling technology on the various lines has been evolving. The purpose of this paper is to describe the evolution of signalling technologies in Hong Kong, covering mechanical signalling, colour-light signalling, speed code, distance-to-go (DTG) and communication based train control (CBTC). The paper also describes the two major signalling replacement projects in 1993-1999, covering replacement of speed code technology by DTG, and the latest CBTC technology adopted in the replacement of signalling systems on eight existing metro lines since 2013. In addition, the paper provides brief technical information on the CBTC adopted for the new fully automatic line being commissioned, and the Chinese Train Control System (CTCS) technology to be adopted for the Express Rail Link connecting Hong Kong and mainland China.

The Railway Network in Hong Kong

In Hong Kong there are ten metro lines and one light rail line operated by MTR Corporation Limited. The whole railway network, with a total route length of 221km, carries around 5.5 million passengers every day. The lines are listed in Table 1, and a map of the railway system is shown in Figure 1.

An Overview of Signalling Technologies in Hong Kong

Since the railways in Hong Kong were built in different years, signalling technologies vary from line to line. Technologies have evolved, with distance-to-go (DTG) currently being deployed on seven lines (EAL, TWL, ISL, KTL, TKL, AEL and TCL), and communication based train control (CBTC) on three lines (WRL, MOL and DRL).

The timeline of the evolution of signalling technologies on existing lines is shown in Figure 2.

The system architecture and the interlocking and automatic train control components of the existing signalling technologies are summarised in Table 2.

In the coming ten years, the seven metro lines which are currently equipped with DTG will be upgraded to CBTC. In addition to the adoption of CBTC on South Island Line which is being commissioned for fully automatic operation, the Chinese Train Control System (CTCS-2 and CTCS-3) will be deployed in the Express Rail Link connecting Hong Kong with mainland China.

Evolution from Semaphore signalling to DTG on East Rail Line

Semaphore signalling

The East Rail Line (EAL) was the first railway in Hong Kong, opened in 1910. At that time the signalling system used wires or channel rods to operate the points, with lever frames to operate mechanical signals (semaphores) for single line working with passing loops at station platforms. Train operation was based on station-to-station block working. Tokens, in the form of balls or tablets, were used to control the movement authority between adjacent stations. The hand signalman at a station used a green flag to give the train driver the signal to depart.

In 1946, EAL was operating eight train trips a day including a through train between Hong Kong and mainland China. With additional locomotives in 1947, EAL operated 24 train trips a day, increasing to 32 train trips a day in 1951 to meet growth in...
The Evolution of Signalling Technologies in Hong Kong

Semaphore Signalling
1910

Colour Light Signalling
1968

Speed Code Signalling
1979

Distance-To-Go Signalling
1996

Communication Based Train Control (CBTC)
2003

CBTC for Fully Automatic Operation
2005

Evolving from two-aspect and three-aspect signalling to modern signalling

Single-line working imposed a significant constraint on system throughput, in the face of continuously growing demand due to expanding populations in new towns along the EAL and increasing numbers of freight trains from mainland China. EAL was expanded to a double-track line under the Modernisation and Electrification Project, commencing in 1978.

In this project a new signalling system, with four-aspect colour light signalling over the inner suburban section (southern section) and three-aspect at the outer suburban section (northern section) and relay interlocking, was controlled from a hardware-based control room in a combined signalling and electrical control centre at Kowloon Station, via a hardwired entrance-exit (NX) signalling panel in a combined signalling and electrical control centre at Kowloon Station, via a hardwired entrance-exit (NX) signalling panel. There was full track circuiting, with electro-hydraulic point machines, and the Automatic Warning System on trains and locomotives.
Because 25 kV traction was introduced in this project, immunisation of the signalling system against inductive interference from the overhead line system was a challenge throughout commissioning. The new signalling system was rigorously tested on completion of each stage. When it was proved satisfactory the corresponding overhead line section was tested and energised, after which the new signalling system was re-tested to check its immunity to inductive interference. On successful completion of the interference tests, the signalling was permanently changed over to the new system and the overhead line thereafter remained energised.

This project was completed in 1983, and it allowed a significant enhancement to system safety and line capacity on the EAL, so that headways for the inner suburban section and the outer suburban section were improved to around four minutes and eight minutes respectively. The four-aspect and three-aspect suburban section were improved to around four minutes and so that headways for the inner suburban section and the outer section respectively. Both the ATP and SSI are installed in the Central Equipment Room in the new Control Centre at Fo Tan Railway House. The SSI performs remote control and indication, train supervision and regulation functions. The SSI performs interlocking functions and interfaces with the TCS and with the TBL ATP system, allowing mixed operation of lineside signalling and cab signalling. The ATP maintains a safe distance between trains, and between trains and fixed structures, and prevents over-speeding. The new system re-used the DC track circuits, signals and point machines.

Intermittent ATP is adopted, whereby trains receive signalling information from trackside balis and inductive loops at specific locations, for train position calibration and train position determination respectively. The ATP is based on DTG technology for achieving optimum performance, while it is still based on the signal block layout. The status of the signal and track ahead is transmitted to the onboard ATP as a limit of movement authority, for continuous supervision of the speed of the train and to ensure that it will not exceed the movement limit. A new aspect, the blue aspect, is added for facilitating cab signalling operation. With cab signalling, the safety of train operation and system performance are both significantly improved.

The original lineside signalling is retained and integrated with the new signalling so that trains which are not equipped with onboard ATP can operate in accordance with lineside signal aspects with the protection of the Automatic Warning System.

In order to further optimise headway, lineside signalling blocks between home and starter signals are divided into two cab signalling blocks at station platforms. The boundary between the two cab signalling blocks is then marked with a headway board. A specific aspect sequence has been developed through sub-sectioning of the track sections for these two cab signalling blocks, so as to allow follow-on moves under the supervision of ATP. As soon as the preceding train is leaving the platform, the following ATP-equipped train receives a movement authority based on the clearance of the sub blocks. Figure 3 shows the splitting of a lineside signalling block into two cab signalling blocks.

In cab signalling mode, trackside signals display the blue aspect, and the train is driven manually following the target speed and target distance displayed on the cab display unit. When an ATP-equipped train approaches a three-aspect or four-aspect signal, the colour-light aspect is extinguished and replaced by the blue aspect. This is maintained when the following train is equipped with ATP and the timer of the blue aspect has not expired. In lineside signalling mode, trackside signals display colour-light aspects and the train is driven in accordance with the aspect sequence with protection by the Automatic Warning System.

The coexistence of cab signalling and lineside signalling modes facilitates mixed running of domestic trains and the mainland through trains. The ATP Project was completed in 1998. With DTC on EAL, a headway of 150 s (24 trains per hour in each direction) was achieved.

**Evolving from ATP to ATC**

Automatic Train Control (ATC) is defined as a system that automatically controls train movement, enforcing train safety and directing train operations. ATC includes Automatic Train Operation (ATO) and ATP functions.
Starting in 2000, further improvement works were launched, including upgrading TCS to a server-based platform. ATO was introduced for more efficient train regulation. Radio infill communication (2.4 GHz with Direct Sequence Spread Spectrum) was adopted for sending signalling information to onboard ATP with a wider transmission coverage than transponders and inductive loops. Sub-sectioning was added to critical station platforms for shortening the headway.

ATO provides control of train movement, specifically the regulation of speed at or below the safe speed limit, and stopping at stations. The introduction of ATO was limited to onboard equipment, because the existing trackside transmitting devices used for the ATP could be used for the ATO. The onboard ATO receives the trackside messages through the onboard ATP, processes them, and controls rolling stock equipment for automatic train running and station stopping. The ATO only allows automatic driving of the train when authorised by the onboard ATP. For energy optimisation, the ATO executes a coasting function in accordance with a coasting level sent by TCS. The introduction of ATO is welcomed by train drivers because manual driving is no longer the normal mode.

The radio infill was the first application in Hong Kong of 2.4 GHz to transmit signalling messages from trackside ATP to onboard ATP. The trackside radio infill equipment is mounted on signals or headway boards.

With the completion of these improvement works including the introduction of ATC in 2002, headways of 133 s (27 trains per hour per direction) for the southern section and more stable train operation were achieved.

Evolution from speed code to DTG signalling on TWL, ISL and KTL

Speed code signalling for ATC

With the continuous growth of population in Hong Kong, construction of metro lines was started in 1973. The Kwan Tong Line (KTL) and Tsuen Wan Line (TWL) were the first two, opening for passenger service in 1979 and 1982 respectively, with automatic train operation. The signalling system at that time comprised a conventional train service regulator's console with separate NX control and indication panels. It employed 50 Hz AC track circuits (double rail on plain track, single rail in points and crossing areas and in the depot), electro-hydraulic clamp lock point machines, relay interlocking, and speed code ATC comprising ATP and ATO functions. The speed code signalling provided a service headway of 120 s.

The fundamental system of control to authorise train movement is the generation of relevant ATP codes (speed codes) for the safe working of trains. These codes are transmitted to the train and used either to drive the trains automatically, or to provide cab signal indications for manual driving.

The codes convey information to the train relating to its maximum safe speed and target speed as the fundamental safety control of train running. It is a fail-safe system which continuously compares the actual train speed with the maximum safe speed for the track circuit currently occupied by the train. If the train exceeds the maximum safe speed, the ATP commands the emergency brake to bring it to a stand.

In the ATP, code generators (modulation generators) are provided. Code selection is implemented by relay logic (code selection circuits) based on the status of track circuits, signals, points, routes and emergency devices. The code selection circuits send the relevant signals to the transmitters (with two carrier frequencies) for the trackside equipment to generate ATP code signals and feed them to the rail or inductive loop, to be received by the trainborne ATP. Two carrier frequencies and four modulation frequencies are used, generating ATP codes for 22, 40, 65 and 80 km/h. The 22 km/h code is mainly used for reduced overlaps in point and crossing areas.

A particular ATP code consists of two parts, the maximum safe speed and the target speed. ATP codes are referred to, for instance, as ‘80/65’; this means that the nominal maximum safe speed is 80 km/h and the nominal target speed is 65 km/h. When the on-board ATC receives this code, it commands the train to brake from 80 km/h to 65 km/h before entering the next block. Code ‘65/65’ means that the train can run at the maximum safe speed. Each ATP code block ensures sufficient service braking distance and emergency braking distance for the various speed codes. The ATP code applies to track circuits occupied by a train and the track circuit immediately ahead of a train. Table 3 and Figure 4 show the sequence of ATP codes, and the code selection principle.

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Table 3 – Code sequences, assuming line speed is 80 km/h.

![Figure 4 – Graphical representation of code sequences behind a train.](image-url)
When a train enters a track circuit the on-board ATP, which incorporates ATP antennae and tacho-generators, detects the code and compares the actual speed of the train with the speed represented by the code. Speed in excess of the maximum safe speed results in a command for an emergency brake application.

The ATO comprises trackside and on-board equipment. In the signalling equipment room, programme plugs provide the ATO data which is transmitted to the trackside marker loop. The trackside marker loop initiates and transmits serial messages which repeat continuously and are fed to marker loops laid in the rail web. The ATO data contains three marker categories, XC, X1 and X2, with suitable data for coasting distance / velocity, distance to next marker, gradient data, and distance to go to stopping point. The ATC allows three levels of coasting: Normal Coast; Make-up Coast; and No Coast. Normal Coast and Make-up Coast allow energy saving, whilst No Coast is used for delay recovery.

Lineside signals are two-aspect. A red aspect means ‘stop’. A blue aspect in association with ATP codes means ‘proceed.’ A blue aspect without ATP codes means ‘proceed after obtaining authority.’ It is provided only to authorise shunt route moves (without ATP code), or to authorise main route moves in the event of failure of ATP code generation or ATP code receipt by the train. Thus lineside signals are only necessary in points and crossing areas, or to authorise movement of trains towards the next interlocking area in either the normal or the reverse direction of running. This principle reduces the number of lineside signals significantly.

The speed code signalling performed satisfactorily on the KTL, TWL and ISL lines from 1979 until it was totally replaced by Distance-To-Go signalling in 1999.

**Era of jointless track circuits, electromechanical point machines and processor-based telemetry**

In 1985, the Island Line (ISL) was opened for service with relay interlocking and speed code as on the KTL and TWL lines, except that new technologies were adopted for track circuit, point machines and telemetry. This started the era of audio-frequency Jointless track circuits, electromechanical point machines, and processor-based telemetry subsequently for the TXL, TCL and AEL lines.

Deployment of jointless track circuits allows deletion of most insulated rail joints and active trackside equipment, which significantly improves overall track circuit performance. However there was a constraint, in that ATP code could no longer be fed into the rails because of the incompatibility between ATP codes and jointless track circuits. To address this issue an inductive loop was laid in each track circuit for transmitting ATP codes to the onboard ATP. The use of inductive loops created another problem in that the ATP code could be coupled into the overlap track or tracks in rear (because the absence of insulated joints) when a track circuit was occupied. Special code sequence logic and inductive loop layouts were designed to resolve this problem.

The electromechanical point machine proved more reliable because of its simple construction with very few components. Processor-based telemetry provides a shorter system response time and reduces the quantity of hardware required.

**Era of SSI**

In 1989 the KTL line was extended to the Island through the Eastern Harbour crossing. The same speed code signalling and tuned jointless track circuits were adopted, but the interlocking functions and ATP code selection logic were implemented by SSI rather than relay logic. This started the era of SSI in Hong Kong.

**Evolving to DTG technology**

After the KTL line opened in 1979 passenger growth was rapid, leading to a situation where the train service operated on the TWL, ISL and KTL lines was one of the most intensive in the world. To meet these ever-increasing passenger demands consistently, the speed code signalling had to be replaced by a new generation of ATC system able to provide a much shorter headway. In 1994, the Automatic Train Control Replacement Project was launched for the replacement of speed code signalling, telemetry and 50 Hz AC track circuits by distance-to-go (DTG) signalling, processor based telemetry, and jointless track circuits.

The new generation ATC system (SACEM) selected is based on DTG technology, in which a train needs to know its location before it can operate at line speed, and the target speed varies according to the track occupancy ahead.

The DTG system operates a line divided into sectors, and each sector is monitored by two vital computers in redundant configuration. The sector itself is divided into sections. In each section ATC messages are simultaneously injected all along the section by a continuous transmission loop, to be received by the trainborne ATC. Each message describes a small portion of the line, that is the segment covering track circuits, signals and points. The segments standardise the description of the line. They are defined in accordance with the message length, and are numbered in sequence.

The system architecture includes distributed trackside equipment, where the sector computers collect the signalling data along the lines, and on-board intelligence, where the trainborne ATC receives the description of the sector, both dynamic and static data, from the trackside equipment for determining target distance and target speed. Two main links between trains and trackside equipment are provided by using continuous track-to-track transmission loops, and intermittent train-to-track return channel loops.

At specific locations beacons are installed for intermittent track-to-track transmission covering moving train initialisation and wheel diameter calibration, stationary train initialisation and location calibration.

Along the rail, continuous transmission loops with a maximum length of 900 m are laid in the web of the rail for continuous track-to-track transmission. At platform headwalls and tailwalls, return channel loops are installed for train-to-track transmission.

With DTG technology, an empty block (that is, an overlap) between preceding and following trains is no longer required. The trainborne ATP allows a train to run up to the safety distance from an occupied track circuit. This improves the system throughput significantly, yielding a design headway of 95 s on the TWL, ISL and KTL lines. Figure 5 shows how an empty block is not required in DTG.

With DTG, the trainborne ATO performs off-peak and peak hour regulation, through slacker and tighter running profiles based dynamically on energy consumption and on the difference between planned and actual travelling times.

For system availability, dual redundancy is provided in the processor based telemetry and the sector computers. In addition, two new functions are delivered for minimising the impact to train service in the event of failure of a track circuit or of a continuous transmission loop, as follows.
completed in 1996, followed by ISL and KTL in 1997 and 1998. DTG were running concurrently with trains equipped with speed code, until all trains had been converted to DTG. With this migration strategy, there was a period when trains equipped with onboard speed. functions and train operation during non-traffic hours. Upon the conversion from speed code to DTG for testing and commissioning of the new technology, ‘track circuit reconfiguration,’ has been developed to allow a train to run over a failed track circuit at normal speed. This function is useful on the TWL, ISL, KTL, and TKL lines, because most distances between stations are less than 1.5 km.

The sector computer has to detect the following sequence before activating the track circuit reconfiguration function:

(a) The sector computer has received the first train’s rear end train identity at station ‘N’ tailwall through the tailwall return channel loop, and
(b) the first train has departed from station ‘N’; and
(c) the sector computer has received the first train’s rear end train identity at station ‘N’ headwall through the headwall return channel loop, and
(d) the first train has arrived at station ‘N+1’, and
(e) the sector computer has received the first train’s rear end identity at station ‘N+1’ tailwall through the tailwall return channel loop.

At this stage the section between the stations is considered to be clear, and the track circuit reconfiguration function is activated. The second train receives a ‘track clear’ message, and either automatic mode or coded manual mode can be selected to operate the train through the section at normal speed.

Transmission loop reconfiguration

In view of the disturbance to the train service during a failure of a continuous transmission loop, transmission reconfiguration is designed for maintaining normal train running speed whenever possible. The activation of the transmission reconfiguration function is an automatic process in the sector computer. The function is activated when the sector computer detects a transmission failure and all the track circuits within the failed loop as well as the first track circuit in the loop next to the failed loop are clear. Full transmission reconfiguration is not possible for track sections where there are points, signals, platform emergency stop plunger or other emergency devices.

During the transition period, the DTG system was overlaid with the speed code signalling along the track. Some DTG trains were converted to DTG for testing and commissioning of the new functions and train operation during non-traffic hours. Upon the completion of the trackside DTG for the whole line, trains were then converted from speed code to DTG. With this migration strategy, there was a period when trains equipped with onboard DTG were running concurrently with trains equipped with speed code, until all trains had been converted to DTG.

The migration was implemented progressively, with TWL completed in 1996, followed by ISL and KTL in 1997 and 1998 respectively. The evolution from speed code to DTG went smoothly, without adverse impact on train service.

Although DTG is still track circuit based, it does provide a much shorter headway than speed code ATC. The overall ATC Replacement Project, including replacement of telemetry and 50 Hz AC track circuits with jointless track circuits, was completed in 2001.

With DTG technology the overall system performance is improved, with the following key enhancements:

(a) overall system safety.
(b) dynamic performance, i.e. reduction of headway.
(c) regularity through the increasing of headway margin with respect to nominal headway and the possibility of self-regulation on each train.
(d) overall availability taking into account the degraded mode through the rational use of reconfiguration to ensure train service while minimising the amount of disturbance following local failures.
(e) reduction of installation and operating cost.

Further adoption of DTG technology

The DTG technology was adopted for the TCL and AEL lines in 1998, and the TKL line in 2002. The only difference is that on these lines SSI and Computer Based Interlocking are used respectively instead of relay interlockings.

Era of CBTC technology

In conventional signalling, train separation is ensured vitally with wayside signals, speed codes and target distance control to ensure that no train can enter a signal block that is occupied by another train. In contrast, moving-block communication based train control (CBTC) provides improved safety and increased capacity resulting from fine train location resolution obtained by having rapid and continuous bi-directional data communication between the trainborne controller and the trackside controller. The accurate positioning system, precise speed measurement functions, and continuous bi-directional communication between track and train are the key elements of CBTC.

CBTC is flexible in that its design can be based on either virtual block or moving block. Even if signal blocks still exist, CBTC can safely allow multiple train occupancy in the same block, improving headway and increasing passenger moving capacity significantly. In theory, the interval between a preceding train and a following train is the safe braking distance of the following train plus the required safety margin.

The communication system between trainborne controller and trackside controller may be GSM-R, 2.4 GHz / 5.8 GHz Direct Sequence Spread Spectrum, Frequency Hopping Spread Spectrum based on IEEE802.11, or inductive loops laid along the rail. With radio communication, trackside transponders are...
installed for train position calibration. With inductive loops, the loop is transposed at regular intervals and the trainborne controller detects the change in phase of the signal for calibrating the train’s position by reference to the alignment map on board the train. Figure 6 shows the principle of moving block.

**Loop-based CBTC**

On the WRL and MOL lines, loop-based CBTC has been adopted since opening, in 2003 and 2004 respectively. The CBTC uses moving block, the safe separation between trains being dynamically calculated based on maximum operating speeds, braking curves and locations of the trains on the track. Because of the high resolution of position reporting, a following train can safely close up to the safe braking distance from the last verified position of the rear of a preceding train, based on the maximum allowed speed in that section of the track. This allows a significant reduction in headway compared to fixed block systems since a CBTC train need not be stopped at the entrance block occupied by a preceding train.

Vital supervision of safe train separation is implemented by providing the trainborne ATC with the maximum allowable train speed and the current stopping point continuously. The communication is updated cyclically, to ensure that continuous updates are sent to the trains so that they can safely operate within the envelope defined by the set maximum speed, the confirmed stopping point, the braking curve and the track gradient.

As well as its important safety benefits, the CBTC provides the following operational benefits on WRL and MOL.

- **(a)** Minimum headway, allowing maximum throughput.
- **(b)** Precise adherence to the civil speed profile.
- **(c)** Accurate station stopping.
- **(d)** Minimum turn back times.
- **(e)** Full bi-directional operation capabilities, including direction reversal at all stopping points.
- **(f)** Reduction of station approach times and headway through the use of safety distances optimised for the characteristics of each station and for the different types of trains.
- **(g)** Schedule adherence and recovery from minor delays, made possible by the automatic train regulation function.

A centralised CBTC architecture has been adopted for WRL and MOL. The CBTC is basically categorised into three levels, management, operational level, and activation. The management level is executed by the System Management Centre, while the operational level is executed by the Vehicle Control Centre where the interlocking and ATC functions are fully integrated. The activation level covers the vehicle on-board controller (VOBC), station control system, platform door interface unit, and axle counter system.

For system availability, dual redundancy and 2-out-of-3 redundancy, and head-tail redundancy in the VOBC, are provided in the major subsystems of the CBTC.

Along the track, inductive loops between the rails facilitate bi-directional communication between trackside and trainborne equipment. The inductive loops are transposed approximately every 25 m. The VOBC on the train detects the phase change in the signal as it crosses each transposition and uses this to calibrate its position.

At point and crossing areas, point Indicators are installed instead of conventional signals. The point indicators are controlled by relay logic separate from the CBTC.

Although primary train detection is achieved by the continuous train position reporting by the VOBC, axle counters are provided as secondary train detection for tracking non-CBTC equipped trains and for degraded mode operation.

**Radio-based CBTC**

**Disneyland Resort Line (DRL)**

The DRL line is the first in Hong Kong to have fully automatic operation. The signalling system, which employs radio-based CBTC, has been operating since 2005.

The CBTC uses the fundamental virtual fixed block principle, with advanced communication and positioning technology to implement the required functions. The fixed blocks traditionally implemented by track circuits are replaced by virtual fixed blocks defined within the CBTC databases. Each block represents an area of the track. The length and quantity of virtual blocks can be easily adjusted to accommodate specific applications, without the need for installation work at the trackside.

The position of the train on the track is determined by the on-board system, using transponder tags expressed in fixed block data, which are communicated to the wayside system via the radio-based communication system.

ATC is implemented at three levels of control: the central control and supervision level, implemented by the ATC; the wayside control and supervision level, implemented by the Wayside Control Unit; and the vehicle control and supervision level, implemented by the VOBC. For system availability, dual redundancy, and head-tail redundancy in the trainborne ATC, is provided.

The data communications system (DCS) adopts 2.4 GHz frequency-hopping spread spectrum, and provides all the necessary support for data communications between various components of the ATC. It is distributed along the route, and consists of a combination of networks, both cable and wireless using commercial protocols. All communication interfaces to the DCS are at Ethernet ports via security devices.
Along the track, two-aspect signals are installed with red and blue aspects. As on the WRL and MOL lines, axle counters are provided for secondary train detection for non-CBTC trains and degraded mode operation.

**Southern Island Line (SIL)**

On the SIL line, radio-based CBTC with a centralised architecture is provided for fully automatic operation on the main line and in the depot. This is the first fully automatic depot in Hong Kong. In this CBTC, the system is equipped with ATS, CBI, DCS, trackside and trainborne ATC, and axle counters for providing secondary train detection. For system availability, dual redundancy, 2-out-of-3 redundancy and head-tail redundancy in the trainborne ATC are provided.

The CBTC separates CBI and ATC so as to provide degraded operation safeguarded by the interlocking in the event of ATC failure. However, the ATC cannot work alone when there is a total failure in the CBI.

For the DCS, redundant networks cover the whole line. For protecting CBTC data against any interference, 5.7 GHz - 5.8 GHz with radio spread-spectrum technology using OFDM (Orthogonal Frequency Division Multiplexing) is adopted. The architecture rests on complete separation between the channels for CBTC. Such frequency separation ensures the integrity of each channel and also provides a high level of performance in terms of communication reliability.

Along the track, two-aspect signals are provided, and a signal will display blue aspect when the movement authority is available.

**Current evolution from DTG to CBTC**

In order to meet the ever increasing demand on system throughput and train service performance, the DTG technology used since 1998 is being replaced by CBTC technology on the EAL and DUAT Lines (that is, TWL, ISL, KTL, TKL, TCL, AEL and DRL).

**CBTC on EAL**

On EAL, replacement of DTG with CBTC began in 2013. In this project, the existing TCS, SSI, ATC and DC track circuits will be replaced with CBTC and audio frequency jointless track circuits.

The CBTC on EAL, based on a centralised architecture, is a radio based moving block CBTC comprising ATS, CBI, ATC, and DCS systems. Existing signals, points and other emergency devices are retained and interfaced with the CBTC.

The CBTC features fully automatic operation in moving block on the main line and sidings, and also enables mixed operation with non-CBTC equipped trains including the through trains running between Hong Kong and mainland China. When a non-CBTC train is detected, the CBTC will set up a protection envelope for the CBTC trains and enable the trackside colour light signalling for safe train operation.

For the DCS, redundant networks cover the whole line with the deployment of 5.8 GHz radio with direct sequence spread spectrum for continuous bi-directional communication between trackside and trainborne ATC.

For system availability, dual redundancy, 2 times 2-out-of-2 redundancy, 2-out-of-3 redundancy, and head-tail redundancy in trainborne ATC are provided in the CBTC. This improves overall availability significantly.

**CBTC on DUAT Lines**

On the DUAT Lines, replacement of DTG with CBTC has been under way since 2015. In this project the existing ATSS (Automatic Train Supervision System), relay interlocking, SSI, CBI, DTG, ATC and virtual block CBTC will be replaced by moving block CBTC. Existing signals, points, track circuits and emergency devices are retained and interfaced with the CBTC. TWL is the first line to be upgraded to CBTC, to be followed by the other DUAT lines.

A distributed CBTC architecture has been adopted for the DUAT Lines. The CBTC is based on moving block, with ATSS, Zone Controllers (ZC) with integrated interlocking and ATC control functions, DCS, and VOBCs.

In this CBTC, triple redundancy with on-line, hot standby and warm standby configurations is provided in the ATSS and ZC. Head-tail redundancy is provided in the VOBC and DCS on board the train. For the zone controllers, the on line and hot standby systems and the warm standby system, each with its own uninterruptible power supply, are installed at different stations to ensure full independence.

For the DCS, 2.4 GHz Frequency Hopping Spread Spectrum (FHSS) is used as the primary communication with backup of LTE/4G, for bi-directional communication between track and trains. Also a dedicated radio communication link between zone controllers and trackside interface with platform screen doors will be provided in order to further optimise platform dwell time, critical for headway performance.

The CBTC will feature fully automatic operation on the main line and in the sidings. It allows mixed mode operations of CBTC trains and DTG trains during the transition period. During mixed mode operations, the zone controller provides the necessary interlocking data to the trackside DTG to ensure safe operation of the DTG trains.

This project unifies the CBTC technology on seven lines, benefitting operations and maintenance. The adoption of triple redundancy with separate hardware for on line, hot standby and warm standby systems, and the use of LTE/4G to back up the 2.4 GHz FHSS, increase the availability of the CBTC significantly. With higher availability, the number of zone controllers on each line is optimised.

The use of triple redundancy in major subsystems of the CBTC is a pioneer for providing the highest train service reliability for passengers in Hong Kong.

**Chinese Train Control System (CTCS) on the Express Rail Link**

The Hong Kong Section of the Express Rail Link (XRL) runs from the terminus in West Kowloon, heading north to the Shenzhen/ Hong Kong boundary, where it connects with the mainland section. XRL is a conventional high speed railway with maximum operating speed of 200 km/h. For interoperability between the Hong Kong and mainland sections, the technology of the Chinese Train Control System (CTCS) is adopted. Of the five levels in CTCS, Level 2 (CTCS-2) and Level 3 (CTCS-3) have been adopted for the Hong Kong section.

CTCS-3 and CTCS-2, based on the fixed block principle, are provided for manual train operation on the XRL. On passenger trains CTCS-3 is the primary signalling control, while CTCS-2 is used as a backup when CTCS-3 is not available. The switchover between CTCS-3 and CTCS-2 is seamless and transparent to train operation. On locomotives, the signalling control is based on CTCS-2.
On board the trains, separate CTCS-3 and CTCS-2 trainborne equipment is fitted. At the trackside most of the subsystems, including the Wayside Train Control Centre, Computer Based interlocking (CBI), track circuits and balises are common to CTCS-3 and CTCS-2, but the Radio Block Centre (RBC) and GSM-R are dedicated to CTCS-3.

In CTCS-2, the Wayside Train Control Centre generates the track-to-train message based on the status of track circuits, and on route information from the CBI. It sends this message to the train via track circuits. It also sends information as required, including route status and directional status, to active balises. The trainborne ATP calculates the movement authority in accordance with the status of track circuits, routes and other devices. The trainborne ATP uses the movement authority and information received from static balises to calculate speed and distance in producing the control mode profile.

In CTCS-3, continuous bi-directional communication between train and trackside is implemented through the RBC using GSM-R. The RBC sends the movement authority to the trainborne ATP in accordance with the status of track circuits, routes and other devices. The trainborne ATP uses the movement authority and information received from static balises to calculate speed and distance in producing the control mode profile.

In normal operation, both CTCS-2 and CTCS-3 are active in both trackside and trainborne systems, with CTCS-3 being the primary control. This provides a high availability for train operations on the Express Rail Link in Hong Kong.

**Conclusion**

Over the years, signalling technologies in Hong Kong have gone through four major stages of development, from semaphore signalling, through colour light signalling, speed code signalling and distance-to-go signalling, to communication-based train control. Each development has been to meet growing demand, providing an incremental improvement in operational performance.

The first development, from semaphore signalling to colour light signalling, enhanced system automation with all the train control logic and equipment installed at the trackside, and trainborne equipment limited to AWS. With this technology trains were driven manually, with limited system throughput and operating flexibility due to the fixed-block architecture.

The next development, adopting speed code technology, permitted automatic driving of trains, but system throughput and operational flexibility were still limited by track circuit layouts and the number of available speed codes. Moreover the level of redundancy in interlockings and ATC was limited on account of the widespread use of relay logic and analogue equipment.

The third development, to distance-to-go technology, continued the track circuit based philosophy. However control of train movements was made more precise by increasing the amount of data transmitted to the train and using trackside transponders, so that the train followed specific speed and distance profiles. This technology enhanced system throughput because an empty block between trains was no longer required. In addition to continuous track-to-track transmission, intermittent train-to-track transmission was allowed for sending onboard information to trackside ATP. Since more digital equipment was used, redundancy could be built into critical equipment, improving system availability significantly.

The fourth development, to CBTC, has removed the operational constraint imposed by track circuit layouts, and allows trains to run closer to each other compared to a conventional fixed block system. Continuous bi-directional communication between train and track allows the trainborne ATC to report the train’s position to the trackside ATC, almost in real time, without relying on track circuit detection; this supports maximum system throughput with the shortest headway. Moreover, with continuous bi-directional radio communication between train and track, CBTC allows the transfer of larger amount of data than is possible with DTG. This offers the greatest operational flexibility, such as the deployment of fully automatic operation. The design of CBTC is also flexible in that either moving block or virtual block can be adopted to cater for different operating environments.

Looking ahead, CBTC will replace DTG technology in Hong Kong. In the new generation of radio based CBTC systems, availability will be a focus in addition to system throughput and operational flexibility. This is the key driver for incorporating triple redundancy into the current CBTC implementation on the DUAT lines.

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The authors have been practising, teaching and researching Systems Engineering (SE) in a railway context for more than ten years. We believe that SE can help rail projects deliver better systems more quickly and at lower cost. However, it is evident that the industry does not fully appreciate what SE is, or how to apply it. In this paper we try to aid a better understanding by correcting some commonly-held misapprehensions, or ‘myths’.

Although the defence sector has applied SE since the 1940s, the rail industry has no comparable tradition. However, SE is being adopted increasingly by the rail sector. The IRSE held a seminar on SE for Train Control and Communications in April 2016 at which it was concluded the railway signal engineering community would benefit from a clearer appreciation of SE.

In this article, we aim to put seven myths about SE to rest and, along the way, to paint a picture for those unfamiliar with SE of what it is and what benefits its application promises for rail projects.

Myth 1: SE is about connecting up computers

Some rail engineers use the word ‘system’ to refer to the parts of the railway with electronics and computers inside. For them, it is only natural to assume that ‘Systems Engineering’ means “the business of getting the boxes with computers in to work together to do what we want them to”.

However, to a systems engineer, a system is any collection of hardware, software, people and procedures assembled for a purpose and so, stations, trains and, indeed, whole railways are systems too.

The mythical definition of SE is not completely wrong, it is just too narrow. A better definition is ”the business of getting all the parts of a system to work together to do what we want them to, effectively and in an efficient manner”.

As illustrated in Figure 1, systems engineers see the railway as a system made of interacting sub-systems. But they are also concerned with things which are not visible on any photograph of the railway.

There are requirements, perhaps to transport certain numbers of passengers between certain points with certain comfort, reliability and safety. It is not possible to establish whether these requirements will be met by looking at any sub-system alone – one must look at the whole railway.

There is, or at least there should be, a logic behind the way in which the railway is split into sub-systems and the way in which they work together which will deliver these requirements. A systems engineer might refer to this as an ‘architectural design’.

And finally there are interfaces between the sub-systems which must be carefully managed to enable the interactions that we want (the trains’ wheels must roll on the rails, for example) and to prevent interactions that we do not want (the trains must not graze the platforms, for example). There is a great deal of opportunity for problems if care is not taken over the interfaces between them. As Sir Peter Parker, a past Chairman of the British Railways Board, is reported as remarking, railways have a habit of “falling flat on their interfaces”.

Without accurate, clearly articulated requirements, a sound architectural design and carefully managed interfaces, a project is likely to disappoint. SE provides methods and tools for avoiding such disappointments.

Figure 1 – A system engineer’s view of the railway.
Myth 2: SE is a well-defined discipline

Systems engineers like precise specifications and so it is an embarrassment to us to admit that we cannot agree about precisely what SE is.

We do agree approximately. Few systems engineers would disagree fundamentally with the following definition published by INCOSE (International Council on Systems Engineering):

“Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem: Operations, Cost & Schedule, Performance, Training & Support, Test, Disposal and Manufacturing.

“Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.”

Moreover, a comparison of a number of SE standards shows that all are agreed that SE covers the following topics:

- establishing the scope of the system to be built and the requirements that it must meet;
- understanding how the system should be decomposed into sub-systems and managing the interfaces between these sub-systems;
- where practical and useful, performing systems modelling and analysis before the system has been built to check whether it will meet its requirements;
- validating that the system has met its requirements after it has been built; and
- specifying the processes that will be used to design, build and check the system.

But the standards disagree at the margin. For example, some standards include aspects of ergonomics within SE while others regard ergonomics as an entirely separate discipline.

Readers considering adopting SE approaches within their organisation need to be prepared to make some choices at the margin about what to include and exclude under the title of ‘systems engineering’.

Myth 3: SE is just common sense

SE certainly draws upon common sense. The list of activities in the previous section draws upon the following common sense principles:

- You should be clear about what you are trying to achieve before embarking upon a project;
- You should check whether you achieved what you wanted at the end of a project and, where practical, you should build confidence that you are proceeding in the right direction during the project;
- You should co-ordinate the activities of the parties involved in a project towards the agreed goals;
- You should plan out how you are going to carry out a project.

But SE offers more than just common sense. It provides proven methods and tools for putting these principles into practice.

That, of course, is the nature of engineering. People can successfully build wooden shacks armed with an intuitive understanding of properties of materials and forces on the structure plus a bit of experience. But they are not doing civil engineering. Engineering implies the practical application of theoretical principles and the design of larger and more complex structures requires engineering.

A move from common sense to SE replaces informal textual statements of requirements with structured databases, rigorously checked against defined criteria, and replaces guesses about reliability and performance with justified estimates based upon computer models and simulations. Importantly, though, the introduction of SE also brings the engineering judgement about when to use these tools and when less formal methods are sufficient.

SE also provides a methodology – a logical framework within which SE methods can be deployed. For example, one widely-used SE standard, ISO/IEC 51288 [2] structures its guidance under the heading of the processes depicted in Figure 2.

Adopting an SE methodology helps to ensure that best practice is followed, that resources are deployed effectively and that good work is not undermined by localised omissions and weaknesses.

Figure 2 – An SE standard such as IEC/ISO 15288 provides a framework for SE.
Figure 3 – The promise of ‘left-shift’ is that investment early in a project will deliver savings later.
Top and above, Figure 4 – Suspending Zürich’s tram route 11 and the Forchbahn is simply not acceptable, even for a complete track renewal.

But this does not mean that railway SE should be something apart, cut off from the reservoir of skills and experience accumulated by other industries. That would be a careless and unnecessary loss because the fundamental concerns faced by rail projects are more often the same as those faced by projects in SE’s traditional sectors than different.

It would be an expensive mistake too. Research by Flyvbjerg [3] finds an average cost escalation of 44.7% from a study of 58 railway projects. Another study, funded by the European Union, of large infrastructure projects [4] reports cost escalations of a similar magnitude across transport projects in several countries. The authors remark:

“The NETLIPSE research shows that the origin of reasons for cost overrun and time delay can more often be found in the planning rather than the construction phase. We noticed repeatedly, that the technical, environmental and engineering or construction requirements and scope have been ill-defined at the initial stages of a project and publicly stated cost estimates have been given, based in these uncertain principles.”

These remarks suggest that SE methods, with their focus on requirements and definition, have the potential to mitigate these cost escalations. Conventional SE offers effective techniques for tackling these concerns and rail projects are accumulating a successful track record of applying them with minor adaptations.

When importing conventional SE practices developed in other sectors, we recommend adjusting them for rail projects where necessary, but only where necessary.

**Five realities of railway SE**

Having disposed of seven myths of railway SE, we offer some realities to take their place. Because our seven myths included two pairs where reality lies in the middle, there are five of these:

1. SE may be thought of as “the business of getting the parts of the railway to work together to do what we want them to”.
2. There are different views on precisely what SE is, which is distracting and inconvenient, but there is enough agreement to work with.
3. SE provides proven and well-grounded methods and to put some common sense ideas into practice and a framework within which to apply them.
4. SE overlaps existing rail engineering practice but goes beyond it.
5. Rail projects should be prepared to adapt conventional SE approaches but only where there is a good reason to deviate from established proven methods.

As we have corrected the myths, we have observed that SE offers a reservoir of good practices that have been proven in other sectors to address issues that are problematic for rail projects, including getting the requirements right, managing interfaces and avoiding disappointments with the performance of the finished railway. We have noted that the railway sector is accumulating an increasing amount of experience in adapting these practices and applying them successfully. We conclude that these practices offer effective and applicable weapons in the struggle to deliver high-quality railway systems at reasonable cost.

**References**


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The future of Signal Post Telephones — an engineer’s view
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This paper presents some personal views and thinking about the future of Signal Post Telephones on metro railways and if they offer any technical or operational benefit to the safety of any UK railway in the future. The paper has been written with the intent of opening the debate to the wider railway industry.

Background
In my career I have often been asked by Senior Managers and others why we still need to provide Signal Post Telephones (SPTs), when we have perfectly adequate radio systems. However, SPTs pre-date the deployment of secure radio systems and are now increasingly being seen as a back-up for radio. So are they right, do we really need Signal Post Telephones as a primary form of communications or even as a back-up, who is really driving the need for them; Operators, Sponsors, Trade Unions, Regulators? Are we not just clinging on to the past by retaining them?

System Operation
Signal Post Telephone systems are provided in conjunction with Signalling schemes on the railway. SPT handsets are typically provided at signals in a controlled signalling area to provide voice communication between the signaller responsible for the area and the train operator or driver. Typically this communication path has been used to request authority to pass signals set at danger.

Historically, SPTs communicated with the local controlling signal cabins or, in some locations, with the nearest station platform. On some metro railways, systems of this type are still in use on lines where the signalling has not recently been modernised.

In modern installations, where these systems are still in use or required, it is now common practice for provision to be made for the control centre operators, either Line based in the case of Metros or Region based in the case of Main Line Railways, to make and receive calls to individual SPTs within the signalling area they are controlling.

History
There has been a variety of different SPT systems installed over the years, ranging from traditional telephone concentrators with key and lamp panels in signal boxes and at stations, to PABX exchanges using transmission networks and touchscreens in Control Centres. The reason for this variance is in most cases due to re-signalling works where signal cabins have been condensed in to larger control centres.

The SPT has typically been a standard handset without a dial pad, where the handset is lifted from the cradle to initiate a call to the operator in the control centre or the signaller in the signal cabin.

It's not uncommon on some Metros to see more than one Signal Post Telephone handset at a signal, there are some locations where three or more handsets are installed; 2 on a tall post for access at cab level for different rolling stock types and an extra handset 5-10m beyond the signal at track level in case of a SPAD (Signal Past at Danger) or for trackside staff to use. However the provision of handsets for an operator to access without leaving the cab hasn’t always been successful due to stopping accuracy, short handset cords and the need to get them at exactly the right height.

On some of the older Metros in deep tube tunnels where space is at a premium it is often difficult to locate the SPT handset, which means they are installed in a compromised location where they are either difficult to operate and/or maintain. A similar problem exists on the mainline where SPTs have to be installed in limited clearance (unsafe) areas, which again are difficult to maintain and in most cases shouldn’t really be used.

In recent years we have also seen ‘Come to Telephone’ illuminated signs deployed on some Metros, which enable the train operator to see when the wayside SPT is ringing. This is particularly useful in tunnels and noisy areas where it can be difficult to hear the handset ringing. These ‘Come to Telephone’ signs have been deployed with varying degrees of success, some using LED lights driven from the ringing circuit and others using a 110 volt beacon triggered by a relay on the ringing circuit, the latter being the less successful due to the additional cabling and power supplies needed.

In addition to the ‘Come to Telephone’ lights there has also been an increasing need to undertake significant enabling works as part of the SPT handset installation, e.g. for walkways and
to provide a place of safety for the operators and maintainers accessing the Signal Post Telephone.

All of the above has led to a significant increase in the cost of deploying SPT systems, which has in itself led to questions as to why they are needed and the real benefit versus the cost of providing them.

**Tunnel Telephone**

London Underground also has a Tunnel Telephone system (TT) now commonly referred to as the Emergency Traction Current Discharge System (ETCDS), which uses a mixture of telephones and plungerats at stations and a pair of bare wires through each tunnel section. When operated, and in the case of the wires, shorted together, this causes the traction current to be discharged. A secondary feature of the system is that a telephone could be clipped onto the bare wires to create a speech path to the controller.

It was often suggested that this system could be used as a back up to the radio and SPT systems, given it is continuous through the tunnels. However, whilst this is technically correct it does mean the traction current needs to be discharged first to create the voice channel and it cannot provide confirmation of the exact location of the train, only the tunnel section the train is in. The system also has a poor reliability and availability record due to faults with the bare wires and is also only installed in Tunnel locations.

In the longer term London Underground aspires to replace the ETCDS with a more modern Power SCADA system and possibly eliminate the voice element, using the Secure Radio System as a means of communication to the controller instead.

**Secure Radio Systems**

In the late 1990s both Network Rail (then Railtrack) and London Underground initiated projects to replace their legacy radio systems with new secure digital systems, Network Rail choosing GSM-R to replace the National Radio Network (NRN) and in the longer term Cab Secure Radio (CSR) and London Underground choosing TETRA. Putting aside the legal obligations to provide secure radio systems, there were many benefits to deploying them, the primary one being the continuous secure communication between train operator and controller. However, a secondary benefit was that fixed telephones at the signals may not be needed any more.

One clear advantage of a radio system over a SPT system is the ability to broadcast to many train operators and avoid all train operators calling in at once asking for updates with the SPT control panel lighting up like a Christmas tree.

It’s important to note that at the time of writing this paper, GSM-R was still not demonstrating as high a level of reliability as was originally anticipated.

**Transmission links and architecture**

As described above traditional SPT systems were connected back to a local station or signal box, so in most cases they used direct copper wiring, but as control has centralised there has been a need to use transmission links because of the increased distances. This has involved either dedicated and bespoke systems being installed or the use of a railway owned or third party transmission network link for each SPT or group of Signal Post Telephones.

Some infrastructure operators have flirted with distributed concentrators or Private Automatic Branch exchanges (PABX) to reduce the local copper cabling and provide more diversity in the system. However this has increased the number of assets, rooms and locations that need to be supported and maintained. In recent years Network Rail has deployed a Voice over IP Signal Post Telephone system on the Edinburgh to Glasgow re-signalling project.

It is also understood that Network Rail Digital Railway Programme’s aspiration is to provide a Traffic Management Unified Voice Platform, presenting both the lineside telephony and GSM-R calls to the signaller on a single terminal (the GSM-R Terminal), whilst also providing back up facilities for the lineside telephony should the Terminal fail.

**Safety Integrity Level**

There is much debate in the industry as to whether SPTs should or shouldn’t have a Safety Integrity Level (SIL) level and what it should be. However, where a reliable, redundant and secure radio system is provided then in most cases no SIL level is required, on the basis that they have no special safety requirements.

This is of course open to debate and in some cases Telecoms and Safety engineers have been overly cautious and have recommended a SIL rating of 1 or higher, which itself has led to complexity and difficulty in achieving the required assurances with ‘commercial off the shelf’ (COTS) products.

**Operation and maintenance**

Where secure radio systems are provided, the need to use SPTs, has significantly reduced, almost to zero or only ever when the radio system has failed. Coupled with the inconvenience, safety risk and disruption to service for the operator alighting from the train to the wayside further suggests that elimination should be considered. It is also worth noting that most if not all the calls made from many Signal Post Telephone handsets were made by the maintainer testing the line.

Another reason why they have become less used is the architecture of some of the systems and the location of the equipment, especially the control panel. As mentioned earlier, these systems didn’t always connect back to the signaller controlling that area, particularly in Metro applications. In some cases the Signal Post Telephones were routed to station platforms and or line controllers or regulators, who would then relay messages to the signaller for that area. However in some extreme cases this would require another telephone call to the signaller in a physically different location.

With little or no operational use, faults on these SPT systems can go undetected between planned maintenance checks, so when they are really needed in anger they simply don’t work. Whilst intelligent monitoring systems are now commercially available, they are often expensive and can’t replicate the physical operation of the handset or perform an adequate audible test.

**Cessation**

In 2010 London Underground ceased the use of Signal Post Telephones on the basis that more reliable communication could be achieved by the Connect TETRA Secure Radio system, which was already being used “for the passing of Safety Critical messages”.

This argument was further strengthened by London Underground’s continued rollout of Communications-Based Train Control (CBTC) signalling systems, which by their nature have very few wayside signals. A secondary benefit and one that shouldn’t be over looked is the additional safety benefit that the train operator is no longer required to alight from train to access the Signal Post Telephone wayside.
Network Rail continues to provide and renew Signal Post Telephone systems. In recent years major re-signalling programmes have challenged the requirement by applying GO/GN3677 (Guidance on operational criteria for the provision of Lineside Telephony following the introduction of GSM-R) and using the Fixed Lineside Telephony Assessment Tool (FLAT) to only provide SPTs at critical locations. However, it appears that this process has had very limited success so far.

In the future, could and should Network Rail follow London Underground and cease the use of Signal Post Telephones or will they always be required as a back up to the radio system? What exactly is stopping the cessation of SPTs? Is it just confidence in the GSM-R system’s reliability as mentioned earlier or is it the complexity and fragmented nature of the UK Rail industry that is preventing proper consultation and progress? How reliable does GSM-R need to be before the provision of SPTs could cease?

In the same way that CBTC removed wayside signals on the upgraded London Underground lines, ETCS deployment will ultimately do the same for Network Rail; could this further strengthen the argument?

To help progress this technically could a joint working group between London Underground and Network Rail Telecoms and Operations teams be set up to share experiences and lessons learned?

**Interoperation and mixed running**

As noted above, London Underground has ceased the use of Signal Post Telephones. However, on the Metropolitan Line between Harrow-on-the-Hill and Amersham there is dual running of Chiltern Railways and London Underground trains and whilst SPTs aren’t required for London Underground operation, they are still required for Chiltern Trains.

As part of London Underground’s upgrade of the Sub-Surface Railway (Metropolitan, District, Circle and Hammersmith & City Lines) a review of the requirement to provide SPTs is ongoing, with a view to either significantly reducing the quantity of by applying GO/GN3677 or not providing any Signal Post Telephones at all. The question has to be asked; why is it ok for London Underground but not for Chiltern Trains?

**Other uses of the system**

If the SPT system was made redundant what else could the local loop copper cabling and handset be used for? I previously worked on an idea of a virtual Signal Post Telephone using spot radio technology, but it always sounded like another CSR/GSM-R system. However if the Signal Post Telephone handset box was converted or replaced by a WiFi hot spot router, then you could use it for private or public WiFi and if you wanted you could use the connection to create a Virtual SPT connection with a mobile phone or other device, as a backup to the secure radio?

**Conclusion and final thoughts**

If Signal Post Telephones are no longer a mandatory requirement and there isn’t a specific operational need, then it’s my opinion that SPTs shouldn’t be provided as part of re-signalling schemes and serious consideration should be given to ceasing their use where they are provided today.

The secure radio systems that have been implemented over the last TEN years were provided with the long term intent of replacing Signal Post Telephone systems, so why should we continue to provide SPTs just because we always have done.

Important to note the hierarchy of operation: Signal Post Telephones are primarily a fail-back for use in signalling system failure conditions’ radio is often, now, the primary fall back, with SPTs as secondary fall back, so technically they are now a back up of a backup system?

I would also like to turn the argument on its head and say that Signal Post Telephones aren’t required, unless there is good operational reason to provide them, but is anyone in the industry empowered and brave enough to make that call or would it require complex and lengthy consultation which could result in no action being taken and we will forever provide Signal Post Telephones.

The cost of deploying these systems, including all the enabling works, should now be a major part of the decision as to whether they are provided, as should the expected level of use and the level of maintenance effort required to ensure these systems are available and working when the need arises.

Finally couldn’t Signal Post Telephones be something that is only provided on Heritage Railways, to show something we used to have before we had radio systems?
ETCS AND EXISTING INTERLOCKINGS

ETCS level 2 meets existing interlockings – a challenge?

Written on behalf of the ITC by Rod Muttram and Beat Keller

Many lines worldwide would benefit from the adoption of technology including ETCS, but have relay interlockings that are not life-expired, such as the examples in Poland pictured above. The IRSE International Technical Committee has investigated current approaches to interfacing ETCS level 2 to existing interlockings. Rod Muttram and Beat Keller explain the ITC’s findings.

Background

There are a wide variety of interlocking systems in use in railway networks worldwide. The system found on any particular route depends on a number of factors, often representing the most commonly used technology (of that particular era) at the time of installation or of the last renewal (mechanical, electro-mechanical, relay based, electronic), but also influenced by local standards, overall system architecture, local resource availability (and its technical maturity) and the peripheral systems to which the interlocking interfaces. The key issue is that many non-Computer Based Interlockings (non-CBIs) remain in service, often with a long remaining service life. Indeed there are examples of quite recently constructed relay based interlockings such as Zwolle in the Netherlands and even very large scale installations such as Delhi Central Station in India.

ERTMS/ETCS is today’s most accepted standard for ‘heavy rail’ train control systems/ATP, mandated by Directives within the European Union for all new mainline railway routes and for most existing routes when renewed or upgraded.

More and more countries and railway companies are, or are considering, introducing ETCS for at least some railway routes. Countries such as Denmark, Norway and Switzerland are committed/committing to national network roll out. Key freight routes or ‘corridors’ of the Trans European Network (TEN) are or are being fitted with ETCS to facilitate the free movement of freight traffic without the need for changing locos and/or train crews at borders.

Most readers will be familiar with the three ETCS Levels or architectures. Level 1 relies entirely on local (and therefore intermittent) communication between the signalling system and the train with all calculations regarding safe movement of the train done in the on-board EVC (European Vital Computer). The problem with Level 1 is that it can be expensive to implement, particularly if local headway/capacity is to be maintained which may require a lot of local ‘infill’ communications. In the case of ETCS Level 2 or 3, a Radio Block Centre (RBC) is used which continually monitors train movements over a wider area and passes safe movement authority information to the trains via the GSM-R radio. To do that the RBC has to be interfaced to the interlocking system, be that new or old. In general, suppliers have favoured connecting to CBIs which come from the same technology generation as the RBCs and are therefore easier to interface. Where other technology interlockings are present in a route to be ETCS fitted, it is usually recommended to renew them with a modern CBI but Infrastructure Managers (IMs) are sometimes reluctant to do that particularly if limited renewal funds are available. Renewing an asset which still has many years of residual life is, to say the least, undesirable and certainly does not sit comfortably with a whole life cost asset management philosophy, possibly requiring a write-off of the book value of the existing asset. There has therefore been a lot of pressure from IMs on the suppliers to provide the ability to overlay ETCS Level 2 onto relay interlockings in particular.

Note that this paper will make no further reference to Level 3; the principal objective of that architecture is to eliminate most lineside infrastructure so implementation as an overlay makes no sense. Also, the Level 3 architecture relies on train position information being tracked by the train borne equipment and reported back to the interlocking via the RBC, thus requiring bi-directional communication which is not readily available with a non-CBI.

Sufficient projects have now been completed by different suppliers to be able to state quite clearly and categorically that ETCS Level 2 over relay interlockings is not only feasible but is also proven. However, the use of what is, in effect, mixed technology generations does have some drawbacks and limitations and this paper attempts to set out some general guidance of the “do’s & don’ts” in implementing such schemes.

Introduction

To become more competitive compared to road transport is a big challenge for railways. Because of the long history of national railway companies, with different operational rules and technical solutions, the railway sector is still far away from having a standardised railway system within a whole region, e.g. Europe, South-East Asia etc.

It is clear that if a standardised railway signalling system and operational rules could be achieved, a lot of operating cost could be saved. Further, transit times for international freight would be significantly reduced making rail more competitive with road in both cost and journey time terms. However, it is also very clear that the complete implementation of such a new system to existing railway networks would be extremely costly and complex and require a very long implementation time. The initiative to bring ‘interoperability’ to Europe’s railways is already more than two decades old but is still many years from being completed. ETCS is a big step towards such a standardisation and for new build high speed lines has been widely adopted in places as far apart as Spain and China.

In the early days of writing the ERTMS/ETCS Specifications a debate took place on how comprehensive the standardisation should be: standardisation of the air gap between train and infrastructure only, additional standardisation of the interfaces between major components of the train control system and full standardisation to a common technology solution. These were respectively known as the ‘Black box’, ‘Grey box’ and ‘White box’
solutions. The railways favoured the Grey or White box solution which they saw as more favourable to opening up competition in the spares and re-supply market; Industry favoured Black box as they did not want to have to re-train all their staff and saw themselves as competing on technical excellence, not just cost. Many saw the black box case as quicker to implement.

The European Commission chose ‘black box’ (given that the specifications are really only just becoming mature more than 20 years later, it is tempting to speculate how long it might have taken if ‘grey box’ or ‘white box’ had been chosen). As a consequence, for ETCS Level 2, the interface between RBC and any interlocking system is not standardised.

Because of the wide range of existing and disparate interlocking solutions a standardisation of the RBC/interlocking interface would (anyway) have been very difficult for existing interlockings; the solution has often been to replace all, or at least most, of the existing interlocking systems with new electronic types capable of more readily interfacing to an RBC. This can raise difficult economic questions particularly where the existing interlocking assets still have a long predicted life perhaps with a high ‘book value’ which would need to be written off. Another potential downside of standardising the RBC to CBI interface is that this would also tend to fix the partitioning of functions between RBC and CBI which might make it more difficult to interface RCks to older generation interlockings (both CBI and non-CBI).

Further difficulties can also arise within some Infrastructure Managers or within integrated railways where responsibility for the wayside part of train protection such as ETCS and for Interlockings falls to different entities or departments. Careful coordination and alignment of all involved entities is needed.

Railway companies introducing ETCS Level 2 onto their network must therefore decide whether to replace some or all of the existing interlocking systems or to invest in complex and invasive adaptations to existing interlocking systems to achieve the interface to the RBC. This question was discussed generally (and more specifically for Finland) by Laura Järvinen’s IRSE Aspect 2012 paper in London on 11 September 2012.

The same subject is picked up in this article with an emphasis on lessons learned from projects executed to date.

Interfacing between interlocking systems and an RBC

Existing electronic interlockings - ‘ETCS L2 ready’

Most up-to-date electronic interlocking types can be considered ETCS Level 2 interface ready. Most of the major manufacturers have systems running between their own platforms and as far back as the Olten-Luzern L2 pilot line in the late 1990’s/early 2000’s a RBC from one manufacturer was interfaced to an electronic interlocking from another.

For electronic interlocking types, a number of proprietary protocols exist for the ‘communication layer’ interface between RBC and interlocking. Siemens, Thales and some other suppliers use a protocol called RaSTA (formerly known as SAHARA) which DB Netz and its suppliers would like to evolve and promote as a standard. Bombardier has a detailed specification based on Subset-98 (which was originally developed for RBC/RBC communication and has also been used by Alstom and Ansaldo/Hitachi) for the interface between its current RBC and CBI both of which run on its largely COTS (commercial off the shelf) based generic safety platform.

Normally, some requirements for the communication between interlocking and RBC still have to be defined for a particular project/installation based on additions/modifications to the chosen protocol, with this having to be realised in both subsystems and, of course, tested together in detail.

Existing interlocking – ‘not ETCS L2 ready’

Many older electronic interlockings, nearly all relay interlockings and probably all electro-mechanical or mechanical interlocking types are not ready for ETCS L2, i.e. to interface to an RBC. Most will not have a communications bus of any kind to allow communication with other systems, although control of relay interlockings from centralised locations has been practised for many years using several proprietary communications systems for commanding routes and bringing back indications. These are rarely suitable for RBC communications either in terms of message format, or safety integrity.

So, where an existing relay interlocking needs to remain in operation for economic reasons, it must be modified or upgraded to be able to interact with the RBC. Since the status of relay interlockings can be read but their logic is essentially ‘hardwired’ and cannot be remotely modified it follows that without significant changes the interaction will be uni-directional, viz only from interlocking to RBC.

Siemens and Bombardier have found the simplest solution is to use an intermediate vital computer as a gateway to pick up information from the relay interlocking and translate that into a form more suitable for communication with an RBC. ADIF has adopted a similar approach for its suburban lines in Spain equipped with ETCS. The authors believe that this is always likely to be more cost effective than attempting to interface the RBC directly using any kind of hardwired electronics. This does not mean that some other additional hardware can be avoided, particularly if there is a shortage of spare contacts within the interlocking; and the introduction of additional repeaters or different relays presents additional issues with respect to re-testing.

On the E30 project in Poland Bombardier has used its EBILock R4 CBI platform for this intermediate computer at Wegliniec and Legnica stations – developing a detailed specification for the CBI/Relay interlocking interface. The advantage of this approach is that the RBC sees this as an interface identical to any other CBI, but possibly with some reduced functionality. Effectively the relay interlocking becomes an internal sub-system of the interfacing CBI/vital computer. The high-level block diagram for Bombardier’s Polish implementation is shown below.

High level block diagram for Bombardier’s implementation of ETCS technology on the E30 project.
ETCS AND EXISTING INTERLOCKINGS

Based on the experience to date in providing ETCS L2 over relay interlockings the following guidance can be offered:

- Within many railways the documentation related to signalling assets is not always 100% accurate; particularly where large projects were implemented in phases or where later modification schemes have been done. This can lead to additional and perhaps initially unexpected, costs for correlation and/or re-work after what must be very well structured and comprehensive testing.

- Since communication is uni-directional it follows that any ETCS function requiring bi-directional communication cannot be offered. Great care must therefore be taken in developing project specifications to ensure the client understands the limitations otherwise expensive re-work or derogations will result.

- It follows from the above that overlaying relatively simple layouts and operational requirements will be quite feasible but as layouts become more complex difficulties will be encountered unless the number and complexity of routing options are restricted. Since the boundary between ‘non-complex’ and ‘complex’ is not always clear cut, this again reinforces the necessity for detailed work at the specification/conceptual design stage.

- With uni-directional communication from interlocking to RBC and the latencies involved in the extra layers of hardware and software, the performance improvement normally possible with ETCS Level 2 cannot always be delivered and performance is more likely akin to a Level 1 system.

- Where redundant systems are used for any part of the implementation (2oo3) or particularly 2 X (2oo2) a reliability analysis of the full system configuration for all modes should be conducted to ensure that redundancy switching will not adversely affect traffic operation. This is to ensure that timing differences between the redundant systems and the specific handling of the RBC/CBI interface do not cause information to become lost or corrupted.

Often it is not just infrastructure such as interlockings which poses a challenge when overlaying ETCS. Existing rolling stock needs to have on board equipment and relevant driver machine interfaces fitted - often within a very constrained and electrically noisy environment.

Left, Bombardier EBICab 2000 ETCS on-board DMI retro-fitted into Polish rolling stock. Above, one of the fitted locomotives leaves Wegliniec station.

All photographs courtesy of Bombardier RCS.

Whole Area Renewals

Where whole areas are being renewed such as in Denmark’s re-signalling ‘Mega project’ it makes clear sense for all interlockings to be renewed, not only from an ETCS interface perspective but also for reasons of logistics, software and hardware maintenance and spares holding. The challenges with such mega projects will be determining the stage works, commissioning, cut over (and most likely an ‘over and back’) strategy and implementation that allows the introduction of ETCS L2 operation without significant disruption to on-going services.

Putting ETCS Level 2 into operation, commissioning

Validation Strategy and practice

To reach the status of a completely tested interface from interlocking to RBC is one thing. To reach the status of completely satisfying the specified ETCS L2 operational requirements and gaining full safety approval is a much larger step which should not be underestimated. Converting an older interlocking of any type can be challenging for the safety approval process, even if part retains ‘grandfather rights’ a costly safety case may be needed for the interface and if the modifications concerned are too extensive with regards to functionality or contribution to system level safety integrity then a full safety analysis may be required with all of the costs and risks that brings.

Before starting the rollout of any specific ETCS L2 configuration over a railway network extensive laboratory simulation followed by trial operation over a limited area on a representative route is highly recommended. The duration of trial operation will depend on a number of factors including complexity and the extent of the follow-on implementations planned, but up to one year is not out of the question. During the trial phase, some adjustments will be necessary (e.g. on the interface between interlocking and RBC). Experience tells us that the trial phase will have several iterations both technically and operationally and will allow a growth in confidence in the safety and reliability of the combined system architecture.
Task sharing

Both RBC and interlocking system contain static information about track layout and track elements. The functions of each are (generally):

- **Interlocking system**
  - Controlled by Centralised Traffic Control (CTC) and/or local control system;
  - Setting and releasing of train routes;
  - Proving the track is vacant (detection of track occupation) via track circuits/axle counters;
  - Controlling of outside elements and systems, such as signal lamps, point machines, level crossing systems etc;
  - Avoiding dangerous situations for train pathing, namely head-on collision, slanting collision and collisions with parked rolling stock.

- **RBC**
  - Calculates movement authority;
  - Transmits movement authority to the train by radio;
  - Reacts on hazardous situations by withdrawing authorisations.

This task sharing can lead to synchronisation problems, because both static and dynamic data and even some operational functions may be available (and in some cases must be available) in both systems. This is not without some safety risks and a clear functional split and careful verification and validation is essential.

Signal aspects displayed at ETCS Level 2 boundaries must be carefully coordinated/integrated by technical measures with the aspects of neighbouring signals (which may be controlled by another interlocking) as must the release speeds transmitted by the RBC.

Interlocking system sends data to RBC

For calculation of the movement authority, the RBC needs dynamic inputs, which are only available from the interlocking system as vital information, namely:

- The route is geographically clearly defined (starting and ending position, plus all relevant intermediate positions within the route);
- Route is safe (set and locked);
- Type of movement allowed on the route is defined (‘fully supervised’, ‘drive-on-sight’ or ‘shunting’);
- Unexpected switching of signal aspects of the route to red (or a change in route status leading to the same thing) initiated by the interlocking system in emergency situations.

Additional data transmission from interlocking system to RBC is possible (depending on national or local standards or requirements), but not absolutely necessary.

Whatever data is required will need spare contacts in the relay interlocking or the addition of repeater relays or different relays with more contacts, to provide the outputs to the RBC interface system. If repeaters or relay types with more contacts are added then fail safe design principles must be applied to these changes (to ensure that the new interface has no negative impact on existing relay interlocking functions), and it must be assured that the outputs to the RBC always fully correspond to the correct state of the interlocking (bearing in mind some of the timing and noise issues mentioned below). The relay interlocking will require revalidation/retesting for the functions or connections potentially impacted by the new interface. This may be a significant task, particularly if the original interlocking design information is no longer available or is not in a modern/suitable form.

For Legnica and Wegliniec stations on the Polish E30 project, this involved Bombardier in full testing with an NX (entry/exit) panel to:

- Test the correct functioning of circa 600 outputs from spare contacts and repeater relays.
- Validate the mapping of the individual relays to the individual inputs of the RBC interface system. The state of all relays affected by the new interface was changed using the NX panel and all signal aspects were exercised and points swung.
- Testing of software (conventional level interlocking logic used for the CBI/Relay interlocking interface). During this stage Bombardier tested that all states of the input information were processed in the correct way i.e. whether actual status of interfaced objects on the station was properly reflected in the system.
- Testing of ETCS functions: In this stage balise linking tests, moving train tests and degraded status tests were conducted to confirm and validate the results of off-line (laboratory/factory) tests.

This all required a lot of test time and resources; significantly more than would normally be the case with a Bombardier CBI where formal methods and automatic testing are extensively used.

For the Polish E30 project, Bombardier were involved in full testing of an existing NX panel to verify correct operation with ETCS.

In the same project, a monitoring tool was used to compare the status of relays and CBI states during testing.
RBC sending data to the interlocking system

The interface between RBC and interlocking system can be:

- unidirectional, if data is transmitted only from the interlocking system to the RBC;
- bidirectional, if data is transmitted in both directions.

In the Siemens Nordbahn project in Austria, and Bombardier’s Legnica and Wegliniec stations on the Polish E30 line, the RBC is interfaced with existing relay interlocking systems in a unidirectional approach, with some reduced functionality compared to that which could be provided with a bidirectional solution.

Depending on national or local standards, and/or depending on technical or operational requirements (e.g. to provide for a higher capacity of trains), bidirectional data transmission is necessary which really requires replacing the existing interlocking infrastructure with a CBI.

This balance between operational performance, first cost of renewal and the whole life cost of the specific area is fundamental to the determination of the business case for the particular scope and size of the project. Another IRSE ITC paper providing guidelines on the preparation of ETCS business cases is planned in the near future.

Other Lessons learned to date

ETCS equipment and Interlockings usually have similar quality and availability requirements for their power supplies, so the tendency will be to power both from the same power source (usually an uninterruptable power supply, UPS). However, SBB experience shows that 1/3 of all Interlocking power supplies are already overloaded and thus not able to feed additional ETCS equipment (especially in the test and commissioning phase, where the power supply may need to simultaneously feed both a class B [legacy] system and ETCS). Great care should therefore be taken to check total loading under all conditions in order to prevent overloading and potential outages.

Also some railways (c.f. SBB) have many interlockings still in operation using earthing concepts not acceptable today. This introduces an additional risk that the earthing and bonding concept must also be updated which is potentially very costly. Thus great care should be taken not to produce a system design that risks such a major earthing and bonding upgrade being required and the potential cost of this should be included in any risk assessment of the alternative solutions.

As stated above, the unidirectional interface involved in overlaying relay interlockings only provides information to the RBC about the state of relay contacts.

The biggest problem seen by Bombardier in the E30 project involved some specific functions of the relay interlocking systems. A particular problem was with automatic release of the train route. In the relay interlocking system the train route is released when the train has moved over the last set of points in the route without going to the end of the signal section. Thus when the train cleared the last set of points the interface informed the RBC that the route was released and therefore the RBC withdrew the authorisation for the train which was consequently tripped (i.e. braked to a stand) as it was still moving towards the end of the route. For this issue to be resolved without having to change the RBC, it was necessary to implement a timer (similar to that used for end-of-route release in a CBI) to sustain the route release information to the RBC.

Another issue was temporary track circuit occupancy not caused by a train, i.e. track ‘bobs’ or short term transients not uncommon in relay circuits. This situation would cause the route to be indicated as Degraded and the RBC to withdraw any authorisation given to enter this route.

Similarly, transient ‘out of control’ situations for some relay contact chains caused by switching time differences between relays can also generate a degraded status to be indicated to the RBC.

A general lesson learned is that the system which works as the interface between the relay interlocking system and RBC has to be as flexible as possible within safety limits and it should have suitable time delays in input circuits because relays are ‘noisy’ and produce short term transient errors that need to be filtered out. The times for these ‘filters’ need to be chosen carefully to preserve safe functioning when there are real operational issues. The Bombardier approach of making the relay interlocking effectively a sub-system of the CBI handles all these issues within the CBI so that the RBC/CBI interface is no different than for any other implementation. Regardless of the specific approach, the relay interlocking logic needs to be well maintained and serviced (i.e. needs to be in good condition) and all maintenance procedures will need to be reviewed to ensure there are no adverse effects on ETCS operation.

As with any complex system there is a need to assess all possible operational modes of the mixed technology implementation, including degraded modes, and develop robust operational processes and procedures to handle all the required operational scenarios.

Conclusion

Overlaying ETCS Level 2 onto non-CBI Interlockings is wholly possible and should now be considered as a proven approach.

However, the limitations of a unidirectional interface cannot be ignored. Specifications and contracts should be carefully developed taking that into account. The more complex the layout and the more demanding the operational requirements, the larger the test and validation burden becomes when compared to renewal with a CBI. The capital saving gained may become significantly eroded in considering a whole life cost business case. Any business case will also be dependent on how many installations any non-recurring costs of developing special interface units and producing safety arguments is spread across.

Siemens and Bombardier have both found the use of an intermediate safety critical computer to be the most efficient and effective way to facilitate the RBC/Interlocking interface.

Relay technology is robust, reliable and long lived but electrically ‘noisy’ and slow compared with electronic systems and appropriate ‘matching/filtering’ needs to be included in any interface.

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Cyber-attacks on both company and individual's computer systems are an increasing threat to the continuity of business and there is no chance that this menace will ever go away. There is no way of 'immunising' against the threat of attack, nor is there any fool proof method to prevent such attacks from causing harm to the data systems involved.

Cyber-crime takes many forms: at the bottom end is the 'nerd' in the bedroom who sees it as a challenge to hack into supposedly secure systems just to see if it can be done; at the top end are rogue states who attack computer systems to seriously harm (or even destroy) a country's infrastructure or military capability. Somewhere between these extremes are organisations that hack for espionage, commercial gain, activism or the uncovering of sensitive personal details. High profile law suits and public enquiries have made the headlines in recent times, with attention being focussed on the relevance / attractiveness of the target and the possible perpetrators. In the main, the bulk of cyber-crime is financially motivated.

For the rail industry, the threats are many and diverse, with implications for Network Rail, the TOCs/FOCs (train operating companies and freight operating companies), the supply industry and the data support providers. To be hacked is at best a nuisance and at worst a risk to safety. Many rail organisations have already experienced attacks so awareness of the threat is growing. Some firms are employing data security experts who advise on the precautions that should be taken. There is no single high-tech action that can be taken and protection measures follow a logical pattern. Other companies might still be in the situation of either believing that their products would be immune to hacking or that hopefully it will not happen to them. A significant risk exists within the emerging control and communication networks (i.e. signalling) and the SCADA system for electrification control, both of which will rely on the nationwide digital communication networks for the distribution and resilience of control data. Whilst enormous efforts are being made to safeguard the safety elements of these systems, cyber-attacks can take many forms. A denial of service attack where techniques such as basic encryption do not provide protection, would cause major disruption to train services.

So where is all this leading? A new European Directive has been agreed that will have implications for everyone and certainly lead to a focussing of minds.
The Directive is to become European law and would have been transposed into national law sometime in early 2018. Although it remains to be seen how the English wording of the legislation is written, it is anticipated that the expected compliance requirement will be balanced by a defence of having adopted adequate procedures to guard against cyber threat. It is going to happen and organisations should begin to prepare for it right now.

So what does it mean?

Some readers will have realised that the onus is being placed on the potential victims of cyber-crime rather than on the perpetrators. This may seem unfair but it is the only pragmatic solution if the menace is to be minimised. Already some regulated industries should be taking necessary action to remain compliant with their regulatory obligations. An example would be a business in the financial services sector, where a breach of the regulatory requirements that demand suitable security measures be taken, would likely trigger sanctions if the protection of data was found to be inadequate. The recent hacking of records within the telecommunications provider TalkTalk had to be reported because of telecom-specific data protection regulations.

The Directive is not intended to be draconian in its policing and Member States will be expected to adopt a proactive role in helping organisations comply. There is a realisation that one size cannot fit all. Small companies will not be expected to dramatically increase their expenditure on cyber security since this could well make them uncompetitive when the risk is likely to be small. For larger organisations it may be different and significant sanctions may result if a serious breach of data protection law occurs. All this is a bit scary but it is early days and providing industry guidance is adopted, then punitive action is unlikely.

Understanding the responsibilities

There continue to be many conferences and seminars on cyber-crime and how to combat it. Companies tend to fall into a number of categories as to their preparedness:

- Unaware – incidents just happen;
- Routine – controlled response to incidents should they happen;
- Planned Reactive - planned response to incidents if they occur;
- Elements of Proactive – some knowledge of what might happen in the future;
- Mainly Proactive – good resilience measures in place;
- Proactive – decisive actions based on fact will be implemented.

The more proactive a company is in this chain of measures, the less likely it will be for any penalties to be imposed. Having a cyber incident response plan in place will be key. Some basic ground rules have been in place for some time to minimise risk of attack and includes:

- Having in place effective firewalls;
- Education and knowledge of staff – beware of disgruntled employees and careless attention to data devices such as personal safeguarding of laptops;
- Control of passwords and access control sequences;
- Constant monitoring of technical data;
- Minimise open TCP / UDP ports;
- Robust behaviour for firmware updates;
- Penetration testing by experts to assess vulnerability.

In short, multiple levels of protection will be needed to both assess the risk and nature of any attack and to then devote time, thought, energy and money to prepare the business for the necessary action when the attack happens. This will include means to identify and neutralise the cause, mitigate and repair the damage so as to restore business but also to learn lessons from what happened so as to improve the protection for the next time. Advice for what constitutes ‘appropriate’ will always be on offer but remember that the situation is not static. The people engaged in hacking will for ever be trying to ‘beat the game’ and thus constant vigilance is necessary with associated updates to protection always being necessary.

One essence of the Directive will be the responsibility to report attacks. This is already in place in Germany, Austria and Norway but is only voluntary in the UK. A report will need to be made promptly. Once known, the Computer Emergency Response Team will then probe;

- Was there a serious breach of data protection law;
- Is substantial damage or distress likely;
- Was the contravention deliberate, whether the organisation was aware that damage or distress was likely and had reasonable steps been taken;
- Should a fine be imposed.

Awareness and actions for the rail industry

Most rail organisations are aware of cyber-crime and associated security. To what extent the true level of threat is understood is an unknown and probably rightly so, since high profile public statements and detail are inappropriate for this clandestine world. The UK government has defined 9 categories of essential infrastructure of which transport is one and communications is another. Rail is a major element of the first and has considerable impact in the second. The Centre for Protection of National Infrastructure (CPNI) studies and gives advice to all industries involved in the nine categories and is well aware of critical rail systems. Many such rail systems are not unique to the UK — ERTMS, ETCS and GSM-R being examples where European deployment is underway and thus a sharing of knowledge with other countries is important. It must also be recognised that the said systems cross the wheel rail divide thus involving both infrastructure providers and train operating companies.

The NIS Directive is known within the railway but it is suspected that a general lack of awareness will exist when ‘drilling down’ into the supply chain companies. The rail and transport operators may be attractive targets for hackers and thus a collective view, particularly on what constitutes ‘good practice’, is to be recommended. With the fragmented railway that exists in the UK this in itself is a challenge. There will be issues where IPR rights on proprietary infrastructure and rolling stock technology and products make firms reluctant to share information (a similar problem exists in the motor manufacturing industry) and thus makes collective decisions more difficult. The railway has safety critical systems that are increasingly data dependent and it may be that cyber security has to be linked to Safety Case certification. Every rail organisation should be asking:

- What can my company afford?
- What mitigation measures and actions are in place if attacked?
- Is there a cyber response plan in place?
- What penetration testing has been carried out and when was it last tried?
Current actions being taken by the UK rail industry

UK cross-industry rail groups are actively working on cyber security. Two are the High Integrity Systems Group (HISG) hosted by RSSB (formerly the Rail Safety and Standards Board), and the Digital Railway Cyber Security Steering Group (DRCSSG) hosted by the Digital Railway programme at Network Rail. HISG is investigating what the cyber risks are and DRCSSG is looking into cyber security for future systems. RSSB also facilitates provision of cyber security guidance from the Department for Transport.

To communicate the findings, RSSB has formed the Cyber Security Advisory Group (CSAG) that will advise on the development and content of the cyber security strategy. In particular, it will mitigate the risk of duplicative effort and facilitate management of interfaces. The development of the strategy will take into account the NIS Directive as appropriate. The strategy is intended to assist parties in the industry to understand their responsibilities and be able to put in place informed, proportionate and cost-effective measures to mitigate cyber security risk.

In summary

The requirement to report cyber-attacks may be easier for rail than other industries since it already has procedures in place to report accidents and near misses, this being a regulatory requirement. Extending this and educating staff to include cyber-crime could be an important early step. Whatever, there is no ‘silver bullet’ and advice from legal professionals on how to comply with the Directive related cyber legislation will be needed.

INDUSTRY NEWS

Bombardier certifies four LTE suppliers

[RGI] COMMUNICATIONS: Bombardier Transportation announced on 4 August that it has certified four telecoms companies that can supply 4G LTE technology to be used with its main line and metro train control systems.

A series of laboratory tests was carried out with Ericsson, Huawei, Nokia and ZTE at simulated speeds of up to 200 km/h. Bombardier’s Cityflo and Interflo signalling was tested, sharing LTE bandwidth with CCTV, passenger information and onboard internet services. In CBTC tests, uplink and downlink latencies of less than 100 milliseconds were achieved, with packet losses approaching zero.

Praha driverless metro design contract

[RGI] CZECH REPUBLIC: Metropojekt has been awarded a KC440 million (£14mn, €16.3mn, $18mn) contract to prepare a design study for the future driverless metro Line D in Praha.

The 10.6 km line with 10 stations would run from Náměstí Miru in the city centre to the southern suburb of Písnice via Pankrác and Krč. It is intended to relieve the congested Line C, and would run parallel to it for part of its route. Interchanges would be provided at Náměstí Miru with Line A and at Pankrác with Line C.

The initial 7.9 km section from Pankrác to Depo Písnice is scheduled to open in 2022-23, although construction could be delayed by problems with land acquisition.

Siemens awarded Port Talbot resignalling contract

[RGI] UK: Infrastructure manager Network Rail has awarded Siemens Rail Automation a contract for the detailed design, construction and commissioning of the Port Talbot West Phase 1 resignalling project in South Wales, which is scheduled for completion in October 2017.

The contract covers 153 Signalling Equivalent Units, and includes the replacement of life-expired relay interlockings with a Siemens Trackguard Westlock computer-based interlocking.

Control will be transferred from the existing NX panel at Port Talbot to a new Siemens Controlguide Westcad control desk at the Wales Rail Operating Centre in Cardiff. Track circuits will be replaced by axle-counters, and new and additional power supplies commissioned.

Paris metro live LTE test completed


The aim of the research project was to demonstrate the feasibility of using a single radio communication technology to deliver both safety-critical and non-safety-critical services on a metro network simultaneously. The test included a CBTC simulation based on pre-recorded real data, onboard and platform CCTV, operational voice communications with push-to-talk and group calls, onboard emergency passenger communications, the passenger information system, and onboard sensors that monitor performance to make maintenance recommendations.

The test marks the final stage of the €4.56 million (£3.9mn, $5mn) SYSTUF (Système télécoms pour le Transport Urbain du Futur) R&D project, part of a French government initiative to modernise municipal infrastructure through the introduction of new digital technology.

RATP defined the applications that must be supported by the network and determined what constraints are to be met to complete a convincing, secure and non-disruptive trial.

4G LTE technology was originally provided by Alcatel-Lucent, which subsequently merged with Nokia. In addition, the company provided project management and network optimisation. Alstom supplied communications-based train control, which includes a new LTE onboard mobile router.

Other partners in the project included Eurecom, the IFSTTAR consortium of research laboratories, Mitsubishi Electric and Telecom Bretagne. Simpulsa Railenium, SystemX and B-COM are technological research institutes associated with the project.
Taipei Circular Line driverless train unveiled

[Taiwan] Hitachi Rail Italy unveiled a prototype train for the Circular Line of the Taipei metro at its Reggio Calabria plant on 30 August.

Taipei’s Department of Rapid Transit Systems awarded a €334 million (£280 mn, $372 mn) turnkey contract for the first phase of the Circular Line in 2009 to a consortium of Ansaldo STS and AnsaldoBreda (now HRI). Ansaldo STS’s €220 mn (£185 mn, $246 mn) share of the contract covers the supply of electrical and mechanical equipment, including CBTC signalling.

The initial 15.5 km section of the route will serve Dapinglin in the south of the city to connect with the new airport express line to Taiwan Taoyuan International Airport Line at Wugu Industrial Park in the west. There will be 13 elevated stations, one underground station and a depot. Two further phases would extend the Circular Line to 52 km with 48 stations and three depots.

FRA awards $25m of PTC implementation grants

[USA] The Federal Railroad Administration (FRA) announced on August 16 the award of a total of $25m to 11 projects to assist with the implementation of Positive Train Control (PTC). The FRA received 30 eligible applications requesting a total of $90.6 million (£69mn, €80mn).

“These grants get us a bit closer to implementing Positive Train Control, a long overdue technology that prevents accidents and saves lives”, said Transportation Secretary Anthony Foxx. “We will continue to do everything in our power to help railroads install this technology. We encourage Congress to fully-fund the President’s request for significant funds to help more railroads activate PTC.”

Siemens signalling for Samsun line

[Turkey] Siemens announced on 10 August that it had won a contract to supply ETCS Level 1 signalling systems for the modernisation of the 380 km line from the Black Sea port of Samsun to the junction at Kalin near Sivas in central Anatolia.

Siemens is to supply its Trackguard Westrace electronic interlockings, points machines, level crossings and telecoms, and is to equip the operations control centre in Samsun.

Services on the route with 31 stations are currently suspended while TCDD undertakes a modernisation programme which will enable the maximum speed to be increased from 70 to 120 km/h and cut the journey time from 9 h to 5 h. Reopening is scheduled for the end of 2017.

We need your news

IRSE NEWS is always on the lookout for news articles, technical papers, reports on IRSE activities or your letters. If you have something to share please do send an email to any of the editorial team listed on p1.

Editorial deadlines for forthcoming issues are:

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<tr>
<td>November</td>
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Please remember to send ...

- articles in Microsoft Word or Rich Text Format;
- high quality photos welcome - typically JPEG in excess of 5MB, TIFF or RAW files;
- diagrams in their native format, typically MS Visio or Powerpoint, Adobe Illustrator.
News from the IRSE
Francis How

2016 IRSE Examination
At the beginning of October well over 200 candidates will be taking one or more modules of the IRSE's Annual Examination. We wish them success! Each paper will be marked by two markers, and the results announced in early 2017.

International Convention 2017
Save the dates between 25 and 29 September 2017 for the 2017 IRSE International Technical Convention, IRSECON17, to be held in the Dallas/Fort Worth area of Texas, USA. Planning is well under way for an exciting programme of technical papers and site visits for the delegates and of course a special programme for the guests, along with the traditional Convention events. Look out for more news in the coming months as the schedule is firmed up.

ASPECT 2017
ASPECT, the IRSE’s International Technical Conference will be taking place on 28-29 November 2017. For the first time, ASPECT will be held outside the UK, in the dazzling city state of Singapore, a world-leading centre of urban transport technology, and at the heart of one of the world’s most dynamic regions, Asia. Key conference themes are:
- Metro technologies;
- Professional development;
- Condition monitoring;
- High speed rail.
If you would like to present a paper at the conference on a topic relevant to the themes above, or the wider themes that characterise all ASPECT Conferences, look out for the Call for Papers, coming soon.

Bursaries will be available for younger members, and sponsorship and exhibition opportunities will be available for companies. Contact the Conference organisers via aspect@irse.org, and watch for announcements on the IRSE website at www.irse.org/aspect.

Second Presidential Programme Technical Paper
The second paper in our 2016-17 Presidential Programme series will be presented on Wednesday 9 November 2016 in London. The author is Jan Swier, Strategic Advisor, ProRail (Netherlands), and the subject is “Asset Management”. The venue is the Institution of Mechanical Engineers, 1 Birdcage Walk, London, UK.

Asset management is a key topic for railways, but people often have trouble in articulating what it is, how it is done and what is really new in the field. Cost reductions and performance improvement are promised but it is unclear how it is realized and what the results are. Jan Swier’s paper is a case study of the development of ProRail, the asset manager in Netherlands. It describes what ProRail considers as the essence of asset management, what the challenges are and what the most critical milestones were in its own development.

Mentors needed
Members will be aware that the IRSE operates a Mentoring Scheme to support people in career and professional development (see bit.ly/2cd45MN - you will need to log in). We have a number of IRSE members who are mentors, but we really need more – particularly from countries other than the UK. If you might be willing to offer your services to help others in this way, please contact Matt Slade via mentoring@irse.org.

Guidance on professional conduct and obligations
The UK’s Engineering Council, of which the IRSE is a licensed member, publishes a range of guidance material to support engineers and technicians in meeting their professional obligations. The most recent of these is on the subject of Security. Other topics covered are sustainability, risk, ethical principles and whistle-blowing. The complete set of guidance notes can be found on the Engineering Council website (see bit.ly/2ch3hGT).
Many people in the rail industry started their careers as apprentices, with some now occupying the most senior roles in the industry. In the UK over the last 20 years or so recruitment of apprentices has been erratic and apprenticeships have seen a lot of change — but we are now in the grip of what is probably some of the most fundamental and exciting changes for decades, and I thought readers would be interested to know more.

Please note that the changes to which I am referring in this article apply to England only — skills policy is devolved to individual parliaments and assemblies in the UK, so the approach in Scotland, Wales and Northern Ireland differs.

For many years apprenticeship ‘content’ has been set out in so called ‘frameworks’, and some of you may have come across these if you have supervised, assessed or been responsible for apprentices in the workplace. In late 2013 work started to progressively replace all these frameworks with employer-led apprenticeship standards. The main drivers were to:

• put employers at the heart of the standards development, to ensure that these new apprenticeships would deliver the skills and knowledge that employers really need;
• improve the quality of apprenticeships and;
• give employers more purchasing power when selecting delivery partners.

Over the last couple of years a significant amount of work has been undertaken by rail employers collaborating to develop new standards for rail occupations. This is far from complete but new standards are now available for:

• Rail Engineering Design Technician (Level 3) — launched September 2015;
• Rail Engineering Operative (Level 2) — available from September 2016;
• Rail Engineering Technician (Level 3) — available from September 2016;
• Rail Engineering Advanced Technician (Level 4) — available from April 2017.

All of the above apprenticeships are designed to provide a common rail engineering core, with individuals then able to choose a specialism in track, signal/telecomms engineering, electrification, rail systems or rolling stock. The core material is included in order to support transferability and flexibility. New qualifications are being developed and these will replace those previously offered. Assessment processes are also undergoing change and whilst there will still be work-based progress assessments there will also be something called an ‘End Point Assessment’ which will review all aspects of what the apprentice has learned during their apprenticeship.

Importantly, the new apprenticeships at Level 3 and 4 are fully mapped to the requirements of the ‘UK Spec’ for EngTech registration, so on completion of their apprenticeship the individual will be ‘EngTech ready’. The IRSE is working closely with those developing the new standards to ensure as much alignment as possible between the apprenticeship assessment and the corresponding IRSE Licence assessment(s), to remove any potential duplication and to streamline processes where possible.

In addition to the above changes, last year the UK Government also announced plans to reform how apprenticeships will be funded, indicating their intention to introduce an apprenticeship levy on all companies with a total salary bill over £3m per annum. The levy will apply across the whole of the UK. Employers paying a levy will be able to claim it back, together with a small government ‘top up payment’, to pay for their apprenticeships. This is due to come into force from April 2017 and companies are starting to look at how much levy they will have to pay and how they can make best use of it by running apprenticeships.

So, briefly, (and somewhat simplified!), those are the changes. With the UK rail industry committing to create 20,000 apprenticeships between now and 20201 there has perhaps never been a better time to either be an apprentice or to recruit one!

If you or your company is interested in finding out more about apprenticeships or wants to get involved in the development of apprenticeship standards, contact me at elaine.clark@irse.org and I will put you in touch with the relevant industry groups.

1 The Transport Infrastructure Skills Strategy launched in February 2016 has committed the industry to creating 20,000 apprenticeships between now and 2020.
On the morning of Saturday 16 April 2016, some 34 members and guests of the Minor Railways Section arrived at a sunny Whitby station, terminus of the Esk Valley line from Middlesbrough, in the county of North Yorkshire. This was in order to view the new signalling arrangements provided to allow the North Yorkshire Moors Railway (NYMR) to operate an improved train service from a new and dedicated platform 2 at the coastal town, over the national rail network to the heritage line at Grosmont and onto Pickering. The NYMR carries more passengers than any other heritage railway in the UK and may be the busiest steam heritage line in the world, carrying 355,000 passengers in 2010. The 18 mile (29 km) railway is the third-longest standard gauge heritage line in the United Kingdom.

Upon arrival at Whitby, members and guests were met by Craig Donald (NYMR S&T Maintenance Manager) and Charles Weightman (NYMR Signalling Design Engineer and Minor Railways Section committee member) and the group was split into three in order to view the site by rotation. Charles Weightman was responsible for briefing the signalling arrangements at Bog Hall sidings (just outside of Whitby station), where the point indicator is located for trains arriving into both platform 1 and 2. Platform 2 is accessed by the use of the main ground frame. This in turn releases the ground frame at the buffer stop end of the station to allow for locomotive run round. Craig Donald was responsible for briefing the signalling arrangements on platform 2, where the token machine for the section from Whitby to Glaisdale is located. This token machine is provided in series with the token machine also located on platform 1 and the section is supervised by Nunthorpe Signal Box near Middlesbrough (No Signalman Token Remote). An intermediate token instrument is provided at Grosmont and allows a token for the Whitby to Glaisdale section to be obtained or returned at Grosmont. The third site visit was the opportunity to receive refreshments at the station team room.

At lunchtime, members and guests were provided with a packed luncheon (produced by the NYMR) and boarded a service train from Platform 2 to Grosmont, hauled by Ex BR 2-6-0 Class K1 Locomotive No. 62005. As the train travelled through Ruswarp station, heavy rain began to fall, which remained with us for most of the afternoon. Upon arrival at Grosmont, the group was again split into three in order to view the site by rotation. Craig Donald was again on hand to explain the operation of the signalling interfaces between the NYMR and Network Rail at the far end of Grosmont station. This included the sequence of events in order to release/restore the key token from/to the intermediate token instrument and the operation of the Network Rail and NYMR No.1 and No.2 ground frames for train movements both on and off the Esk Valley line. Craig also discussed the background and details regarding the recovery of the Top, Whitby Station platforms 1 and 2. Middle, Whitby signalling layout. Above, Token instrument on platform 2 at Whitby. Photos Ian Allison.
signalling gantry from Scarborough Falsgrave signal box and how it was adjusted and restored for installation at the Grosmont.

Charles Weightman was again on hand to explain the operation of Grosmont Crossing Signal Box next to the station. The signal box itself was built and commissioned by the NYMR in the 1990’s using signalling equipment collected from all over the North East of England. Charles explained the sequence of events for train movements both on and off the Esk Valley line. The third site visit was a briefing/presentation in the nearby Crossing Club by Past President Philip Wiltshire, who is the Professional Head of Signalling and Telecommunications for the NYMR. Philip explained about the recently commissioned Electric Key Token working using broadband internet between Goathland, Levisham and New Bridge. This was developed with assistance and support of Siemens Rail Automation in the UK.

Upon conclusion of the site visits at Grosmont, members and guests were again afforded refreshments in the station tea room, having time to take part in lively discussions until the departure of the class 101 unit diesel multiple unit in the late afternoon to Pickering. Members and guest were then able to view the fantastic North Yorkshire Moors scenery along the line and observe the electric key token working at first hand at Goathland and Levisham in the splendid sunshine after all that rain!

The Minor Railways Section would like to thank Craig Donald, Charles Weightman, Philip Wiltshire and the staff and volunteers of the NYMR for their support and enthusiasm during the day. The Section would also like to thank our Chairman and Visits Co-ordinator, Mike Tyrrell, for arranging such an enjoyable day. Until the next time!
It is always surprising to see the level of ingenuity that exists on Heritage Railways to overcome constraints in both operating and engineering practice. These railways do not have big budgets and solutions to problems have to be realistic as to both cost and safety implications. The Keighley and Worth Valley line is no exception to this situation and a recent visit there by the IRSE Minor Railways Section revealed some interesting aspects as to how the railway is signalled.

The line has been in the ‘preservation’ business for many years. Built by local mill owners but operated and later taken over by the Midland Railway to connect the main line through the West Yorkshire town of Keighley with the mills and associated communities up the Worth Valley, it was closed by British Rail (BR) in 1962 (pre Beeching). Most famous of these communities is Haworth, the home of the Bronte family where the famous sisters wrote their powerful novels in the Victorian era. The terminus is at Oxenhope, some five miles from the starting point, so it is not a long line in terms of heritage operations. BR management was blinkered to the tourist prospects of the area but local interest was not so short sighted and a preservation society was duly formed. It took until 1968 for the railway to re-open as a very basic railway. Over time, a locomotive workshop and shed has been provided at Haworth, a carriage depot and exhibition shed at Oxenhope and a rail museum at Ingrow. The railway became famous when the first ‘The Railway Children’ film was shot on the line in 1970 using Oakworth station and tunnel as the centrepiece, traffic booming as a result. This created many capacity problems and new facilities including signalling became a necessity. In 2018, the railway will celebrate 50 years in the preservation business.

Operating the Line
Before the BR closure, the whole line had been worked as one single line section and this was how the preservation days started. A BR signalbox existed at Keighley and controlled the connection to the main Leeds – Settle – Carlisle line but at all locations on the branch, ground frames were used for level crossing protection, for access to sidings and for the run round loops at Keighley and Oxenhope. The single line One Train Working Staff incorporated an Annett’s Key to release the ground frame control levers.

With passenger levels rising following the Railway Children film, single section working could not cope with the crowds on busy days and thus an intermediate passing loop was provided at Damems in 1971, roughly half way along the line, to allow two train operation. This was a virgin site and had no electricity or running water when built. Initially, the two ends of the loop were controlled by ground frames to enable early implementation. A signalbox was subsequently provided, coming from Frizinghall on the Shipley to Bradford Forster Square line. With no electric power or mains water, the facilities here were at first very basic and signalling power came from dry cells. Subsequently, both utilities have been installed, making it more comfortable for the signalman.

One Train Working (OTW) continues to be used for operation of a single train over the whole line, but when the signalbox is opened the OTW Staff is locked in the frame and Electric Token Block Working using Tyer’s Key Token instruments is enabled on the two sections thus created.

The signalled level crossing at Damems Station (in truth a one coach halt) was originally ground frame operated but again, crossing keeper comfort needed attention and a small gatebox, recovered from Earby on the now closed Colne to Skipton line, was acquired. The gates still have to be manually opened and closed. Treadle-operated annunciators alert the crossing keeper to an approaching train.

At Keighley, the railway controls two platforms (numbers 3 and 4) but on most operating days, only platform 4 is used for passenger trains. The connections to Platform 3 at each end are needed for locomotive run round purposes and operated by two ground frames, North and West. These are operated by the train crew using the Annett’s Key on the end of the One Train Working Staff or the Keighley section token. When Platform 3 is also to be used for passenger trains, Station Yard Working is introduced, as described later.

Sidings exist at Ingrow, Haworth (which also has a loop to facilitate entrance and exit to the locomotive shed from either direction, as well as local running round) and Oxenhope (for the carriage sidings and exhibition shed), all of which are ground frame controlled by Annett’s Key.
The Signalling Technology

As with most heritage lines, much of the signalling has been acquired after modernisation and closures on the main line network made equipment redundant. The railway has perpetuated some Midland Railway practice. The catch handle frame at Damems Junction passing loop box is of the Midland tumbler type, a locking technology requiring particular knowledge to modify and to record on drawings. The frame at Damems Crossing is a Midland tappet type. Home signals are a mixture of Midland lower quadrant (a type no longer seen on the main line) and LMS or BR(ER) upper quadrant semaphores with fixed distant signals. With Damems Station and Junction being very close to each other, there was considered to be a risk of trains going towards Keighley ‘reading through’ the loop outlet signal at danger if the level crossing protection signal was off. To prevent this, the level crossing signal is ‘slotted’ from Damems Junction. In technical terms, this means having two return weights, requiring a lever in both boxes to be pulled off before the signal arm clears to proceed; an example of past technology that is rarely seen nowadays.

At Oxenhope another curiosity exists. The points leading to the carriage sheds and the run round loop at the North end have an ‘economical’ type of facing point lock mechanism developed by the Midland Railway to achieve movement and locking with only one lever. The point stretcher bar has a vertical roller that engages with a slot cut into a movable plate. When the lever is pulled, the plate moves parallel to the track, with the roller being moved sideways by the main diagonal portion of the slot to move the switch rails. At each end of the slot there is a short stage of the plate’s movement in each direction. Thus the plate performs both a moving and locking action. The arrangement was always tricky to adjust and the points were often ‘heavy’ to pull. All other facing points on the railway have the more usual two-lever arrangement with the facing point lock activated separately.

The simple working method at Keighley is satisfactory for normal two train operation but the use of both platforms for passenger movements enables more operational flexibility for special workings such as galas, including the running of Ingrow shuttle services. On such occasions, ‘Station Yard Working’ is introduced under the control of a Keighley signalman. An Outer Home signal (normally off) on the approach to Keighley is placed to Danger from an adjacent ground frame known as Globe GF after the adjacent public house. This releases a key for the signalman to release the two ground frames at Keighley station yard. Shunt signals in the Keighley station yard area, which are normally physically covered, have their covers removed and are also worked from the ground frames. The Station Yard Working key enables the signalman to operate the ground frames and control the run round and other movements within the station yard with a train in section, the yard being protected by the Outer Home signal at Danger. To allow a train to approach the yard from the section, the signalman clears a subsidiary signal beneath the Outer Home but controlled from Keighley West ground frame. The driver is thereby informed that Station Yard Working is in operation at Keighley, to approach cautiously, obey ground signals and deliver the Staff or Token to the Signalman on arrival.

The signalman has to walk to and fro between each end of the station for run round moves, which is a bit time consuming. The intention is therefore to have the station fully signalled from a conventional signalbox, already erected and having previously been at Shipley Bingley Junction. Additional levers have been added to the original frame making 32 in all. The tappet locking has yet to be fitted and there is very much more work to be done in the box as well as outside, where ducted cable routes have been installed as a first step. The plan is to have mechanical signalling at the West end and power signalling at the North end with track circuits throughout. Signals have been recovered from various locations and a simple gantry is to be built. It is likely to be a five-year project at best.

There is a main line connection at Keighley used for stock movements and the occasional incoming excursion train. This is protected by a mechanically-operated derailer and requires mutual operation of the release by both K&WVR staff and the signalman in York Integrated Electronic Control Centre (IECC).

Telecommunications

No railway can operate without communications and unlike the signalling, the telecom systems and equipment are surprisingly modern. Unusually, the line plant still uses an overhead pole route but with 0.5 mm drop wire twins rather than open copper wire. Two electronic exchanges exist (at Haworth and Ingrow) of the ISDX type interconnected by digital trunks. These provide a data capability as well as connectivity to the BT network. To represent heritage practice, the exchanges still accept loop disconnect dialling and many old fashioned telephones exist to create the right ambience. 2.3 Mbit data lines are provided to all stations allowing a virtual network for credit card sales and this will shortly be extended to gather data from EPOS terminals. Wifi internet access is widely available to staff. An omnibus telephone line calling at all places is kept in place just in case all else fails!

The railway does not have a dedicated radio network other than back to back portables of a modern design that can range up to two miles. Other radio communication relies on the public cellular networks. CCTV with digital recording exists at the main places where passengers congregate and some vulnerable sites. Main stations have public address systems and there is a remote link to Ingrow for when that station is unstaffed. Traditional master clocks drive slaves at some stations and one also sounds a time signal on the omnibus circuit twice daily to provide a common time reference. Providing electronic point of sales (EPOS) terminals on the trains is a planned next step using public WiFi to link to the railway’s accounting system.

In Summary

The K&WVR is a fascinating heritage line that has adapted well to the local area and modern tourist requirements. It has a delightful mixture of old and new technology, with the former comprising equipment no longer seen on the main line. Due recognition is taken of occasional anti-social behaviour in the locality and valuable assets are protected appropriately for when the line is closed. The future sees some signalling challenges at Keighley and we will all watch with interest how this progresses.

Thanks are given to Bruce MacDougall, David Harrison and their staff from the railway’s S&T department for explaining the engineering, and to the providers of the excellent lunch in a Pullman carriage at Oxenhope.
Exam study day – June 2016
Matt Slade, Chair, YM Section

To the majority of long serving IRSE members the IRSE exams may seem like a distant memory. However, for the younger generation it’s a rite of passage that can often feel like an unassailable mountain! It is no secret that passing the IRSE exams requires a broad breadth of experience and knowledge, that within today's increasingly silo-ed industry requires a significant amount of study and practice to pass. It's for this reason the case for the IRSE exam has never been stronger. It is a vital tool the signalling profession requires to create a breed of signalling engineers with the breadth of knowledge required to face the challenges within the industry. The exam provides a structured curriculum over a diverse range of topics that enables students to gain knowledge in areas they wouldn’t usually experience within their daily routine.

Thanks to the hard work and sacrifice of a number of those who have already conquered the mountain, the weekend of the 2nd and 3 July saw the annual Module 2, 3 and 5 study weekend hosted at Signet Solutions in Derby (UK). The weekend was led by Peter Woodbridge and hosted by Signet, and the event catered for those looking to take the exam modules in 2016 and as an introduction for those considering undertaking in 2017 or subsequent years.

Following a week of heavy rain, the study weekend started with glorious sunshine and prospects of high temperatures, perfect conditions for indoor studying! Despite this, 35 delegates convened bright and early and divided into groups based on exam preferences and mock exam questions completed prior to the event. The event was kicked off by Peter and the volunteers introducing themselves and welcoming the group. The module 2 hopefuls disappeared to a day of headway calculations and placing signals on layouts, led by Dorothy Pipet of Alstom. Those wanting to focus on Control Tables were under the tutorage of Reuben Dakin of Signet. The remaining delegates, looking to focus on modules 3 and 5, started with introductions from Jeremy Rickets and Jesper Phillips, providing insight into how to approach studying for the exams and answering the exam questions – both emphasising the IRSE Examiners’ continual plea: ‘Read the Question’!

Signet’s practical facilities provided an opportunity for many of the delegates, who wouldn’t usually get the opportunity, to get up close and personal with wayside equipment. Dan Heeley and Richard Atkinson of Network Rail led the overview, providing insight on how to configure and maintain the equipment. Many of these sessions were related to 2015 exam questions and used to support the learning. Others were provided in response to students’ requests, particularly to support those wanting a more general understanding of signalling. Equipment that was demonstrated included HW points, Clamplock Points, TI21 Track Circuits, Signal Heads, SSI Interlockings and even a mechanical ground frame.

At the end of the day the delegates retired to The Brunswick Arms, a well-known venue of Derby’s signalling establishment, for a debrief of the day’s learning and a look ahead to the next day.

Sunday began with a range of mock papers under exam conditions, allowing delegates to put Saturday's knowledge into practice and experience the sobering reality of an IRSE Exam Room. Other sessions were provided for those not registered for the relevant modules in 2016. Following lunch, the volunteer tutors ran a range of sessions to review the most popular exam questions, enabling delegates to review how they performed and to improve.

Thanks to the experience and advice of the volunteers and the enthusiasm of the delegates, this annual event continues to be a huge success. Speaking for myself and the delegates, I spoke with during the event, it succeeded in providing a learning opportunity that isn’t always available within the normal working day.

The Younger Members committee would like to say a thank you on behalf of the Younger, Student and Associate Member community to Signet Solutions, including specifically Andy Knight, Reuben Dakin and Isobel Knight for hosting the day and providing all the facilities, lunches and refreshments; and Peter Woodbridge for organising the event and investing a significant amount of time and effort in ensuring the event was a huge success (without him the event really would not have been possible). Finally, we also thank the volunteers who gave up their weekend and evenings in preparation for the event as well as during the weekend itself, to provide support and guidance to the exam hopefuls - Dan Heeley, Dorothy Pipet, Jeremy Ricketts, Jesper Phillips, Richard Atkinson, Tom Corker (yes we had a record three Thoroughgood Scholars supporting us this year!). Lastly, thank you to Vivich Silapasoonthorn for much of the pre-event administration.

The class of 2016, posing with their tutors, mentors and other supporters.
MEMBERSHIP MATTERS

ADMISSIONS
We have great pleasure in welcoming the following members newly elected to the Institution:

FELLOW
Gupta H Western Railway India
Legros D INEO UTS France
Li K Beijing Jiaotong University China
Mandoc D Network Rail UK
Singh S Mumbai Rail Vikas Corp India

MEMBER
Chen B MMC Gamuda Malaysia
Cobain G Northern Ireland Railways UK
Lardy M Ansaldo France
Lim C L C MTR Corp Hong Kong
Shintre N B Ansaldo Australia
van Bruchem R F Dekra Rail Netherlands

ASSOCIATE MEMBER
Allsop M D Balfour Beatty UK
Arenas Salmeron L Network Rail UK
Diswar S S Serco UAE
Edmeades A D Atkins UK
Edwards D R London Underground UK
Nicholls L Atkins UK
Pereira N M Bombardier UAE
Shrivastava P AECOM UK
Vidyarthi A Ame UK
Vincent L SETEC Ferroviaire France

ACCREDITED TECHNICIAN
Longhurst S T Network Rail UK
Wigley P Network Rail UK

AFILIATE
Bolland S R Siemens UK
Chan C F KML Engineering Hong Kong
Deshmukh S A John Holland Australia
Humar M F UniKL MFI Malaysia
Jenkins L AECOM UK
Jonassen M T KiwiRail New Zealand
Meacher D WSP Parsons Brinckerhoff UK
Morris P B Delta Rail UK
Pandian L SMRT Singapore
Peel D Cityzens Australia
Ramamoorthy M TVM Sig & Trans Systems India
Sweet N Bombardier Netherlands
Wan Abdul Malik W M UniKL MFI Malaysia

TRANSFERS
MEMBER TO FELLOW
Cox C J Metroselskabet Denmark

ASSOCIATE MEMBER TO FELLOW
Nock D M Network Rail UK

ASSOCIATE MEMBER TO MEMBER
Chintalapudi V V S Atkins India
Hussain A Atkins India
Palanisamy K K Alstom Australia
Samuel T L Siemens UK
Smith S Atkins UK
Soper G D London Underground UK

AFFILIATE TO MEMBER
Bolton M B Siemens UK
Tong C F J WSP Parsons Brinckerhoff Hong Kong
Turner R M Mott Macdonald UK

ACCREDITED TECHNICIAN TO ASSOCIATE MEMBER
Stuart D T Network Rail UK

AFFILIATE TO ASSOCIATE MEMBER
Boulter B J J Network Rail UK
Loganathan S Cyient India
Rajamani V Atkins India
Singh Sachin Atkins India

AFFILIATE TO ACCREDITED TECHNICIAN
Mandalapu S R AM Rail UK
Ramesh S AM Signalling Design UK
Vadyala S R AM Rail UK

RESIGNATIONS

DEATHS
It is with great regret that we have to report the death of the following members: Haldar P and Smith V H.

In addition to these changes, the names of 258 members whose subscriptions had not been paid for two years were removed from the register.

Current Membership: 5312