Rail Accident Investigation Branch

Rail Accident Report

Collision between a train and tractor at Hockham Road user worked crossing, near Thetford
10 April 2016

Report 04/2017
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This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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Collision between a train and tractor at Hockham Road user worked crossing, near Thetford, 10 April 2016

Contents

Summary

At 12:30 hrs on 10 April 2016 a passenger train travelling from Norwich to Cambridge collided with an agricultural tractor and trailer on a level crossing at Hockham Road, near Thetford in Norfolk. The train was travelling at 87 mph (140 km/h) when, on the approach to the crossing, the train driver saw a tractor moving closer to the railway tracks. The train driver sounded the train's horn and applied the emergency brake, but could not stop before colliding with the tractor. The train did not derail, but its driving cab was damaged, and the driver and four passengers suffered minor injuries. The tractor was destroyed, and its driver was seriously injured.

The level crossing at Hockham Road is on a restricted byway, and has gates which are operated by crossing users. About one minute before the collision, the tractor driver had obtained permission to cross from a signaller at the Network Rail signal box at Cambridge. The signaller had given him permission to cross when there was insufficient time before the train would arrive at the crossing. This was because the signaller had lost his awareness of the position of the train because his levels of concentration may have lapsed, and his competence to operate the workstation safely and effectively had not been adequately monitored.

A system that had been installed at the level crossing in 2012, intended to display green or red lights to crossing users to warn them whether or not it was safe to cross, was not working at the time of the accident. It had been decommissioned by Network Rail following concerns which the company had about the safety integrity of the system. This had meant that users had to telephone the signaller for permission to cross. The RAIB found that Network Rail had not come to a clear understanding with the manufacturer of the system about how the equipment met the required safety integrity level, and having assessed the risks, had decided to turn off the system while improvements were made.

An underlying factor was that the arrangements in Cambridge signal box for managing fatigue among signalling staff were inadequate.

The RAIB has made three recommendations to Network Rail. The first concerns Network Rail's approach to managing user worked level crossings, with the intention of either eliminating the need for a signaller to have to decide whether it is safe for a user to cross the railway or providing better information for signallers when making these decisions. The second relates to the processes that Network Rail uses when introducing new signalling equipment whose operating interface differs significantly from existing equipment, and the third covers the management of the competence of signalling shift managers when they also operate signalling equipment.

Introduction

Key definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B. Sources of evidence used in the investigation are listed in appendix C.

The accident

Summary of the accident

3 At 12:30 hrs on 10 April 2016 passenger train 1K77, the 12:04 hrs Norwich to Cambridge service operated by Abellio Greater Anglia (AGA), struck a tractor and animal feeder trailer at Hockham Road *user worked crossing* (UWC[1]) on the *up* line between Harling Road and Thetford, in Norfolk (figures 1 and 2).

4 The train was travelling at 87 mph (140 km/h) when, on the approach to the crossing, the train driver saw a tractor moving closer to the railway tracks. The train driver sounded the train's horn and applied the emergency brake, but could not stop before colliding with the tractor.

5 The train did not derail but the driving cab was damaged. The train driver sustained minor injuries to his hand. The tractor and trailer separated and were knocked into the *cess*, clear of the running lines. The tractor driver was seriously injured. Four of the 135 passengers that were on board the train were treated for minor injuries and shock.

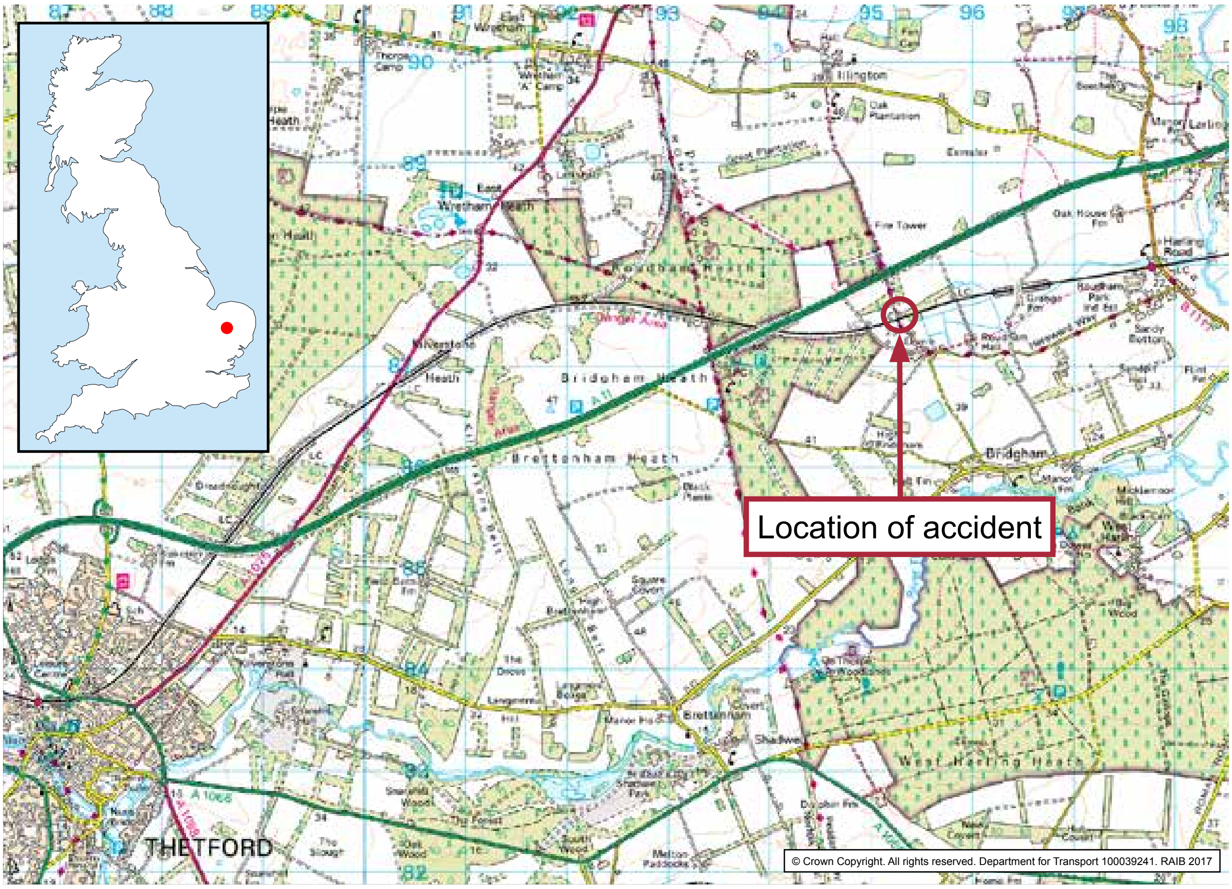

Figure 1: Extract from Ordnance Survey map showing location of accident

[1] The crossing is fitted with telephones for users to contact the signaller, and as such is classed as a UWC(T) by Network Rail. This report uses UWC to encompass references to user worked crossings in general.

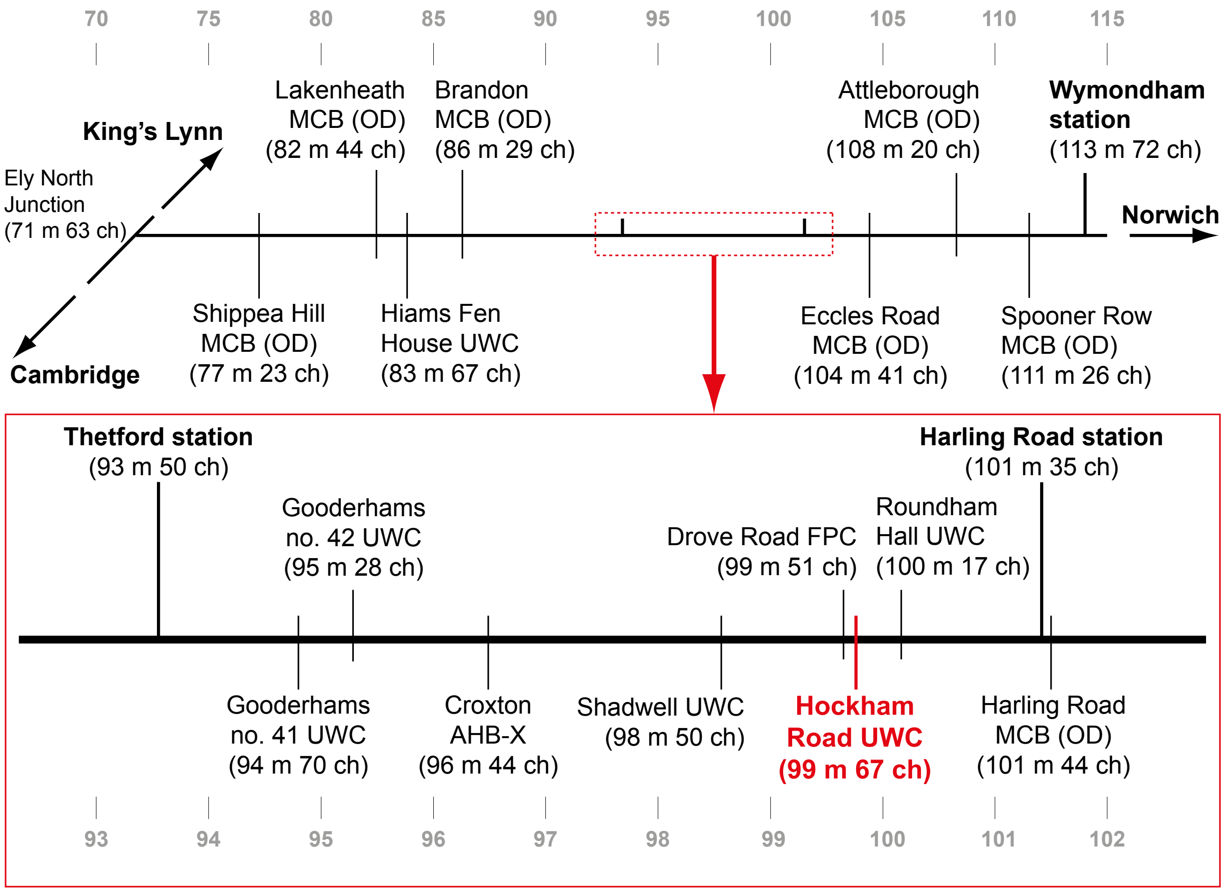

Figure 2: Overview of the Thetford workstation area of responsibility

Context

Location

6 Hockham Road UWC (figure 3) is located at 99 miles 67*chains* on the double track railway between Ely and Norwich, which is known as the Thetford line. The signalling system, which is controlled from Cambridge *Power Signal Box* (PSB), is operated under the regulations for *track circuit block* with train detection by means of *axle counters*.

7 The road which crosses the railway at this point is classed as a restricted byway[2]. The level crossing has one *authorised user*[3], who is permitted to use the crossing with farm vehicles, horses and pedestrians. The road also serves fields and one house. It is also used as an unauthorised access route to and from the A11, the main road between Thetford and Norwich, and a paintballing outdoor activity centre (see paragraph 42). There is a public footpath level crossing alongside the road crossing.

[2] A restricted byway is a category of right of way created under the Countryside and Rights of Way Act 2000. The byway allows a right of way on foot, on horseback, or leading a horse, cycling and for any vehicles other than mechanically propelled vehicles (excluding the authorised user who is permitted to use farm vehicles and equipment).

[3] The vehicular use of this crossing is restricted to the authorised user, and staff employed by its tenant who require access from the farm to the piggeries, various agricultural and public fields.

8 Hockham Road UWC is supervised by the signaller at the 'Thetford' workstation within Cambridge PSB[4]. The signaller monitors the visual display units (VDU) at the workstation which controls the trains travelling on the route, and deals with any requests or technical problems relating to 43 level crossings, which consist of active crossings with *Manually Controlled Barriers with Obstacle Detection* (MCB (OD)), *automatic half-barrier crossings* (AHBC), user worked crossings with miniature red/green warning lights (MSL) and passive user worked crossings (UWC). In normal operation, an Automatic Route Setting (ARS) system sets the routes for trains passing through the area, and the AHBC, MCB-OD and MSL level crossings operate without requiring the signaller's intervention.

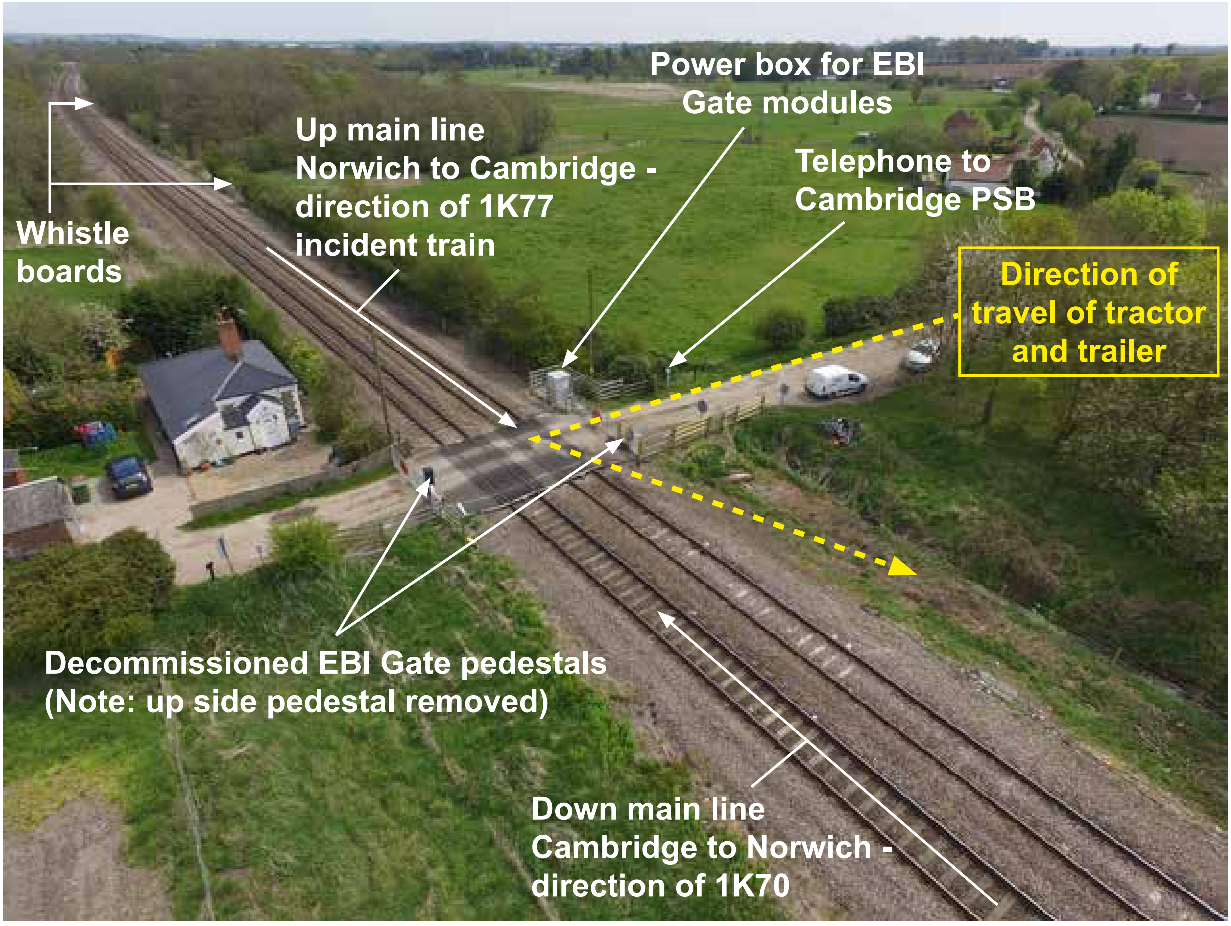

Figure 3: Hockham Road UWC from the north-west

Organisations involved

9 Network Rail owns, operates and maintains the infrastructure, and is responsible for the specification, approval and maintenance of the equipment at the crossing.

10 Abellio Greater Anglia (AGA) was the operator of train 1K77 and the employer of the train crew.

11 Bombardier Transportation Ltd was the designer and manufacturer of the miniature stop light system that was fitted, but not in use, at the crossing.

[4] During 2011 to 2012 the Ely to Norwich (ETN) re-signalling project resulted in the closure of Harling Road signal box (which had previously supervised the use of Hockham Road UWC) and eight other mechanical lever frame signal boxes. Control of the area was transferred to Cambridge PSB in 2012.

12 The owner of Roudham Farm is recognised by Network Rail as the crossing's authorised user. All of the parties involved freely co-operated with the investigation.

Train involved

13 Train 1K77 was formed of a class 170 'Turbostar' *diesel multiple unit* (DMU) of three carriages. The investigation found that neither the condition of the train, nor the actions of the train crew played any part in the accident.

Rail equipment/systems involved

14 Hockham Road UWC is fitted with telephones on each side, connected to the Thetford workstation at Cambridge PSB. The telephones enable a person who wishes to use the crossing to contact the signaller (figure 4). Signs on both sides of the crossing tell users with vehicles or animals that they must obtain permission to cross. There are two 'whistle' boards in each direction on the approach to the crossing, instructing train drivers to sound the train horn to warn footpath users at both Hockham Road and nearby Drove Road (Drove Road UWC was closed in 2010, but the adjacent footpath crossing remained in use).

15 An *overlay* Miniature Stop Light (MSL) system (a system that is not integrated with the signalling system) known as EBI Gate 200 (see paragraph 49) had been commissioned and installed at Hockham UWC in October 2012, providing the crossing with red and green lights which indicated to users whether it was safe to cross. In October 2015 Network Rail withdrew its product acceptance for the EBI Gate 200 system and decommissioned the equipment at Hockham Road crossing. Further details of these events are in the analysis section of this report.

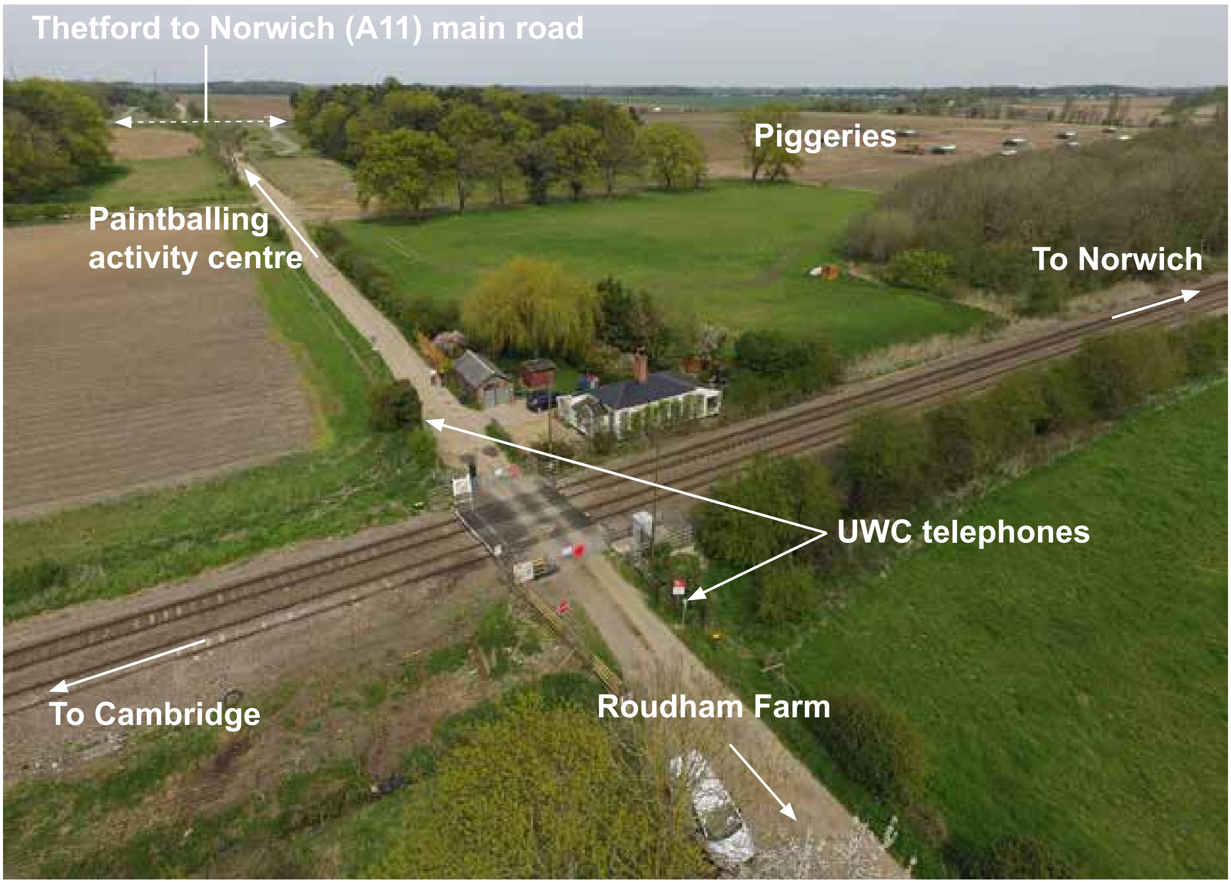

Figure 4: Hockham Road UWC from the south-west

Staff involved

16 The *shift signalling manager* (SSM) who was working as signaller at the Thetford workstation at the time of the accident had worked on the railways since 1971. At the time of the accident the SSM was working on the workstation providing cover for another signaller. The SSM is referred to as the signaller for the remainder of the report. He worked as a signaller in both *lever frame and entrance-exit panel* (NX) type signal boxes in the Cambridge area, and in a variety of positions in signalling teams and operations management until 2003. As a consequence of a route modernisation project he was then moved to a *mobile operations manager* (MOM) position at Ely.

17 In 2007 he was diagnosed with diabetes (type 2-insulin dependent), and because this restricted the type of work he could do, he was moved to a SSM role at Cambridge PSB.

18 During 2012 and 2013 the signaller was given initial training in the various new signalling technologies (VDU-based signalling system, axle counter technology and level crossing obstacle detectors) that had been introduced on the Ely to Norwich route.

19 The tractor driver had been employed by a tenant of the authorised user as a stockman since November 2014. His duties included the care and feeding of the livestock (pigs). This required him to use Hockham Road crossing frequently to travel between the farm and the piggeries, with a tractor and animal feeder trailer. The authorised user had briefed and provided training to his own staff and his tenants' staff, including the stockman, on how to cross using both the telephone and the EBI Gate 200 system when it was in operation at the crossing.

External circumstances

20 The accident occurred in daylight. The weather was dry and bright, with clear visibility.

The sequence of events

Events preceding the accident

21 The signaller awoke at around 04:15 hrs on 10 April, as he was rostered to work as SSM on day shift (06:00 hrs to 18:00 hrs). He had breakfast before travelling the short distance to work at Cambridge PSB. He booked on duty at 06:00 hrs and worked on various administrative duties until around 09:00 hrs. As there is no rostered meal relief provided to staff, he started to provide meal relief for each of the signallers on the NX panels (which control the railway between Stansted and King's Lynn, and associated branch lines) and the Thetford VDU workstation.

22 Between 10:00 hrs and 11.30 hrs, while the signaller was working on the NX panels, he became aware that his colleague working on the Thetford workstation was dealing with technical problems at Brandon level crossing. Signalling technicians had been sent to Brandon and the problem was rectified a short time later (see paragraph 63). From 12:00 hrs the signaller took over the Thetford workstation, monitoring the movement of the trains and dealing with any requests to cross the railway from the 22 UWCs that, at the time of the accident, were equipped with telephones (figures 5 and 6).

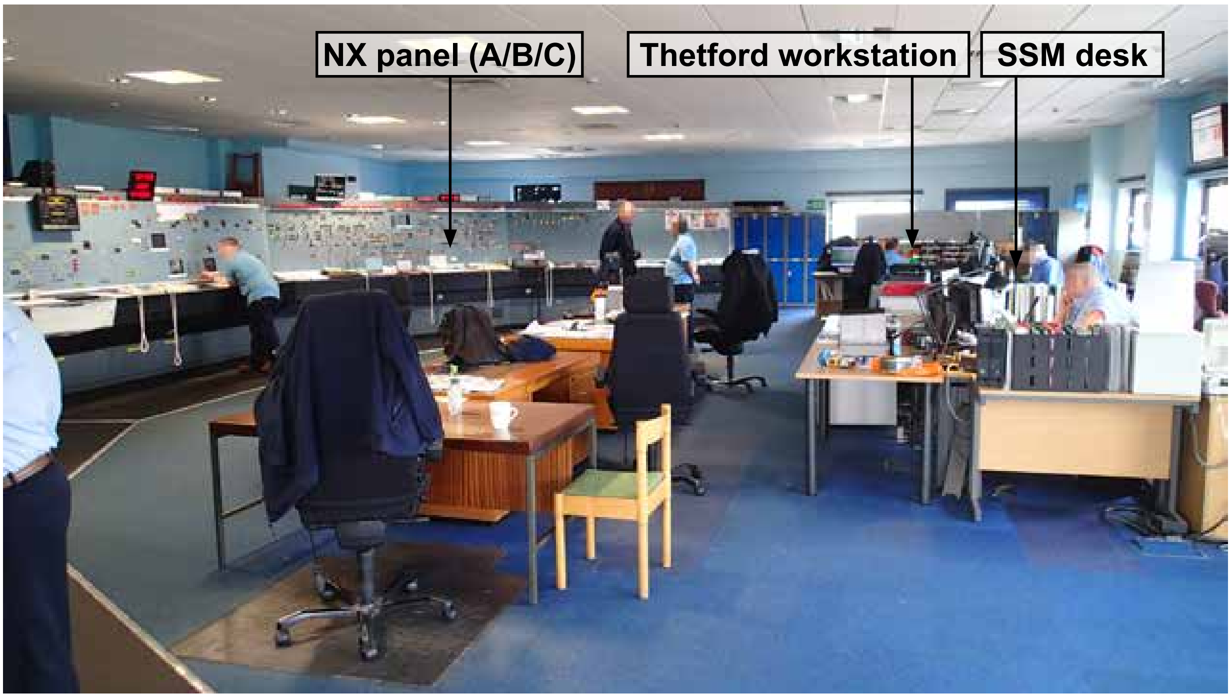

Figure 5: Cambridge PSB operating floor showing the location of the three NX panels (A, B and C), the Thetford VDU workstation and the Signalling Shift Manager

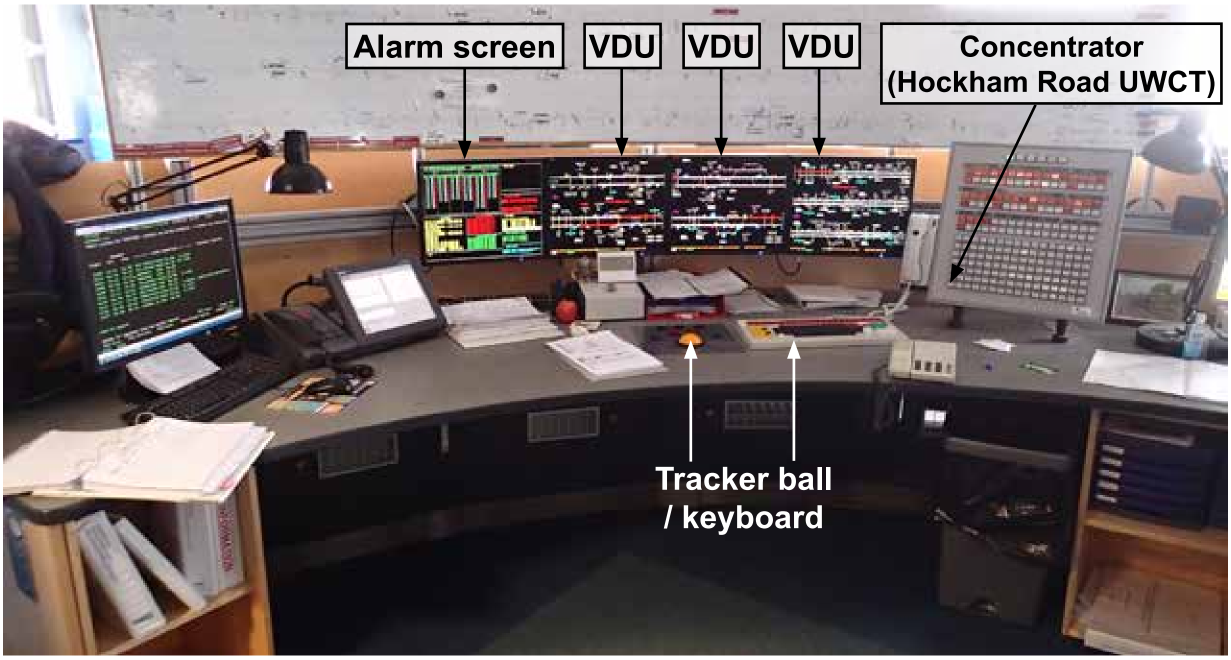

Figure 6: The Thetford workstation within Cambridge PSB

23 Shortly before 12:03 hrs the signaller received a call from a user at Hiams Fen House UWC, which is between Lakenheath and Brandon (figure 2). The user, who was driving a 4x4 vehicle, requested permission to cross. As there was a train in the Lakenheath area the signaller refused permission and asked the user to call back when the train had passed. The user called back and the signaller then granted permission for the user to cross the line.

24 At about this time, train 1K77, which was later involved in the accident, departed from Norwich on time. The signaller became aware that train 1K77 had entered the area of railway controlled by the Thetford workstation (see figure 2). The signaller received no further telephone calls until a user at Hockham Road UWC called at 12:28:33 hrs to ask for permission to cross with a tractor (figure 7).

25 The signaller asked the user what he wanted to cross with and how much time he would require to go over the crossing. The user stated that he was driving a tractor (the sound of the engine could be heard over the telephone), and it would take him one minute to cross over.

26 At 12:28:43 hrs the signaller repeated his request for confirmation of the crossing time from the user as '*he had a train in the area*'. The user repeated that he was driving a tractor and the time he required to cross. The signaller then granted the user permission to cross.

27 The phone call from the user was terminated at 12.29.00 hrs[5], with train 1K77 approximately 64 seconds travelling time from Hockham Road UWCT.

Events during the accident

28 The tractor driver, having been given permission to cross, got back into the cab of the tractor and moved towards the crossing. It is not clear from the witness evidence whether the tractor driver opened the level crossing gates before or after his conversation with the signaller.

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[5] At 12:29 hrs train 1K70 departed from Brandon station travelling on the *down line*, and at that time was about 10 minutes travelling time from Hockham Road UWC.

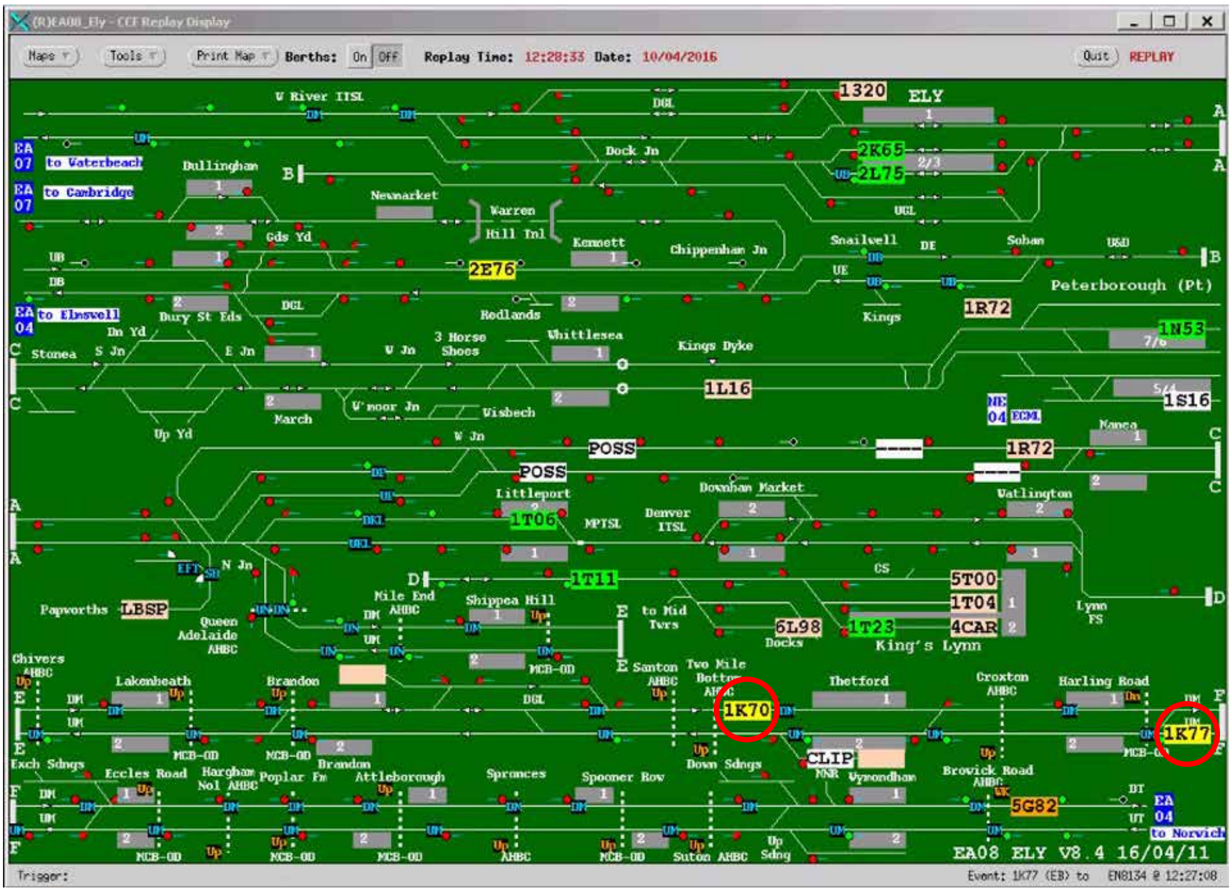


Figure 7: CCF screen shot at 12:28:33 seconds showing the positions of trains 1K77 and 1K70 (see also figures 22a to 22h). This system records train movements, and is not visible to signallers in real time.

Figure 8: View from Hockham Road UWC looking in the direction from which the up train approached

29 At 12.29.56 hrs the driver of train 1K77, which was approaching Hockham Road, travelling at 87 mph (140 km/h), sounded his horn once on the approach to the whistle boards for Hockham Road and Drove Road footpath crossing (which is 318 metres beyond Hockham Road). The train driver then saw the raised bucket attachment of a tractor on the left (Roudham Farm) side of Hockham Road crossing, but due to the vegetation and left-hand curvature of the track he could not see the tractor itself, or tell if the gates of the crossing had been opened. The train driver then saw the raised bucket attachment of the tractor continue to move slowly forward towards the crossing.

Figure 9: View looking towards Hockham Road UWC for trains approaching in the up direction

30 The train driver then sounded his horn continuously for seven seconds, and applied the service brakes, followed immediately by the emergency brake. The train driver then moved himself to a position of safety within the cab (figures 10 to 14) having anticipated the impending collision.

31 As the tractor driver's cab was sound proofed and he was looking forward as he began to cross the railway, he did not see the approaching train or hear its horn. The train collided with the tractor and trailer at 12:30:04 hrs while travelling at 84 mph (135 km/h).

Events following the accident

32 The train did not derail, but sustained substantial damage to the driving cab. It travelled 410 metres beyond the crossing before stopping (figures 10 to 14). The tractor and animal feeder trailer separated, causing the feed trailer discharge auger (a feeder pipe for discharging foodstuffs or grain) to spin around and strike the side of the train several times, breaking windows and puncturing the outer body side skin. The main part of the trailer came to rest next to the tractor unit in the up side cess, clear of the running lines (figures 16 and 17).

Figure 10: External damage to front of train 1K77

Figure 11: External damage to side of train 1K77

Figure 12: External damage to side of train 1K77

Figure 13: External damage to side of train 1K77

Figure 14: Internal view of cab distortion of train 1K77

33 The tractor's offside wheel and hub assembly broke away from the tractor, and was dragged along the underside of the train, causing a large quantity of diesel fuel, 75 litres of engine oil, and 60 litres of hydrostatic fluid to escape (figure 15).

Figure 15: View from the rear of train 1K77 looking towards Hockham Road UWC

34 At 12:30:40 hrs the driver of train 1K77 pressed the *Global System for Mobile Communications - Railway* (GSMR) *Railway Emergency Call* (REC) button in the train cab, twice. The button illuminated but appeared to be damaged. The driver did not believe the radio communication had reached the signaller and so he used the guard's mobile telephone to report the accident to Cambridge PSB, and asked for all trains to be stopped. The signaller, who had momentarily left the Thetford workstation to wash his hands, heard the REC and he and a colleague went to answer the call, which cut off with no message being passed.

35 Two local residents, who were working close to the crossing when the accident occurred, witnessed the collision. They made a call from the crossing telephone to Cambridge PSB and later administered first aid to the tractor driver who had sustained serious injuries. The signaller answered the emergency call, and took brief details of the accident before going back to the signalling shift manager's desk to call the emergency services.

Figures 16 and 17: Remains of tractor and trailer in the up cess after the accident

36 The emergency services arrived at the crossing a short time later and the tractor driver was transferred to hospital. Four passengers on board were treated at the scene.

37 Under the supervision of the RAIB, Network Rail tested the telephones at the level crossing. No faults were found (figures 18 and 19). One of the two decommissioned EBI Gate 200 pedestals, which had been partially covered up (both pedestals were still in situ) was destroyed as a result of the accident (figure 19). British Transport Police (BTP) subsequently examined the remains of the tractor and reported to the RAIB that there was no evidence of any faults with the tractor that could have contributed to the accident.

38 The RAIB attended the site to record and obtain evidence. Repairs were made to damaged equipment and the road surface, and the line was reopened the following day.

Figure 18: Signage and telephone on the up side at Hockham Road UWC

Figure 19: Decommissioned EBI Gate system – image taken on 08/12/2015 (Courtesy of Network Rail)

Key facts and analysis

Background information

Cambridge PSB

39 Cambridge PSB was originally opened in 1982 with one NX panel, which was split into three areas. During 2012 the Ely to Norwich re-signalling project upgraded the technology, installing colour light signals, axle counters and MCB obstacle detectors, and resulting in the closure of the lever frame signal boxes. The control of the signalling on that line transferred from local signal boxes to a VDU-based workstation within Cambridge PSB (paragraphs 111 to 115).

History of Hockham Road UWC and the introduction of the EBI Gate equipment

Design and operation of the crossing

40 Hockham Road crossing has existed since the opening of the Ely to Norwich railway in 1845, when it was provided for the use of occupiers of Roudham Farm. It currently has metal five-bar gates for vehicle access, and separate smaller gates for the adjacent public footpath and restricted byway crossing. As a result of the line speed of 90 mph (144 km/h) and the curvature of the track, the distance at which approaching trains come into sight gives limited warning time, and whistle boards are provided to warn pedestrians of the imminent arrival of a train. Notices instruct people using the crossing with a vehicle or animals to use the telephones either side of the crossing (which were first installed in 1963) to contact the signaller to obtain permission to cross. The user should tell the signaller if they are crossing with a large or slow moving vehicle (although no definition of this is provided). The signage instructs the user to open the far gate before crossing with a vehicle or animals, cross quickly and then to close and secure the gates after use (figure 18).

41 The authorised user reported that two separate incidents had taken place between 2002 and 2004, in which an employee had called the signaller at Harling Road signal box and been given permission to cross when a train was approaching. No further details are available.

42 Network Rail's records show that from 2002 to 2012 Hockham Road crossing had four reported near miss incidents with some users being misdirected across the railway by satellite navigation systems, and persistently suffered from misuse (15 incidents reported between 2009 and 2012) with users not contacting the signaller to ask for permission to cross, or not closing the gates after they had crossed (this is less safe because subsequent users may drive over the crossing without stopping if they come across the open gates and happen not to observe the signage). Witness evidence indicates that some incidents arose from people using the road to reach a site on the north side of the railway which is used for paintballing activity, and for which the normal access is directly off the A11 road (figure 4).

Figure 20: Layout of Hockham Road UWC

43 Network Rail's most recent risk assessment using the All Level Crossing Risk Model (ALCRM) was completed in June 2014. It found that 66 trains per day passed over the crossing, which was used by 24 vehicles and 8 pedestrians / cyclists daily. During the harvest period (June to September) the vehicle traffic increased to 100-120 per day. The assessment identified the main risks as the number of trains and their interaction with vehicles; pedestrians; glare from the sun and deliberate misuse.

44 During the Ely to Norwich re-signalling project Network Rail engineers reviewed the historical records for the various locations where signal boxes had been closed, and identified an opportunity at Pools No.2 UWC (near Lakenheath) to test a new warning system for level crossing users which had been developed by Bombardier. The system was successfully tested and was subsequently given product approval. Further details are provided in paragraphs 49 and 81 to 103.

45 Shortly after the new train signalling system (controlled from the Thetford workstation) was commissioned, an incident occurred on 21 August 2012. A member of the public reported to the signaller that a near miss had occurred at Hockham Road UWC, with a Liverpool Lime Street to Norwich train running over the crossing immediately behind the rear of a heavy goods vehicle. The user had contacted the signaller at Cambridge PSB using the crossing telephone. The signaller mistakenly gave the user permission to cross before the train had passed Hockham Road. Network Rail's investigation into the incident was unable to identify why this happened, but it found that the locations of Hockham Road UWC and Harling Road MCB OD were both labelled with the same abbreviation, 'HD', on the new VDU display.

46 From October 2012, when the EBI Gate system was commissioned at Hockham Road, there were no further incidents or deliberate misuse reported at the crossing for over three years until the day before the accident, 9 April 2016, when a member of the public reported three vehicles going over the crossing and leaving the gates open. No call had been made to the signaller for permission to cross and no near miss occurred.

Network Rail's product acceptance process

47 Network Rail's product acceptance process is defined in its company standard NR/L2/RSE/100/05, 'Product introduction and change', and is managed by the Network Rail Assurance Panel (NRAP)[6]. Its purpose is to ensure that Network Rail validates the suitability of new equipment before it is introduced. The panel reviews evidence submitted by the 'proposer' of the new product to confirm that it is fit for purpose, safe to operate and in compliance with the law and company standards. Product acceptance can be undertaken in a series of discrete stages, including acceptance for monitored trials only, which allows a controlled assessment and review to be completed to identify any operational risks that may emerge. In this way, risk can be minimised and mitigations can be introduced before the equipment or system is given full acceptance, and thereafter is available to be used more widely across the rail network. The standard also outlines the process for the retention of records, and, in the event of a safety issue being identified, the temporary suspension and withdrawal of the acceptance.

48 Certificates of acceptance are issued both before monitored trials and to authorise equipment when fully accepted (appendix D). The certificate records the details of the equipment or system, the conditions under which it may be used, and a list of documents reviewed in support of its acceptance. If a certificate is issued for trial use, the length of a monitoring period can be specified and the criteria by which the outcome of the trial will be assessed can be defined. Certificates of acceptance are generally signed by both a member of NRAP and the professional head of the engineering discipline to which the product or system relates, eg track or signalling.

EBI Gate

49 The EBI Gate 200 system is not integrated with the train signalling system but can be installed at a level crossing to alert people using the crossing to oncoming trains. In the version installed at Hockham Road it is a user demand system, which sits in 'idle' mode with no lights showing until the user pushes a button. The safe operation of the equipment relies on two *Programmable Logic Controllers* (PLC). The PLC equipment is housed within pedestals either side of the crossing. If no trains are approaching, a green light is shown when the user pushes the button. If a train is approaching a red light is shown. Trains approaching the crossing are detected by 'Frauscher' wheel detectors.

50 At Hockham Road UWC the EBI Gate system will display a red light and audible warning, if a train is within 40 seconds of reaching the crossing.

[6] Network Rail Acceptance Panel was retitled Network Rail Assurance Panel in 2016.

51 As at all gated user worked crossings the user should open both gates on the crossing and then check that the light is still green before crossing the railway. The system can be powered by mains electricity or local batteries charged by solar / wind power.

Management of Fatigue

52 Since 1999, a number of companies within the railway industry have used a 'Fatigue Index'[7] to assess the impact of shift work and rostered working hours on their staff. Witness evidence indicates that managers at Cambridge PSB were aware of this technique, but it was not regularly used as part of the process for rostering signallers and SSMs. Further details on the management of fatigue are provided in paragraphs 72 to 80 and appendix E.

Identification of the immediate cause

53 The tractor driver drove onto the crossing as the train was approaching.

54 The tractor driver, who had been given permission to cross the railway, had no reason to believe that it was unsafe to do so and drove onto the crossing as the train approached. This occurred for the following reasons:

i. The signaller gave permission for the tractor to cross when there was insufficient time for it to do so in safety (paragraphs 55 to 79); and

ii. The EBI Gate 200 system that would have detected the presence of the train and warned the user of its approach had been temporarily decommissioned (paragraphs 81 to 103).

Identification of causal factors

55 The signaller gave permission for the tractor to cross when there was insufficient time for it to do so in safety.

56 Network Rail estimated the traverse time for the tractor on the crossing to be 31 seconds. When considering a user's request to cross and the time required to do this in safety, the signaller also needs to take into account the time the user needs to open the gates, get back into the tractor cab[8] and move the tractor forward to cross the railway[9]. The additional time required to open the gates and get on the tractor is likely to be about one minute, but the signaller may also take into account the estimate provided by the user. The time allowed for the user to cross the railway using the EBI Gate system is 40 seconds. This was based upon the user opening both gates, re-joining their vehicle and being sat in the driver's position, before checking the green light was still illuminated in readiness to cross.

[7] Current version available at http://www.hse.gov.uk/research/rrhtm/rr446.htm.

[8] It is not clear from the witness evidence whether the tractor driver opened the level crossing gates before or after his conversation with the signaller.

[9] Having crossed the railway line, the user is then required to get out of the tractor and close the gates again, crossing the line twice in the process. Whistleboards are provided at the crossing to warn the user who should look out for approaching trains while doing this, as other pedestrians using the footpath crossing are expected to do.

57 Evidence shows that at the time of the end of the phone call in which the signaller gave the tractor driver authorisation to cross, train 1K77 was only 64 seconds travelling time from the crossing. This allowed insufficient time for the tractor to cross the track in safety.

58 Although information about the position of the train was available on the signaller's display, the signaller lost his awareness of the position of the train (paragraphs 59 to 62), because of one or both of the following factors:

- his competence[10] to operate the workstation safely and effectively was not adequately monitored (paragraphs 64 to 70); and/or
- his concentration levels may have decreased due to a combination of fatigue and a lack of engagement with the signalling task (paragraphs 72 to 79).

Each of these factors is now considered in turn.

59 **The signaller had lost his awareness of the train's position when he gave the tractor driver permission to cross.**

60 The signaller stated that when authorising crossing users to cross the railway he would normally assess whether approaching trains had passed a particular location (known locally as the 'decision point') and, if they had, he would not give permission until the train had passed the crossing (figures 2 and 22 (a) to (h)). For Hockham Road UWC, his decision point on the down line would normally be at Thetford station. On the up line, the signaller would determine whether the road crossing barriers at Eccles Road MCB (OD) were shown as up, as this would indicate that a user would have more than five minutes to safely cross the railway at Hockham Road UWC. If the barriers at Eccles Road were shown as down with a train approaching, he would not give a user permission to cross.

61 When the signaller took over the Thetford workstation at 12:00 hrs, the VDU screens were configured as shown in figure 21, with two detailed and one overview screen displayed. The signaller stated that, at the time of the telephone call from Hockham Road crossing, and before looking at the VDU screen, he believed that train 1K77 was between Attleborough and Harling Road, which would be three to six minutes running time from Hockham Road.

62 However, the signaller stated that when he then looked at the VDU overview screen in the area of Eccles Road MCB (OD) (located between Attleborough and Harling Road) he overlooked train 1K77, which had in fact already passed Eccles Road and was now shown on the overview and detailed screens approaching Harling Road[11]. During the next 15 seconds of the telephone conversation the signaller did not notice that the displayed position of train 1K77 changed on two further occasions as it passed through Harling Road station (12.28.50 hrs to 12.28.54 hrs) and occupied the Harling Road to Thetford axle counter section (avw) at 12.28.55 hrs. He did not register that the train was closer to Hockham Road UWC than he had thought. The signaller then used his incorrect mental model and concluded that there was sufficient time for the tractor to cross.

[10] Network Rail's competence management process defines competence as a combination of practical, thinking and interpersonal skills, and experience and knowledge (including both technical and non-technical skills) which enable an individual to perform activities to the standards expected in employment.

[11] Train 1K77 had occupied the Eccles Road axle counter section (avl) at 12.24.46 hrs, and was then travelling towards Harling Road (sections AVR / AVW / AVY were occupied between 12.27.07 hrs and 12.28.55 hrs).

63 Although the previous technical issues at Brandon MCB OD (paragraph 22) had been rectified when the signaller took over the workstation, the signaller stated that he may still have had them in mind at the time the tractor driver requested to cross at Hockham Road, because there was a down train, 1K70, in the Brandon area at the time. Evidence shows that train 1K70 was 10 minutes travelling time away from Hockham Road and should not have provided any source of visual distraction on the VDU displays when the signaller was taking the decision to allow the user to cross at Hockham Road. The RAIB has therefore discounted the position of train 1K70 as a factor in the accident. Other possible reasons for why the signaller did not read the display effectively are discussed in paragraphs 72 to 79.

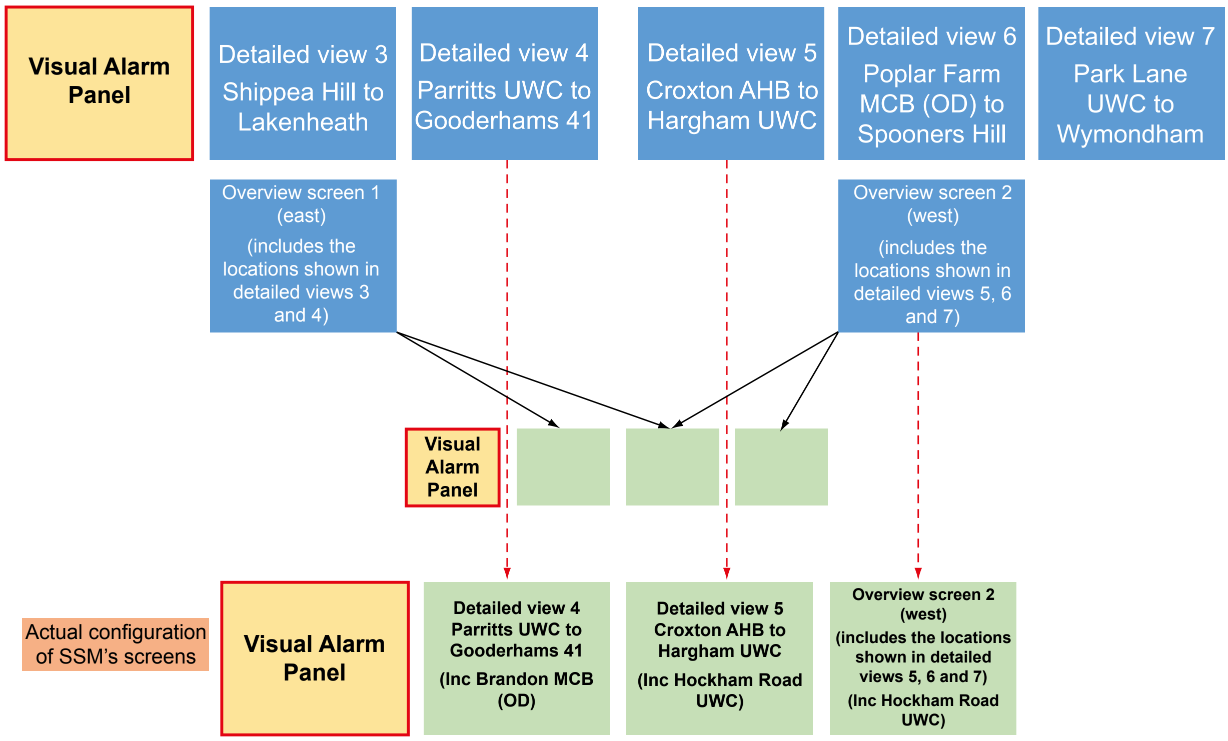
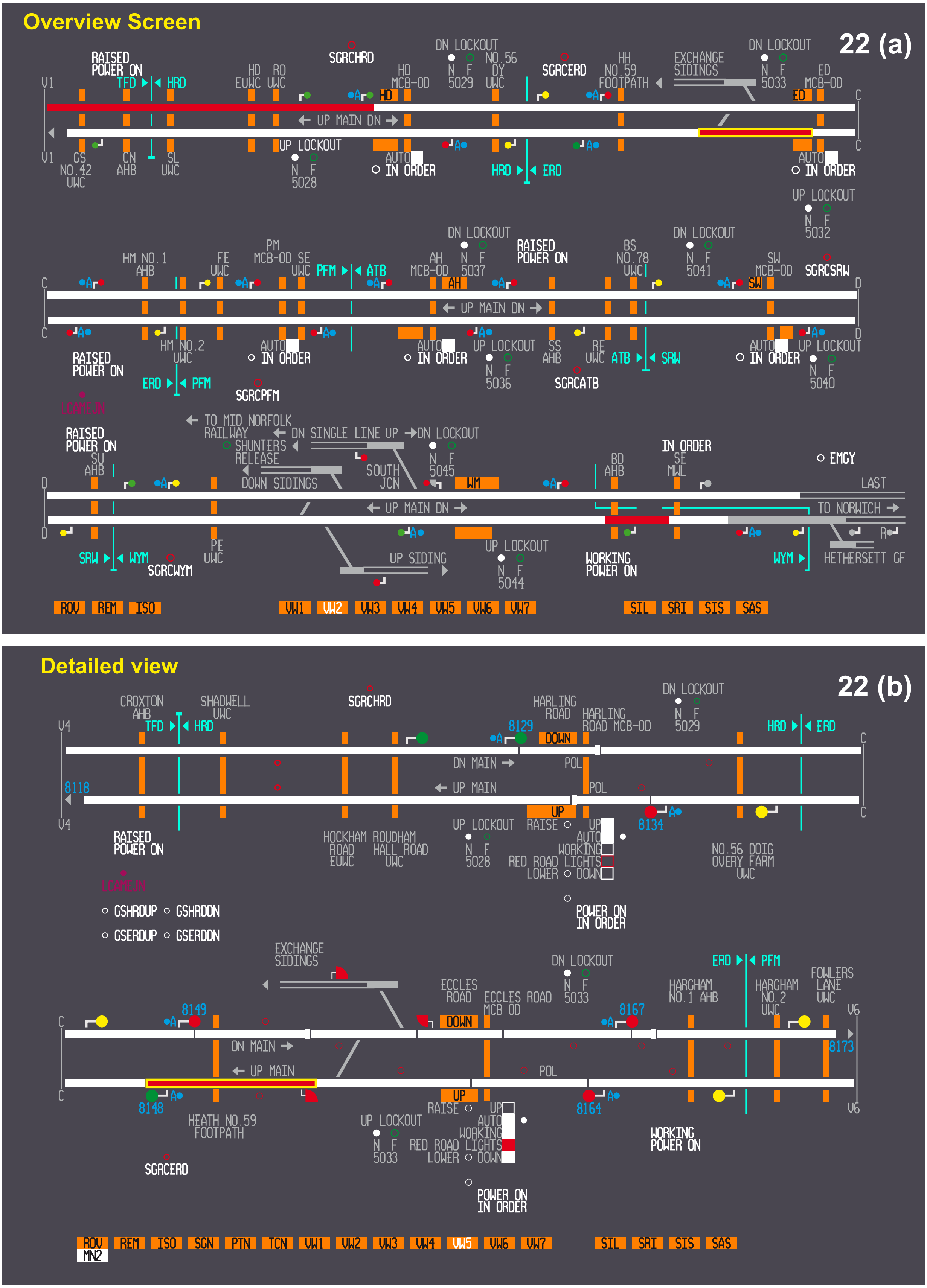
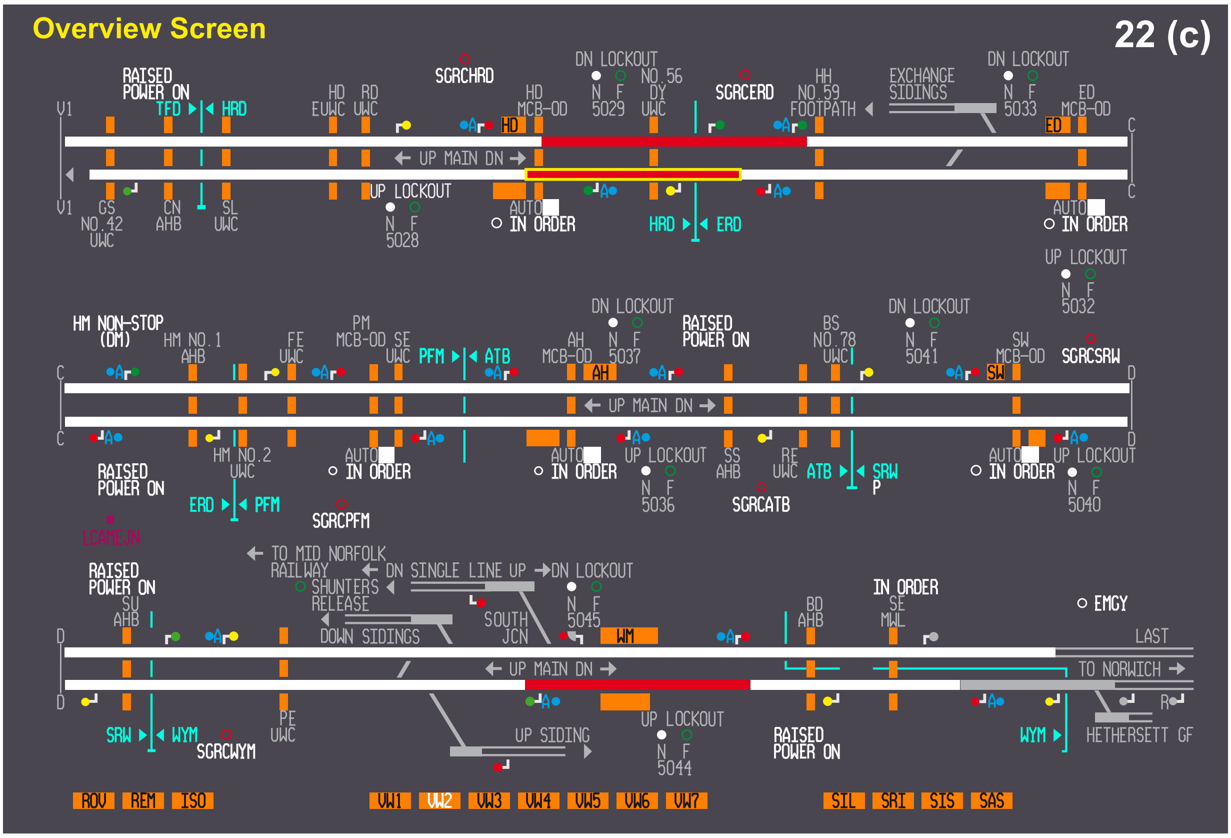


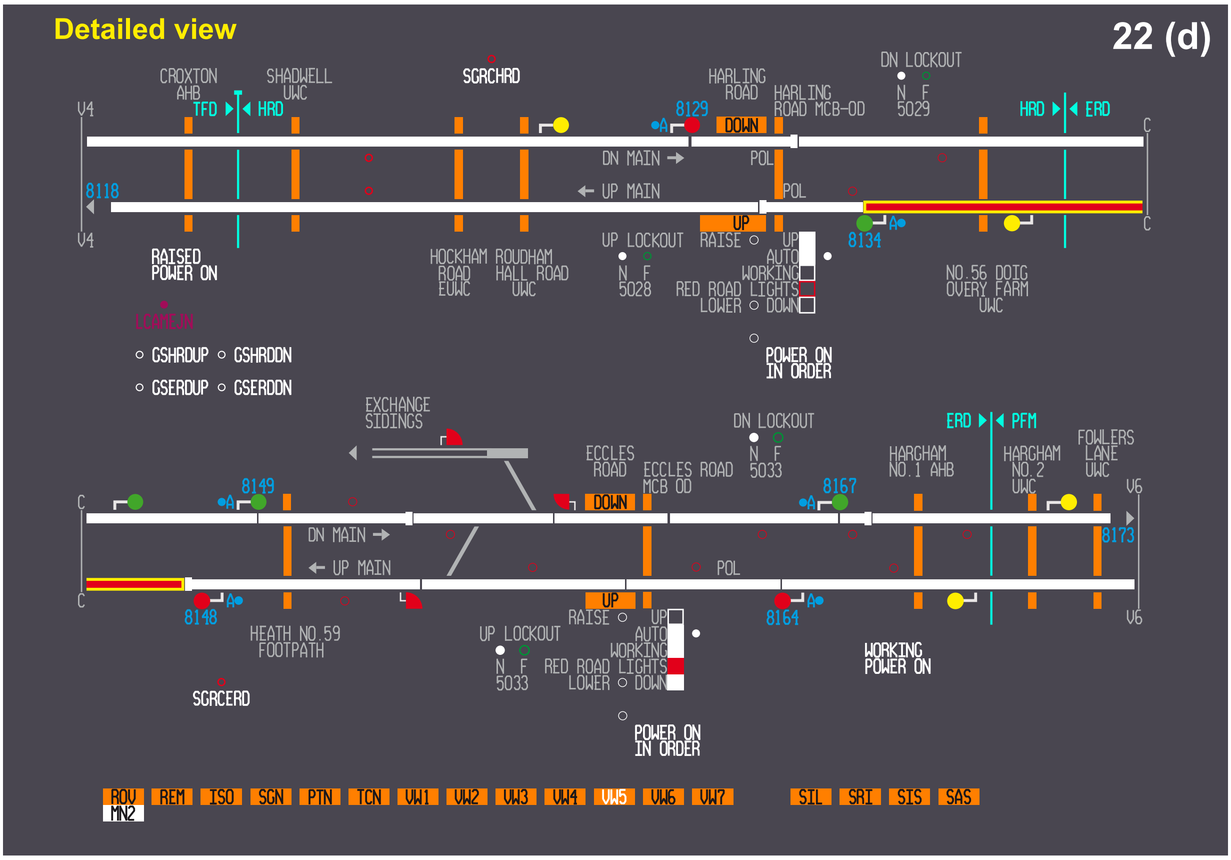
Figure 21: Diagram showing the possible configurations (overview and detailed screen) available to the signaller (in blue) and the actual screen views (in green) visible on the Thetford workstation at the time of the accident

Figures 22 (a) to 22 (h): Reconstructed images of the 'overview' and 'detailed' screen layouts of the Thetford workstation showing the passage of a train from Eccles Road to Hockham Road UWC

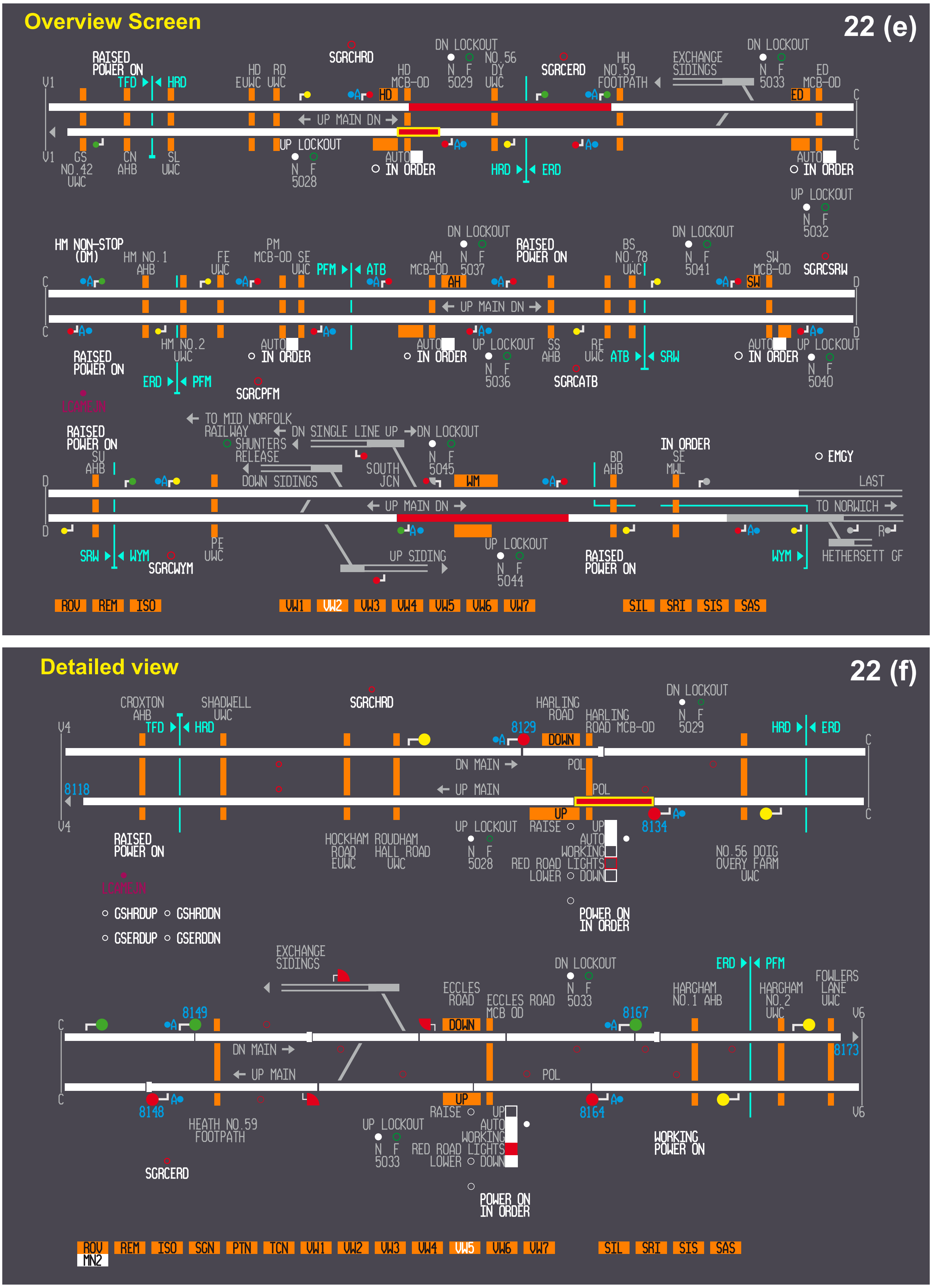


Figures 22 (a) and (b): overview and detailed views with train 1K77 travelling past Eccles Road MCB (OD) crossing at 12:24:46 hrs. Note: train 1K77 was shown as plain red on the VDU display. Highlight (yellow border) added by RAIB.

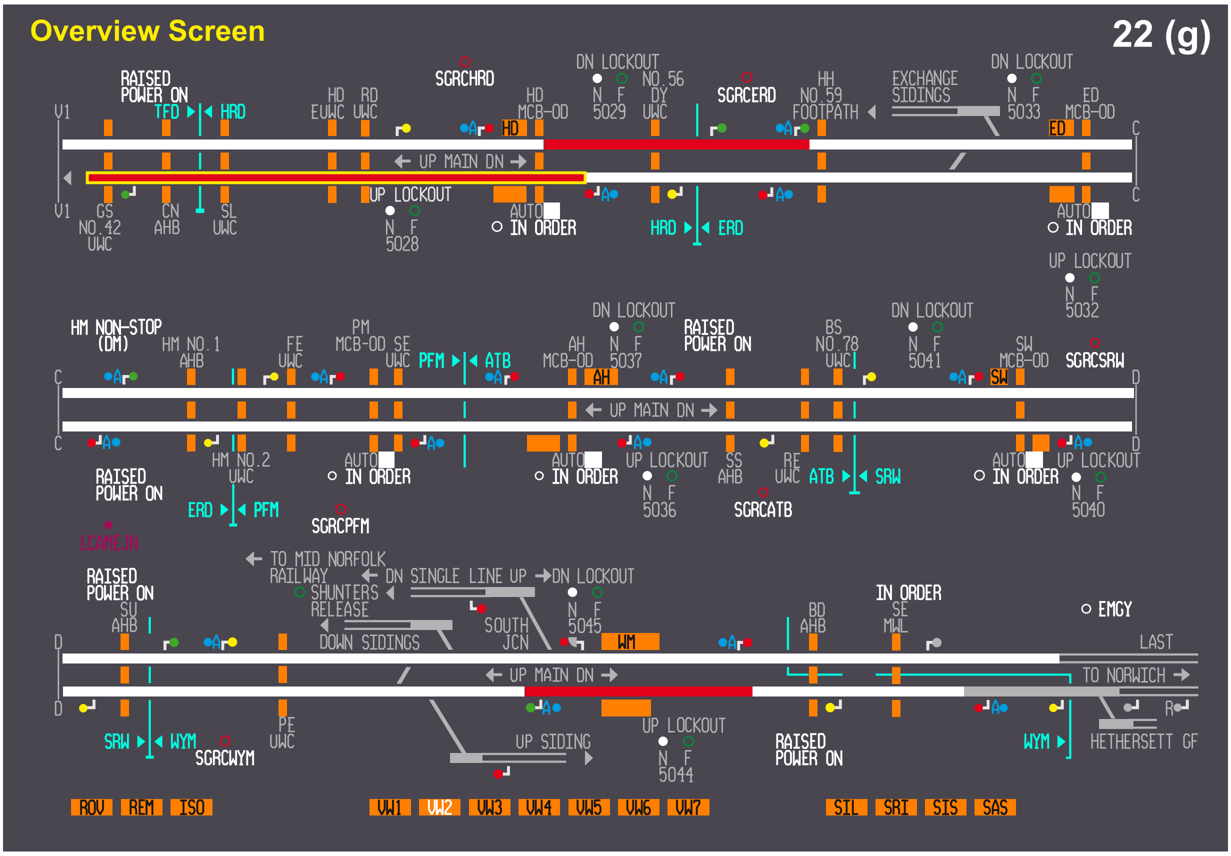


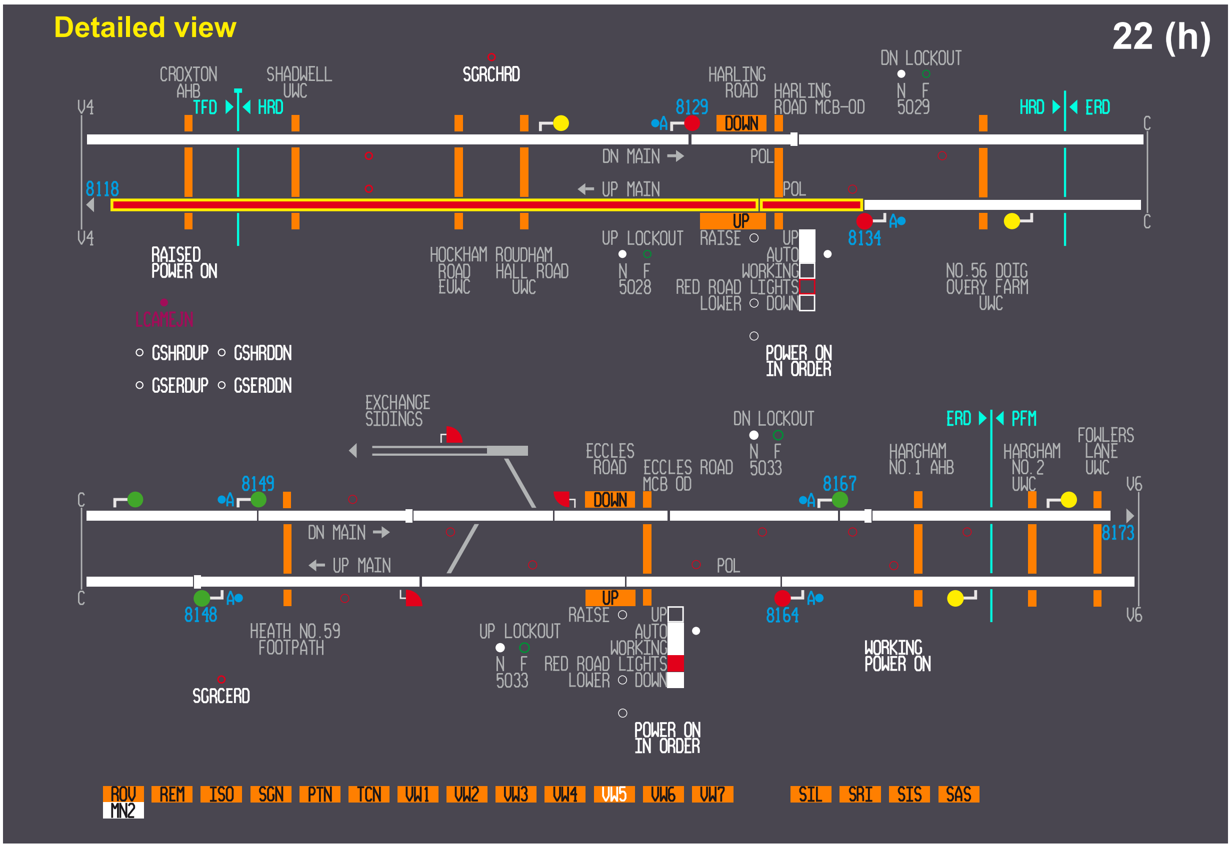


Figures 22 (c) and (d): overview and detailed views with train 1K77 travelling towards Harling Road MCB (OD) between 12:27:07 and 12:28:50 hrs. The signaller received the call from the user at Hockham Road UWC at 12:28:33 hrs. Note: train 1K77 was shown as plain red on the VDU display. Highlight (yellow border) added by RAIB.



Figures 22 (e) and (f): overview and detailed views of train 1K77 travelling past Harling Road MCB (OD) between 12:28:50 and 12:28:59 hrs. The signaller terminated the call from the user at Hockham Road UWC at 12:29:00 hrs. Note: train 1K77 was shown as plain red on the VDU display. Highlight (yellow border) added by RAIB.





Figures 22 (g) and (h): overview and detailed views of train travelling towards Hockham Road UWC between 12:28:59 and 12:30:26 hrs (12:30:04 hrs probable time of collision). Note: train 1K77 was shown as plain red on the VDU display. Highlight (yellow border) added by RAIB.

Training and competency

64 The signaller's competence to operate the workstation safely and effectively was not adequately monitored.

65 Network Rail's intention was that the Ely to Norwich route would be operating with new signalling from July 2012, and the full complement of signallers within Cambridge PSB would be transferred to a new roster that included the Thetford workstation. Witness evidence shows that the project team responsible for the delivery of the re-signalling project had assumed the signallers at Cambridge PSB were already competent in using a VDU-based system. As a result of this assumption the project team had only initially planned a two day refresher training course. Later they identified that staff at Cambridge PSB actually had little or no experience in using a VDU-based system, and so they increased the duration of the training to three weeks. The training was delivered by the Local Operations Manager (LOM), who was not previously an accredited trainer, but had volunteered to attend a revised training course so that he could deliver the training to his staff.

66 The LOM had significant problems with the installation of the equipment which delayed the training programme, and subsequent training (on a simulator and on the actual workstation) of staff on the VDU workstation, resulting in a temporary roster of six trained staff (out of 30) being implemented in order for the workstation to go 'live'. The signaller completed two weeks initial training followed by an additional one week course and, although he was passed as competent, he stated that he did not believe the training had provided him with the necessary confidence when using the system operationally. However, he did not raise this matter with the LOM. The training of all signalling staff was completed in January 2013.

67 In addition to the issues with training, numerous technical failures of MCB (OD) equipment also occurred during 2012 and 2013. The Cambridge signallers frequently had to deal with technical failures of the crossing equipment, some of which occurred at more than one crossing at the same time. This required the signaller to use different detailed screens on the workstation simultaneously, while also trying to maintain an overview of the train movements on the route. Three screens were recommended and installed by the project team at the Thetford workstation. Witness evidence indicates that the staff were unhappy with this number, and requested that more screens be provided to enable both overview and detailed displays to be available simultaneously (paragraphs 112 to 116). Although the technical problems with the crossings and the lower number of` screens were not a direct cause of the accident, the commissioning process, training issues with the simulator and technical failures that occurred in the first twelve months of operation resulted in some of the signalling staff losing confidence in the system.

68 Witness evidence indicates that some of the more experienced staff (including the signaller) disliked the computer technology so much that they actively avoided working on the workstation unless there was no alternative, such as when providing meal relief for a colleague. This is likely to have affected the signaller's confidence, familiarity, technical and non-technical skills and ultimately his competence in using it effectively and safely.

69 Signallers and SSMs within Cambridge PSB are required by Network Rail's operational procedure 4-20 to maintain familiarity with the workstation by working on it at least once every six months. The signallers were able to comply with the standard as they worked on the workstation at least once a week. The LOM was aware that some of his staff changed duties within the shift, as certain signallers were more amenable to working on the Thetford workstation, while some preferred to avoid the workstation and work on one of the three NX panels. The procedure does not define whether the requirement of 'once' every six months must be a full shift, or if it can be made up of a number of shorter periods. As the signaller involved in the accident disliked the workstation, he only worked on it when providing meal relief, for short periods of between 30 minutes and an hour at a time.

70 Evidence from Network Rail's records shows that the signaller only worked on the Thetford workstation for a total of 12 hours in 2014, 13.5 hours in 2015 and 3 hours in 2016 up to the date of the accident on 10 April. It is likely that the nature of the training (on the simulator and supervised on the live workstation) and his lack of experience may have affected his familiarity with using the workstation, thus reducing his confidence and competence in using the system.

71 Since the SSMs within Cambridge PSB were not rostered to work on the Thetford workstation, it is not clear whether the signaller was complying with Network Rail's 4-20 standard (although the LOM believed he was), by undertaking short periods of work, the cumulative total of which was slightly more than one 12 hour shift every 12 months on the workstation. However, these short periods are unlikely to have exposed him to the full range of actions and events that are experienced on the workstation. The LOM also believed the role of the SSMs was to manage the signalling staff, and that therefore the Network Rail process in relation to the SSM working a full shift on the workstation could not be fully applied. As the LOM did not implement the requirement for refresher training and the signaller took no steps to increase his own competence (and improve his familiarity and confidence), the signaller's lack of experience on the workstation was never identified. This may have been an underlying factor in the accident (see paragraph 106). The investigation also identified that managers in other areas of Network Rail were also unsure about how SSMs should comply with the Network Rail procedure in relation to maintaining familiarity with operating signalling equipment.

Concentration levels

72 The signaller's concentration levels may have decreased due to a combination of fatigue and a lack of engagement with the signalling task.

73 Prior to taking over the Thetford workstation at 12:00 hrs the signaller had been providing short periods of meal relief for signalling staff working on the three NX panels. This type of panel requires the signaller to be actively engaged in controlling and authorising the movement of the trains through each section of railway. Witness evidence is that this makes it relatively easy to maintain concentration levels. By contrast, the Thetford workstation only requires the signaller to monitor the trains, and there is no reason for active engagement with the operation of the railway, unless a level crossing user requests permission to cross, or a technical failure occurs, which requires the signaller to intervene to manage the situation.

74 This perceived lack of potential engagement, and an expectation that little vigilance or activity would be required, may have been the reason why the signaller took some food and reading matter over to the workstation as he started the period of meal relief.

75 The signaller was initially engaged in authorising a user to cross at Hiams Fen UWC at 12:03 hrs, and he was not required to perform any tasks for the next twenty five minutes. The subsequent call from the user at Hockham Road would have required him to refocus on the workstation and the task in hand.

76 The signaller had worked his rostered duty of three twelve hour night shifts (18:00 hrs to 06:00 hrs) on the preceding Monday, Tuesday and Wednesday. The signaller said that he never turned overtime down and preferred to work a night duty, and he agreed to work overtime, working similar night shifts on the Thursday and Friday nights, finishing on Saturday morning at 06:00 hrs. This shift pattern raises several fatigue risk factors according to the Office of Rail and Road's (ORR) guidance[12] on fatigue, relating to the consecutive nature of long night shifts. The signaller stated that after returning home from a night shift he would normally retire to bed at 07:00 hrs and wake during the afternoon. However, the signaller also stated that he had recently been swapping his duties to work regular night turns as he had been helping with family commitments during weekdays. This had resulted in a reduction in the duration of sleep, and instead of going to bed at 07:00 hrs each morning, he would not get to bed until 09:00 hrs, and would then have to be awake before 15:00 hrs. Research[13] shows that obtaining less than six hours' sleep per night increases the risk of fatigue. Taking all of this together, the RAIB concludes that the signaller was at an elevated risk of fatigue.

77 The signaller finished his last night turn at 06:00 hrs on Saturday morning, and as he was not helping with family commitments he went to bed at 07:00 hrs and awoke around 12:00 hrs. He did this in an attempt to adapt his sleep pattern as he was rostered on twelve hour day shift the following day. He went to bed at 22:00 hrs on Saturday night, and woke at 04:15 hrs on Sunday morning to travel and arrive for work for his day shift at 06:00 hrs. This pattern of shift change is generally acknowledged to provide insufficient rest and inadequate opportunity to become accustomed to daytime working[14].

78 The LOM was not aware of the signaller's family commitments and their potential effect on his fatigue levels. The roster clerk and LOM had therefore not been able to fully consider the additional risk when allowing the signaller to work the additional hours. Since 2012 Cambridge PSB has been running with between three to five vacancies per year resulting in routine overtime, the management of which may have been an underlying factor in the accident occurring (see paragraphs 105 to 110). However, the signaller's work pattern, including overtime, was not compliant with Network Rail's own fatigue management standard which required the signaller to have a 48 hour break of duty after a block of night turns. Witness evidence shows the signaller only had approximately 11.5 hours sleep between the start of his night shift on the Friday evening and the time of the accident on Sunday, having also worked 66.5 hours out of the previous 134 hours.

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[12] ORR (2012). 'Managing Rail Staff Fatigue'. Available at http://orr.gov.uk/__data/assets/pdf_file/0005/2867/managing_rail_fatigue.pdf.

[13] Dawson, D. & McCulloch, K. (2005). 'Managing fatigue: It's about sleep'. Sleep Medicine Reviews, 9, 365-380.

[14] See for instance ORR Good practice guidelines – Fatigue Factors (November 2016).

79 The signaller did not recognise that his shortened sleep pattern, combined with the change in shift pattern, was probably having a cumulative effect on his alertness. However, the RAIB believes that these factors increased the signaller's fatigue level, prior to the call being received from Hockham Road crossing. Furthermore, the combination of fatigue and a lack of engagement with the workstation may have affected his concentration levels due to boredom. The result of this may have been a lower level of vigilance, which meant that when the call from Hockham Road came through, the signaller may have found it difficult to re-engage with the task.

80 The signaller's blood sugar levels at the time of the accident are not known, and although the signaller said that he managed his diabetes, he reported that his blood sugar levels sometimes dipped during early afternoon. The LOM, who was aware of the signaller's condition, had no reason to believe it was not being effectively managed, and witness evidence indicates that the signaller was eating fruit before receiving the call from the tractor driver at Hockham UWC. Although this condition cannot be entirely discounted in contributing to any loss in concentration, the RAIB found no evidence to suggest that it was a factor in the causation of the accident.

EBI Gate 200

81 **The EBI Gate 200 system that would almost certainly have detected the presence of the train and probably prevented the accident had been temporarily decommissioned.**

82 In 2012, Network Rail had equipped Hockham Road UWC with the EBI Gate system which provided green and red lights to warn users whether or not it was safe to cross (paragraph 15). When train 1K77 approached the crossing, a functioning EBI Gate system would have detected the presence of the train and provided an audible warning and red lights, alerting the user to its presence. The decommissioning of the system was due to the following factors:

i. Network Rail had not come to a clear understanding with Bombardier on how the equipment had met the required *safety integrity level* (SIL) (paragraphs 83 to 94); and

ii. Network Rail assessed the risks and decided to turn off the EBI Gate system (paragraphs 95 to 103).

Each of these factors is now considered in turn.

Product development and approval process

83 **Network Rail had not come to a clear understanding with Bombardier on how the equipment had met the required safety integrity level.**

84 In 2009 Network Rail issued acceptance requirements for adding train detection equipment to existing passive level crossings to create enhanced user worked crossings ((E) UWC). These requirements stated that equipment used at this type of crossing must meet a minimum of Safety Integrity Level 3 (SIL 3)[15]. A description of the derivation and significance of the SIL is in appendix F.

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[15] Network Rail Acceptance Requirements (LCNST/AR/SD/001) Issue 1.1 (September 2009): Enhanced User Worked Crossings.

85 Following the accident at Sewage Works Lane UWC, Suffolk, in 2010 and a subsequent recommendation from the RAIB investigation (RAIB report 14/2011), Network Rail more actively sought a technical solution to providing positive detection of trains approaching level crossings where there was no other train detection or signalling equipment in the area.

86 In June 2010 Bombardier began to collaborate with Network Rail on developing such a system, and issued Network Rail's product approval engineer with hazard identification information and test reports. These were intended to support the validation of Bombardier's own design process, and the separate product acceptance proposal for what it had now named the EBI Gate system. As there was no commercially off-the-shelf SIL 3 PLC available, Bombardier reported to Network Rail that it had used other means to develop EBI Gate's SIL performance against Network Rail's user requirements (which specified SIL 3), and the required SIL level would be demonstrated using *Fault Tree Analysis*[16]. Network Rail reviewed these documents, and in March 2011 its engineers recommended a trial of EBI Gate equipment at Pools No.2 UWC, near Lakenheath, which commenced a month later.

87 From September 2011 to January 2012 Bombardier issued Network Rail with operational service data from the ongoing trial, to validate the operational data against its system architecture document (dated 26/10/11). The operational data showed that the system was behaving correctly, and consistent with the design of the system. Bombardier subsequently issued a system verification statement to Network Rail, which documented how the system would process information and operate. Although Network Rail engineers reviewed this documentation, the software verification report for the PLCs used in the equipment, generated on behalf of Bombardier, was not sent (paragraphs 99 to 101).

88 In February 2012 Network Rail's signal technology engineer reviewed the test data from the EBI Gate 200 trial in accordance with Network Rail's product acceptance process, and recommended EBI Gate 200 for full product approval.

89 The product acceptance certificate issued by the signal technology engineer should have included details of the product (hardware and software versions), the scope of authority for acceptance of the product, details of the assessed documents (safety verification, independent reports and safety case to support product acceptance) and any previous certificate history. However, the reports that were assessed only referred to the test reports, and no reference was made to the safety case documentation that should have been provided to comply with Network Rail's product acceptance process. Staff in Network Rail's signalling engineering department did not identify any issues with the proposals and the processes that Bombardier had used, and did not identify the missing safety documentation in the product approval file. A product approval Certificate of Acceptance for EBI Gate 200 was issued by Network Rail's Acceptance Panel in March 2012, for using the system on non-electrified lines.

[16] Bombardier's fault tree analysis for EBI Gate is dated May 2011.

90 Network Rail subsequently decided to install a further 23 EBI Gate 200 systems at various locations, and in June 2012 Hockham Road UWC and Crown Commissioners UWC were included in this list, because they both had a history of deliberate misuse and near miss incidents. Ebigate equipment at these two crossings was commissioned on 25 October 2012.

91 The system at Hockham Road operated without incident until March 2013, when a user alleged that a ‘wrong side’ failure had occurred, in that a green light showed when a train was passing. The system was temporarily decommissioned for investigation by Bombardier, but no fault was found. A similar allegation was made in December 2013. At the time Network Rail had no staff that had been trained to maintain the system or diagnose faults, and the initial maintenance contract with Bombardier had ended in October 2013. This prevented a technical investigation taking place, so EBI Gate was again decommissioned from April to September 2014, while training was carried out and maintenance arrangements were put in place. The subsequent investigation identified no fault with the equipment had occurred, and the system was re-commissioned in September 2014.

92 During the installation of EBI Gate 200 at Hockham Road UWC, Network Rail issued a new functional requirements document for overlay level crossing warning systems (dated August 2012), and in October 2012 it issued an invitation to tender for the provision of such systems in order to identify other possible technical solutions in the United Kingdom and Europe. The document stated that any overlay system must meet SIL 3, although witnesses have stated that Network Rail engineers indicated that they were also willing to consider SIL 1 products (ie a lower level of safety integrity). In October 2014 Bombardier and another company were awarded framework agreements to supply overlay equipment to Network Rail.

93 The Network Rail signal technology engineer who had dealt with the initial product acceptance process (paragraphs 87 to 88) retired in June 2012. The new product approval engineer who took over the project had no reason to doubt his former colleague’s belief that the Bombardier equipment had met the user requirements (SIL 3) because he believed that the system had been reviewed and had gained product approval.

94 The RAIB has not seen evidence to support Network Rail’s belief that its engineers sufficiently scrutinised the system architecture prior to and during the product acceptance and tender processes. Witness evidence also indicates that the document control and information relating to the user requirements during this period was not effectively managed. The witness evidence indicates that Network Rail engineers and those reviewing and approving product acceptance may have done so in the belief that the system was a novel product in development, that there was some urgency to install equipment of this type, and that the reputation of Bombardier meant that the system would be designed to an appropriate safety level.

95 **Network Rail decommissioned the EBI Gate system having decided it constituted an unacceptable risk.**

96 In December 2014 Bombardier submitted an additional product approval application for enhancement of the EBI Gate software, known as version 27. This was to rectify problems, known as 'dark mode', which occurred as a result of wrong direction train movements and slow moving trains. This failure mode caused both the red and green lights on the user's display to fail to illuminate when the user pressed the button. The signs at the crossing instruct the user to call the signaller if this happens.

97 A Network Rail Principal Product Engineer was asked to review Bombardier's proposal for software enhancement of EBI Gate[17]. He approved the submission for product acceptance. However, the following month the same engineer reviewed the historical product acceptance files relating to EBI Gate and identified that no safety case documentation for the original trial at Pools No.2 UWC was available. In response to this, Bombardier advised Network Rail that a safety case report had been issued to support the initial acceptance, but the company had not supplied it to Network Rail. Network Rail's engineer concluded that product approval appeared to have been given in the belief that a system verification statement supplied by Bombardier (paragraph 87) had shown that the test data for the trial of the equipment demonstrated that it complied with the intention of the design. He also found that the safety documentation had been signed off in the wrong order, with the original product approval being approved in March 2012, and the Independent Safety Assessment document, which did not reference any safety case, being issued in January 2014, some nineteen months later.

98 Having scrutinised the available documentation, the Principal Product Engineer concluded that it was not sufficient to demonstrate that the system met the specified SIL3 level. Network Rail immediately contacted Bombardier to request the missing documents. Several meetings took place between Bombardier and Network Rail engineers to attempt to resolve the issue. However, witness and documentary evidence show that no resolution was achieved, and the business relationship between the two companies deteriorated.

99 At that stage, rather than decommissioning the equipment, Network Rail decided that it would seek a second opinion. In June 2015 Network Rail commissioned an independent body to review the documents that had been supplied by Bombardier. The independent report did not find any evidence that the system would not meet the specified safety requirements. However, the independent assessor reported that the process used by Bombardier to justify the SIL was flawed. The report highlighted a considerable number of examples of poor practice on the part of both Network Rail and Bombardier, with particular reference to the following:

- Insufficient evidence had been provided to support a claim that the EBI Gate 200 product achieved a safety reliability within the limit set for a system operating at SIL 3.

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[17] In 2014 Network Rail restructured its engineering departments, bringing aspects of product development and technical engineering much closer together to enable better coordination and technical expertise.

- The safety case had no certificate of compliance to British Standard BS EN 50128 for the software, and it relied upon fault tree analysis. An independent verification report referenced in the safety case document had not been supplied for assessment (Bombardier stated that the independent verification report was not provided to Network Rail on the grounds that it was the subject of intellectual property rights, and that this had been previously agreed with Network Rail in the early stages of the product development of the EBI Gate system).
- The fault tree analysis provided within the documentation used reliability figures which are higher than can be justified for a non-SIL level rated PLC. On the basis of these figures, the independent assessor believed the best that could be expected for a non-SIL rated component for safety reliability of the product was no more than SIL 1.
- The construction and logic of the fault tree analysis provided in the documentation meant that no convincing argument had been produced to justify the independence of PLC faults, nor had the analysis demonstrated that a single PLC fault could not result in the 'top event' wrong side failure occurring (green light showing when a train was approaching the crossing).

100 Having reviewed the independent assessment report, Network Rail discussed the situation with the safety regulator, the Office of Rail and Road (ORR), on 14 September 2015. Network Rail's Head of Public and Passenger Safety Strategy briefed the ORR on the emerging issues with Bombardier, the findings from the independent assessment and the company's belief that the SIL level had not been demonstrated.

101 On 17 September Network Rail asked Bombardier to review its fault tree analysis and the assumptions it had made, and report its findings in writing. Bombardier then sent Network Rail documents to support its own independent safety verification report, which had been commissioned in May 2011.

102 On 5 October Network Rail's Level Crossing board met. Based upon the findings of the independent review of the EBI Gate 200 system and the information that had been presented and supplied by Bombardier, the Network Rail engineers reported that they did not accept Bombardier's justification for the way in which the system met the SIL3 level. They also stated that they had lost confidence in the EBI Gate 200 system to the extent that the risk could no longer be managed, which they now deemed was unacceptable for public safety. The Head of Level Crossing Engineering reported that he believed the EBI Gate 200 system was not a SIL 3 product, and recommended its immediate withdrawal. This was agreed by the meeting.

103 On 8 October Network Rail informed the ORR and Bombardier of the decision. Ten EBI Gate 200 sites, including Hockham Road, were decommissioned under a managed withdrawal incorporating a risk assessment of each individual location between October 2015 and January 2016.

The decision to decommission EBI Gate

104 Witness evidence indicates that although Network Rail managers did not always record how they had come to their decision to decommission the EBI Gate system, they took reasonable steps to resolve the issues identified with the EBI Gate 200 system. These included:

- completion of an initial review to evaluate the risk in the early part of 2015;
- engagement with Bombardier in an attempt to resolve the areas of concern;
- appointment of an independent assessor to challenge their own conclusions; and
- having reviewed the findings of the independent assessor which confirmed Network Rail's conclusions, consultation with the safety regulator (ORR) before deciding what action to take.

Identification of underlying factors

105 **Network Rail did not adequately define the minimum experience requirements necessary for signallers to maintain their competence to work safely and effectively on the Thetford workstation.**

106 The LOM believed that the signaller was complying with Network Rail's operations procedure 4-20 (paragraph 69) in maintaining his familiarity by undertaking occasional short periods of work on the Thetford workstation. Although the signaller considered that he was not sufficiently familiar with the workstation, he did not bring this to anyone's attention. Since the LOM did not recognise that the signaller's lack of experience on the workstation was a potential problem, and possibly not compliant with the operations procedure, no action was taken to improve the signaller's familliarity.

107 The RAIB identified that managers in other areas of Network Rail were also unsure about the time required by signallers to maintain competence in accordance with the procedure, and the procedure itself is not clear about how a suitable level of experience should be accumulated (paragraph 69).

108 **Fatigue management within Cambridge PSB was inadequate.**

109 The established staffing for Cambridge PSB was 25 signallers and 5 SSMs. Since 2012, Cambridge PSB had been running with between three and five vacancies because of retirements, long term sickness and the length of the recruitment process. Witness evidence indicates that the vacancies and the consequent overtime working had become part of the culture in Cambridge PSB, and that the signaller and other staff very rarely turned down overtime.

110 Although the LOM reported that he monitored any overtime and potential working hours exceedance in accordance with Network Rail standard NR/L2/ERG/003 'Management of fatigue: Control of working hours for staff undertaking safety critical work' (2011), the 8 and 12 hour roster pattern for Cambridge PSB was rarely reviewed against the recognised Fatigue Risk Index (FRI). The low staffing levels made fatigue management more difficult, and this may have been an underlying factor in the accident.

Observations

111 **The Thetford workstation was fitted with three screens rather than four as originally designed.**

112 When the Ely to Norwich re-signalling was first proposed in April 2008, the Thetford workstation was designed to have four VDU screens. Subsequently, an ergonomic assessment took place at each of the signal boxes to be closed to identify the likely workload and demand for the new workstation. The report concluded that the signaller would be able to manage the infrastructure under normal operational conditions using overview screens, and that four screens would be appropriate.

113 Despite representations from the signalling staff, citing the length of the signal sections, the number of UWCs on the route and the anticipated demand from crossing users, only three screens were installed on the workstation when it was commissioned in 2012 (paragraph 67). The RAIB has not been able to establish why the staff's representations were unsuccessful.

114 Further complaints were made by staff during 2014 when two alleged wrong side failure incidents were reported at Hockham Road UWC concerning the EBI Gate 200 system (in March and December 2013), the second of which resulted in the EBI Gate system being turned off for six months and the crossing reverting back to a UWCT (paragraph 90). This again increased the workload for the signalling staff (because they now needed to respond to telephone calls from users asking for permission to cross, up to 120 times each day at some times of year) until the EBI Gate system was turned back on in September 2014.

115 In December 2012 an investigation by the RAIB into a near miss incident at Ufton AHBC (RAIB report 28/2012) identified a risk that the information about level crossings displayed on VDU workstations could be confusing for signallers. In response to this, Network Rail began to undertake assessments at specific power signal boxes. Signalling staff and the Cambridge LOM expressed their concerns and requested that a risk assessment take place to determine the need for additional screens. An additional assessment was then undertaken by the Head of Ergonomics in June 2015, which recommended that the workstation should be increased to a minimum of five screens.

116 In October 2015 the product approval for the EBI Gate system was withdrawn. The decommissioned crossings reverted back to UWCs. This meant that the users were once again required to use the telephones to ask for permission to cross. This again increased the workload on the signallers. The procurement of the additional screens was not authorised until February 2016 and the screens were not installed by the date of the accident. Although the number of screens is not considered to be a factor in the accident occurring, the RAIB observes that there was ample evidence that three screens was insufficient (no recommendation, see paragraph 135).

117 The information displayed to a signaller is not designed to help them judge when it is safe to allow a user to cross at a UWC.

118 When a crossing user telephones for permission to use a UWC, the signaller must gather, from various sources, the necessary information to support a decision on whether it is safe to give the user permission to cross. The RAIB investigation identified that the signalling staff at Cambridge PSB used a range of different information, of variable quality, to inform their decisions. These included conversations with the crossing users to ascertain the time needed to cross and judgements of the train position based upon the information displayed on the VDU. For some UWCs individual signallers had selected a particular screen event, such as the operation of an automatic crossing or the occupation of a track circuit, as an indication that a train is now so close that intending users should be asked to wait.

119 Section 2.1.1 of Rule book module TS9 defines what the signaller should do:

When you receive a telephone call from the crossing, you must find out:

- *which crossing the user wants to use;*
- *what is required to pass over the crossing;*
- *how long it will take; and*

If there is enough time for the crossing to be used before the next train passes over it, you must, except as shown in regulation 2.1.2[18]*, tell the user to use the crossing immediately.*

If there is not enough time, you must tell the user to wait and telephone again.

120 The signs at a UWC do not specify whether a user should open the gates before or after getting permission to cross from the signaller (figure 18). As there is neither a requirement for the user to tell the signaller whether the gates are already open, nor for the signaller required to ask if they are, the user's estimation of the time required to cross, and the signaller's perception of the situation can vary significantly. It is therefore vital that the user and the signaller come to a clear understanding. This can be difficult, as the user, a member of the public, may not fully understand the limitations of the information available to the signaller.

121 The information displayed on the VDU screen allows a signaller to make an informed decision about where a train is located, within certain limits. Although in some cases the indications of the state of level crossing barriers can provide more detail of where a train is, if the train is within a long signal section there may be nothing to tell the signaller how long it is likely to take to reach the crossing, and therefore whether it is safe to allow the user to cross. This can create a safety risk as a signaller may refuse the request, without being able to say how long the wait may be, and the user may become frustrated and decide to cross without permission.

[18] Regulation 2.1.2 deals with users who require to cross with animals or large or slow-moving vehicles. It requires the signaller to place and maintain the protecting signals at danger before giving permission to cross and until the user has finished crossing and reported back that the crossing is clear.

122 The RAIB is aware of a number of recent incidents at user worked crossings with telephones in which signallers have not obtained clear information from the crossing user, or misjudged the location of the train. This has resulted in a signaller giving permission for a user to cross the railway with a train approaching the crossing. Some of these incidents could have resulted in a collision occurring had the signaller not realised their error and called the user back, and others have resulted in a near miss incident. One of these incidents, at Dock Lane crossing near Melton, Suffolk, on 14 June 2016, is currently the subject of a separate investigation by the RAIB. Another, at Thorney Marsh Lane crossing at Castle Cary, Somerset in November 2016, is described in RAIB's safety digest 02/2017.

Summary of conclusions

Immediate cause

123 The tractor driver drove onto the crossing as the train was approaching (paragraph 53).

Causal factors

124 The causal factors were:

a. The signaller gave permission for the tractor to cross when there was insufficient time for it to do so in safety (paragraph 55, **Recommendation 1**).

b. Although information about the position of the incident train was available on the signaller's display, the signaller lost his awareness of the position of the train (paragraphs 59 to 62), because of one or both of the following factors:

- the signaller's competence to operate the workstation safely and effectively was not adequately monitored (paragraphs 64 to 70, **Recommendation 3**, see paragraph 137); and
- the signaller's concentration levels may have decreased due to a combination of fatigue and a lack of engagement with the signalling task (paragraphs 72 to 79, no recommendation, see paragraph 137).

c. The EBI Gate 200 system that would have detected the presence of the train and would have probably prevented the accident had been temporarily decommissioned. This was due to the following factors:

- Network Rail had not come to a clear understanding with Bombardier on how the equipment had met the required safety integrity level (paragraphs 83 to 94, no recommendation); and
- Network Rail decommissioned the EBI Gate system having decided it constituted an unacceptable risk (paragraphs 95 to 103, no recommendation).

Underlying factors

125 Underlying factors were:

a. Network Rail did not adequately define the minimum experience requirements necessary for signallers to maintain their competence to work safely and effectively on the Thetford workstation (paragraph 105, **Recommendation 3,** see paragraph 137); and

b. Fatigue management within Cambridge PSB was inadequate (paragraph 108, no recommendation, see paragraph 137).

Additional observations

126 The Thetford workstation had only three screens, rather than four as originally designed (paragraphs 111 to 116, **Recommendation 2**, see paragraph 135(c)).

127 The information displayed to a signaller is not designed to help them judge when it is safe to allow a user to cross at a UWC (paragraph 117, **Recommendation 1**).

Previous RAIB recommendations relevant to this investigation

128 The following recommendations, which were made by the RAIB as a result of its previous investigations, have relevance to this investigation.

Accident at Oakwood Farm UWC, 14 May 2015

129 Recommendation 3 of this report (RAIB report 07/2016) arose from an investigation into a collision at a level crossing where the introduction of novel protection equipment had not been well managed. The implementation of this recommendation should reduce the risk of a future scheme being undertaken without adequate safety assurance.

130 Recommendation 3 read as follows:

The intent of this recommendation is to reduce the risk from the introduction of infrastructure equipment onto the railway network.

Network Rail should review the robustness of its processes for accepting new equipment and technology onto the railway, including particular consideration of the following:

a) definition and adherence to an appropriate level of safety assurance;

b) the early involvement of human factors expertise, where appropriate, throughout the product's introduction;

c) the risk assessment processes applied to the new equipment itself and the infrastructure into which it is to be integrated;

d) definition and monitoring of trials, implementation of any resulting improvements, and the roll-out of the product to other locations;

e) maintenance of a hazard record for the life-cycle of the product; and

f) a process for undertaking regular audits to check the implementation of its product introduction processes and correcting any identified shortcoming. It should then, where appropriate, produce a time bound plan for the amendment of the standard.

131 No update on progress with implementation of the recommendation has been received by the RAIB at the time of writing this report.

Derailment at Knaresborough, 7 November 2015

132 Recommendation 1 of this report (RAIB report 16/2016) arose from an accident in which a mobile operations manager, working temporarily in a signal box to cover for a sick member of staff, made an error in the operation of the box which resulted in a derailment. It is included here because it covers a similar subject area to an underlying factor identified in this investigation (paragraph 125a), although it relates to a different group of staff.

133 Recommendation 1 read as follows:

The intent of this recommendation is that signal boxes should always be operated by members of staff who have the necessary knowledge and familiarity with the signal box and its operation.

This recommendation relates to the signaller competence action plan which was initiated by Network Rail in April 2016.

When carrying out its review of the effectiveness of the recently revised procedure 4-20 of the Operations Manual NR/L3/OPS/041, Network Rail should review whether the changes to the requirements on non-signallers have resulted in them maintaining the required level of knowledge and experience needed to operate the signalling locations for which they are authorised, including where it has not been practicable for them to operate those locations, and implement any further necessary changes.

134 No update on progress with implementation of the recommendation has been received by the RAIB at the time of writing this report.

Actions reported as already taken or in progress relevant to this report

135 Network Rail has taken the following action:

a. Following the decommissioning of the EBI Gate 200 systems already installed, Network Rail agreed with Bombardier that a complete modification was required for the system incorporating a commercially available SIL 3 PLC and a change in circuit boards to meet Network Rail's product acceptance and installation standard. This version, known as Modification 3, was given product acceptance for trial on 16 September 2016.

b. At Cambridge Power Signal Box, Network Rail has begun a trial involving signallers using a verbal commentary technique when dealing with requests from certain UWCs on the Thetford workstation. This technique involves the signaller commentating on the decision making so as to provide them with a further opportunity to review each decision as they make it. A weekly safety critical communications check has been implemented to monitor the technique and trial.

c. Following the incident in 2016 the label for Hockham Road was changed to 'HOCK EUWC' (see figure 21). Six screens have now been installed at the Thetford workstation and local box instructions now mandate the use of detailed screens when authorising users to cross at a UWCT.

d. Network Rail has also:

    i. set up a review of the product acceptance and validation process which relates to the introduction of new signalling installations, level crossing and control equipment. This will seek to understand how a SIL level 1 rather than 3 was provided, accepted and commissioned at Hockham Road. The review will also include the processes for appointing an independent assessment body to prevent duplication and ensure the report is robust and transparent for all stakeholders.

    ii. undertaken a review of all 'long sections' in modular signalling installations with a view to identifying guidance and technical improvements that would provide a signaller with more information and accuracy as to the location of a train's location (possibly by the inclusion of double axle counter sections particularly in those sections where there are a high number of UWCTs').

    iii. begun to review the process and information required by signallers when deciding to permit a user to cross the railway. This will include consideration of how to define a slow moving vehicle, whether the vehicle is towing a trailer and if the crossing gates are already open, all of which could affect the time required and the signaller's decision to allow the user to cross the railway.

    iv. reviewed its standard 4-20 'Competence to Operate Signalling Equipment', taking into account the findings from this accident and other incidents. This now makes additional reference to the local assessment of time on a workstation, but the standard is not prescriptive about the time required to be worked at a specific location, as this is considered to be a local issue.

136 Network Rail provided the RAIB with a copy of an internal document that describes its long-term national strategy for improving safety at level crossings, entitled 'Transforming Level Crossings'. The strategy identifies a number of implementation milestones – these include a statement that by 2025 telephones will not be the primary means of protection at any user worked crossings.

Actions reported that address factors which otherwise would have resulted in a RAIB recommendation

137 The RAIB investigation identified that the signaller may have been fatigued at the time of the accident, and the processes in place for the management of fatigue (including the control of rest day working) were not adequate. The lack of adequate information on fatigue and lifestyle management for signalling staff was also identified as a factor, as activities outside of work can affect a person's fitness for work. As a result of the accident Network Rail provided RAIB with evidence that the fatigue management process at Cambridge PSB had been reviewed and staff had been re-briefed on lifestyle and looking after their own wellbeing to reduce the risk of fatigue. Therefore RAIB has decided not to make a recommendation.

138 Network Rail has reviewed the competence management arrangements for staff at Cambridge PSB, including shift managers, to provide assurance that all staff are fully competent to operate all the equipment that they may have to use, including the Thetford workstation, and made arrangements to ensure that all staff get sufficient time on shift to maintain their familiarity with the equipment.

139 Network Rail has reviewed and updated the guidance that it gives to signallers on giving permission to level crossing users to cross the railway. This has included identifying best practice and preparing briefing and guidance material for signallers, which has been disseminated through video and written media. This has covered techniques including active engagement with the user, and verbal commentary on the information which is being gathered.

Recommendations

140 The following recommendations are made[19]:

1 *Recognising Networks Rail's stated intention to reduce its reliance on telephone protection at user worked crossings (paragraph 136), the intent of this recommendation is to reduce the risk of signaller error at user worked crossings.*

Network Rail should undertake a review of its measures for the protection of user worked crossings with the objective of identifying means of reducing the likelihood that an accident will be caused by signaller error. Options for consideration should include:

- improved information for signallers (including consideration of ways of better enabling signallers to judge the time needed for a movement over a crossing and the time available before a train arrives at a level crossing);
- increased use of automatic warning systems; and
- closure of UWCs or their replacement by automatic crossings.

The review should also identify criteria for the prioritisation of improvements taking into account both risk and the opportunities presented by planned signalling upgrades. The findings of the review should be incorporated into Network Rail's level crossing strategy and the standards used to prepare specifications for new signalling schemes (paragraph 124a).

2 *The intent of this recommendation is to improve the way in which new equipment is introduced to existing signalling locations, to reduce the risk of operating errors caused by inadequate competence.*

Network Rail should review and improve its processes for introducing signalling equipment where the user interface has significantly altered (eg the replacement of NX panels with VDU-based workstations). This review should include the selection, training and management of staff who operate the new equipment, so that they achieve and maintain an appropriate level of competence (paragraph 126).

[19] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation, and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail and Road enable it to carry out its duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.gov.uk/raib.

3 *The intent of this recommendation is to improve the competence of Signalling Shift Managers.*

Network Rail should review the competence management arrangements for Signalling Shift Managers, to provide assurance that they are competent to use all the equipment that they may be required to operate. This review should include consideration of the amount of time on shift and the frequency of operation required to maintain familiarity with the different types of equipment (paragraphs 124b and 125b).

Appendices

Appendix A - Glossary of abbreviations and acronyms

AHBC	Automatic half-barrier crossing
ALCRM	All level crossing risk model
BTP	British Transport Police
BSEN	British standard / european norm
GSMR	Global system for mobile communications - railways
LOM	Local operations manager
MCB (OD)	Manually controlled barriers (obstacle detectors)
MOM	Mobile operations manager
MSL	Miniature stop lights
NX	Entrance / exit
ORR	Office of Rail and Road
PSB	Power signal box
PLC	Programmable logic controller
RAIB	Rail Accident Investigation Branch
REC	Railway emergency call
SIL	Safety integrity level
SSM	Signalling shift manager
UWC (T)	User worked crossing (telephone)
(E) UWC	Enhanced user worked crossing
VDU	Visual display unit

Appendix B - Glossary of terms

All definitions marked with an asterisk, thus (*), have been taken from Ellis's British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com.

Authorised user	A person who has legal authority to use a user worked crossing.
Automatic half-barrier crossing	A type of level crossing activated by the approach of trains, in which barriers close off half the width of the road.
Axle counter	A track-mounted device that accurately counts passing axles. By using an axle counter evaluator to compare the number of axles entering and leaving an axle counter section, the signalling system can determine whether the section is clear or occupied.*
Chain	A unit of length, being 66 feet or 22 yards (about 20.12 metres). There are 80 chains in one standard mile.*
Cess	The space besides the railway line.
Diesel multiple unit	A diesel powered train consisting of one or more coaches with a driving cab at each end, which can couple to other multiple units and control them from the leading cab.
Down line	The line normally used by trains travelling towards Norwich.
Entrance-exit panel	A signal box control panel fitted with buttons for all entrances and exits, plus some intermediate points. To set a route, the signaller depresses the appropriate buttons in front of the train and at its exit point, and a panel processor sets the route.*
Fault Tree Analysis	To model, in a diagrammatic format, the sequence of events that can develop in a system as a consequence of combinations of basic events which may lead to system error or an unsafe mode.
Global System for mobile communications – railway	A national radio system which provides secure voice communications between trains and signallers, relaying calls via radio base stations built alongside the railway or on suitable vantage points.
Lever frame	An assembly of two or more levers and an interlocking system, arranged to control the points and signals in an area mechanically or electrically.*
Manually controlled barriers with obstacle detection	A type of level crossing with full barriers in which obstacle detectors are used to prove that the crossing is clear before trains are permitted to pass over it.
Mobile operations manager	An individual who manages specified operational issues within an area of Network Rail infrastructure including being the first line of management attendance at operational incidents.
Overlay system	A system that is not integrated with the signalling system.

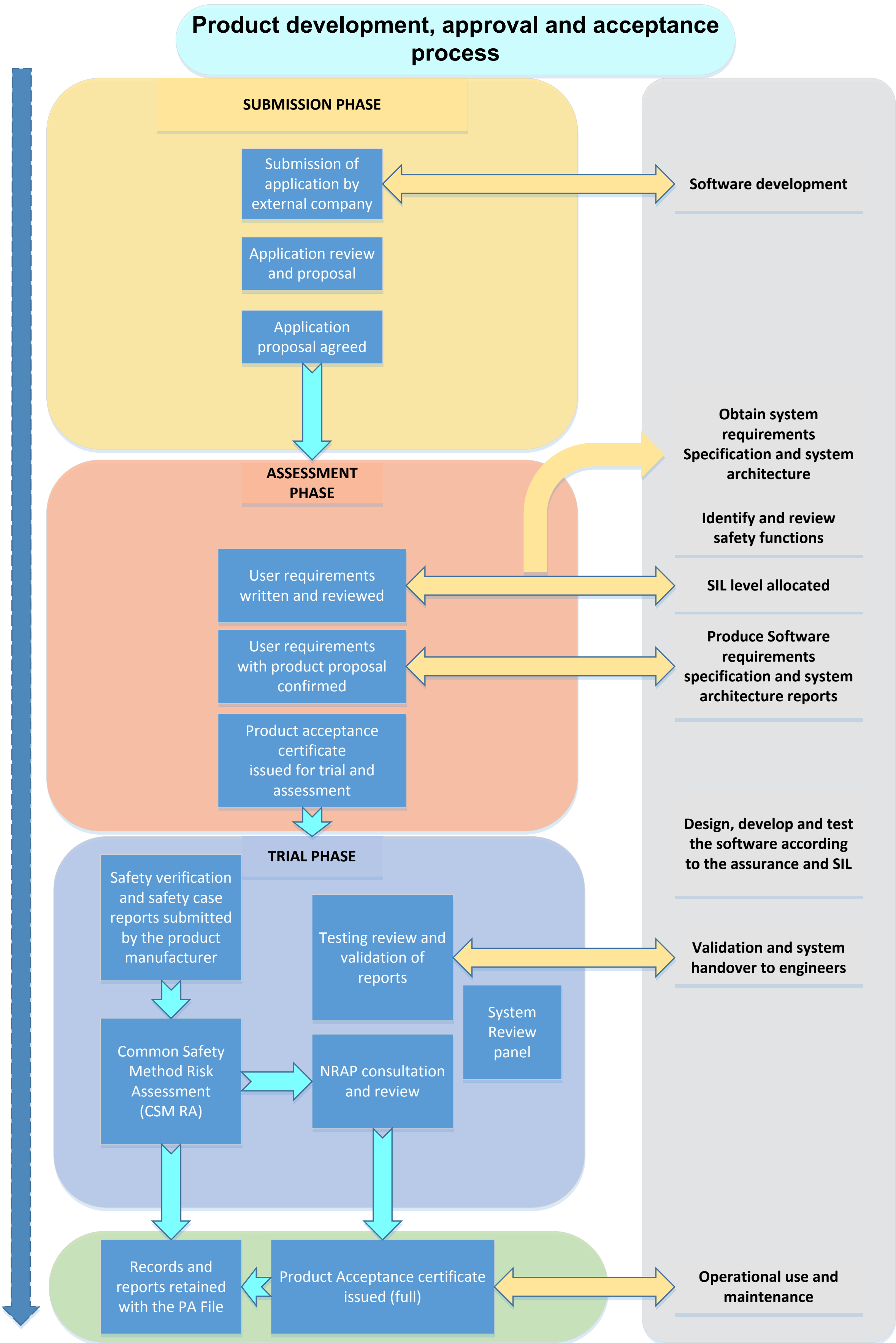
Power signal box	A large signal box which controls the points and signals over a large area by electrical means.
Programmable Logic Controller	A solid-state control system which has a user programmable memory for storage of instructions to implement specific functions.
Railway Emergency Call	The emergency call function of the GSM-R system, which is transmitted to all trains in a signalling area.
Safety Integrity Level	Software safety integrity level classification number which determines the techniques and measures that have to be applied to software. Safety-related software has been classified into four safety integrity levels, where 1 is the lowest and 4 the highest.
Shift signalling manager	A supervisor who oversees operations in a power signal box.
Track circuit block	A method of signalling trains in a section of line where safety is ensured by the use of track circuits or other means of automatic train absence detection and without the use of block instruments.
Up line	The line normally used by trains travelling towards Ely and London.
User worked crossing (including enhanced)	A type of level crossing where the gates are opened and closed by the user. An enhanced crossing is a crossing with an overlay system installed (an overlay system is not integrated into the signalling system to control train movement).

Appendix C - Investigation details

The RAIB used the following sources of evidence in this investigation:

- information provided by witnesses;
- information taken from the train's on-train data recorder (OTDR);
- site photographs and measurements;
- weather reports and observations at the site;
- a review of previous reported accidents and incidents; and
- a review of previous RAIB investigations that had relevance to this accident.

Appendix D - Product development, approval and acceptance process



Appendix E - Safety Integrity Levels and software design

British Standard BSEN50128 'Railway applications – Signalling and processing systems – Software for railway control and protection systems' outlines the approval process for individual systems within the overall railway control and protection system, and BSEN 50129 'Railway applications - Communication, signalling and processing systems – Safety related electronic systems for signalling' (2003) mandates the process to be used in order to develop and validate software used in signalling systems to meet the required Safety Integrity Level (SIL).

The SIL is defined as a relative level of risk reduction provided by a safety function, or a target level of risk reduction. In simple terms, the SIL is a measurement of performance required for safety critical equipment. Four SIL are defined, with SIL 4 being the highest and most dependable (unlikely to generate an unsafe mode and incident within 10,000 to 100,000 years), SIL 3 provides a likely failure rate of between 1000 to 10,000 years (and is the minimum level required for a signalling system on the railway) and SIL 1 is the least reliable and most likely to generate an incident and unsafe mode, between 10 and 100 years. A SIL is determined based on a number of quantitative factors in combination with qualitative factors such as the development process of the product, safety life cycle, maintenance and management processes.

The systematic approach be taken in the development and installation of a software system is necessary to:

- identify hazards, assessing risks and arriving at decisions based on risk criteria;
- identify the necessary risk reduction to meet the risk acceptance criteria;
- define an overall safety requirements specification for the safeguards necessary to achieve the required risk reduction. The system requirements specification identifies all safety functions allocated to software and determines the system Safety Integrity Level (SIL). These requirements are as follows:
  a. define software requirements;
  b. design, develop and test the software according to a software quality assurance plan, the software safety integrity level and the software lifecycle;
  c. integrate the software onto the hardware and verify its functionality;
  d. accept and deploy the equipment;
  e. implement a software maintenance plan;
  f. development, testing and verification of the software data in operation, and
  g. validation, assessment, quality assurance, modification and if necessary subsequent change control.
- select a suitable system architecture; and
- plan, monitor and control the technical and managerial activities necessary to translate the System Safety Requirements Specification into a Safety-Related System validating the safety integrity.

Appendix F - Management of fatigue

Since 1999, a number of companies within the railway industry have used a 'Fatigue Index'[20] (developed by the Health & Safety Executive) to assess the impact of shift work and rostered working hours on their staff. In 2006, the Fatigue Index was enhanced with the addition of a 'Risk Index', which was intended to enable an assessment to be made of the relative risk of the occurrence of an incident on a particular shift, taking account of the rostered hours. The two indices were combined to form the Fatigue and Risk Index (FRI), a spreadsheet-based tool, the latest version of which is version 2.3, introduced in January 2013.

A user is able to input details of the hours worked in the preceding weeks for an individual member of staff. The Fatigue and Risk Index then produces separate scores for fatigue and risk based on a number of parameters which include the time of day, duration of the shift, rest periods and breaks within a shift and a cumulative component in which the individual duty periods are put together to form a complete schedule.

For the fatigue element of the Fatigue and Risk Index, the result is shown as a value between 0 and 100 and relates to the percentage probability of high levels of sleepiness occurring. Whilst neither the Health and Safety Executive nor the Office of Rail and Road advocate threshold values for fatigue, research conducted in the UK rail sector by the Health and Safety Laboratory for the ORR found values up to 30 to 35 for day shifts and 40 to 45 for night shifts to be normal and achievable. The fatigue index only provides an approximation of the risk and deals with a population average. Moreover, the cumulative effect of hours worked is only one factor that can influence fatigue; the distribution of shifts and sleeping patterns may also have an effect[21].

[20] Current version available at http://www.hse.gov.uk/research/rrhtm/rr446.htm.

[21] See, for example, Hobbs, A., Avers, K.B. and Hiles, J.J. 2011, Fatigue risk management in aviation maintenance: current best practices and potential future countermeasures. Report no. DOT/FAA/AM-11/10. (Federal Aviation Administration, Washington, DC).

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