RAIB

Rail Accident Investigation Branch

Rail Accident Report

Unauthorised entry of a train onto a single line at Greenford
20 March 2014

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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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Unauthorised entry of a train onto a single line at Greenford, 20 March 2014

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Summary

At around 11:55 hrs on Thursday 20 March 2014, the 11:36 hrs passenger train from London Paddington to West Ruislip, operated by Chiltern Railways, passed two consecutive signals at danger near Greenford, west London. It was stopped when a signaller sent an emergency radio message to the driver. Although no-one was hurt in the incident, the unauthorised entry of a train onto a single line creates the potential for a serious collision.

A freight train had passed the junction at Greenford shortly before the passenger train was due. Because the freight train was still occupying the line between Greenford and South Ruislip, the signaller at Greenford kept the signal at the junction at danger. The passenger train, travelling at about 20 mph (32 km/h), passed this signal and the next one, 142 yards (130 metres) further on, which was also at danger. It passed over the junction and onto the single-track section towards South Ruislip, which was still occupied by the freight train. The train had travelled about one mile (1.6 km) beyond Greenford by the time that the driver received the emergency radio message.

The investigation found that the driver of the passenger train did not react to the two signals at danger, for reasons which are not certain. It is possible that he had formed the impression that the train had been given clear signals through Greenford, because of his interpretation of the meaning of the signal preceding those that he passed at danger, and he had not been stopped by signals at Greenford in the recent past.

The Train Protection and Warning System (TPWS) was fitted to the train and to both the signals, but it did not intervene to apply the brakes of the train, as it was intended to do. This was because the on-train TPWS equipment had self-isolated when the driver prepared the train for departure from Paddington. The isolation of the equipment was indicated by a flashing light in the cab, but the driver still drove the train.

Although the signaller at Greenford wished to stop the train by sending an emergency call on the GSM-R radio system, he did not attempt to do so because the information presented by the radio equipment in the signal box suggested to him that any message he sent would not reach the train. Instead, he contacted Marylebone signal box, which was able to send a message to the train.

The RAIB has made three recommendations. One is addressed to Chiltern Railways, and covers the need for a review of the company's driver management processes. The other two, addressed to Network Rail, cover the configuration of the GSM-R radio system as it affects the ability of signallers to directly contact trains that are within their areas of control, and the training given to signallers in the use of the GSM-R system. The RAIB has also identified two learning points: one for signallers, relating to the use of delayed clearance of signals to warn train drivers of the state of the line ahead, and the other for train operating companies, relating to the upgrading of on-train TPWS equipment.

Introduction

Preface

1 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.

2 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.

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

Key definitions

4 All dimensions in this report are given in metric units, except speeds and some distances which are given in imperial units, in accordance with normal railway practice. Where appropriate the equivalent metric value is also given.

5 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.

The incident

Summary of the incident

6 On Thursday 20 March 2014 train 2M30[1], the 11:36 hrs Chiltern Railways service from London Paddington to West Ruislip, passed two consecutive signals, GE55 and GE50, at danger near Greenford, Middlesex (figures 1 and 2). It ran onto the single line beyond signal GE50 and continued for about 1 mile (1.6 km) before being stopped. No-one was hurt in the incident.

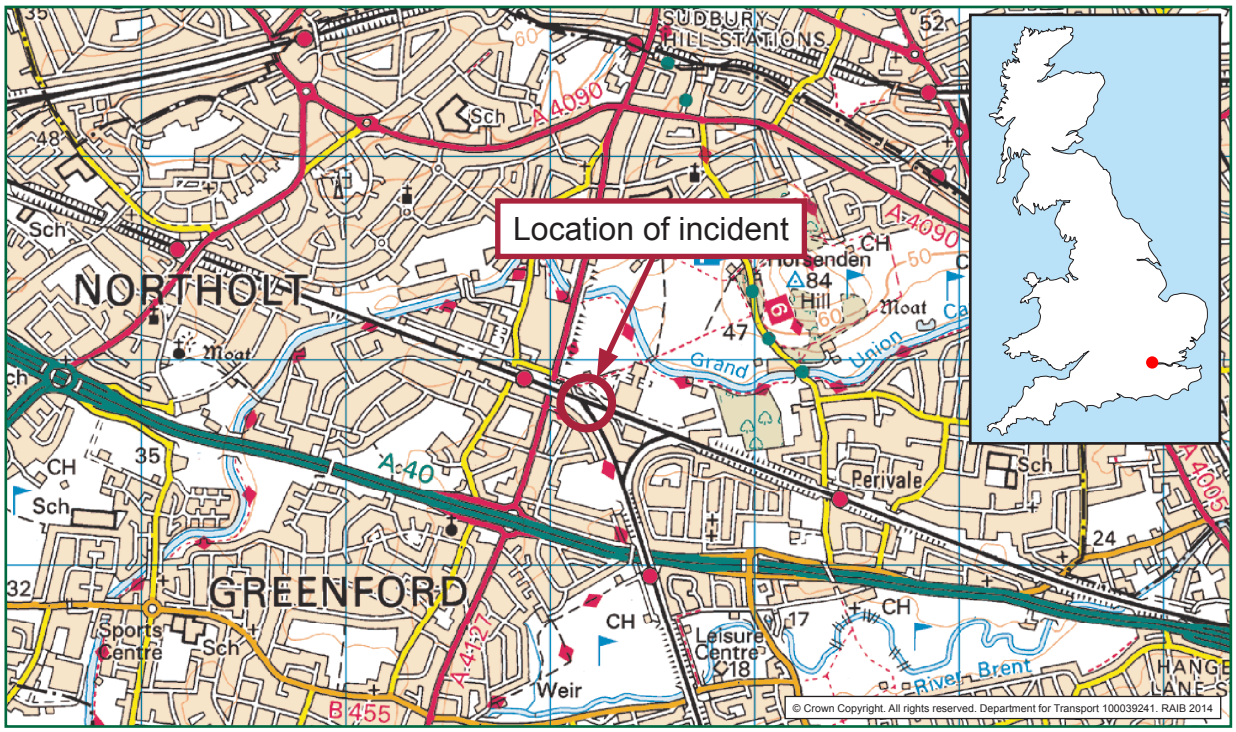

Figure 1: Extract from Ordnance Survey map showing location of incident

Context

Location

7 Greenford signal box controls a triangular junction where the branch line from West Ealing to Greenford joins the former main line from Old Oak Common West Junction to Northolt Junction (South Ruislip). The signal box was opened in 1905, when it was one of a series of mechanical signal boxes on a newly-constructed double track main line, and it then controlled just the junction with the Ealing line and the east end of Greenford station. From the late 1940s, a series of changes saw the signal box take control of a new bay platform at Greenford station and the other two junctions in the triangle. The extension of London Underground's Central Line from North Acton to West Ruislip, opened to Greenford in 1947, runs to the south of the main lines (figure 2). The original Greenford station on the main line was closed in 1963, and in 1990 the line between Greenford and Northolt Junction was reduced from double to single line.

[1] An alphanumeric code, known as the 'train reporting number', is allocated to every train operating on Network Rail's infrastructure.

8 Since 1990 the signal box has controlled an isolated group of *semaphore* signals, surrounded in all directions by more modern signalling. Trains coming from the Paddington direction (*down* trains) leave the Great Western main line at Old Oak Common, and run along a single track route as far as Park Royal, where the line becomes double. Up to this point, the signals, which are all *colour lights*, are controlled from Network Rail's Thames Valley Signalling Centre at Didcot. The first signal controlled by Greenford is GE57, a three aspect colour light, which is 2329 yards (2130 metres) from the signal box. The other Greenford signals encountered by down trains are all semaphores (see paragraphs 30 to 34 for details of the signalling at Greenford). Single track resumes immediately beyond Greenford signal box, and continues as far as Northolt Junction (South Ruislip), which is controlled from Marylebone Area Signalling Centre.

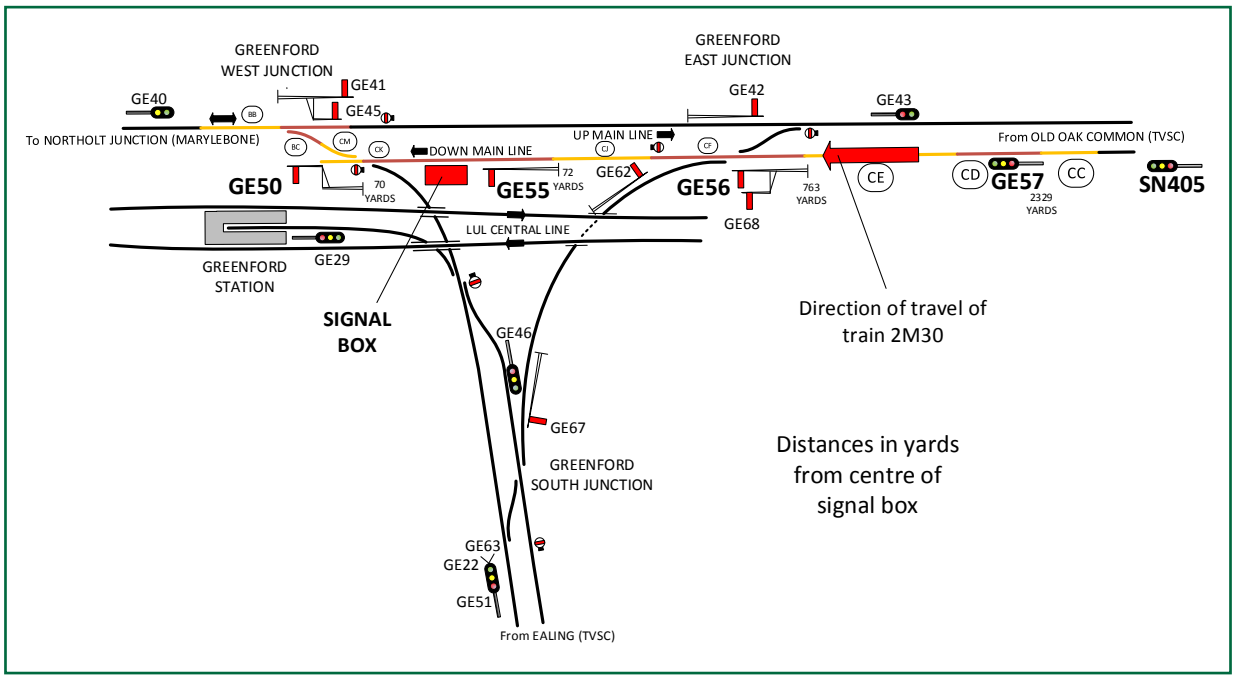

Figure 2: Greenford area, showing track layout and signals

Organisations involved

9 The railway infrastructure at Greenford is owned, operated and maintained by Network Rail (Western Route), who employed the signaller involved in the incident. The train involved in the incident was operated by Chiltern Railways Company Ltd (Chiltern), who employed the train crew (driver and guard).

10 Network Rail and Chiltern freely co-operated with the investigation.

Train involved

11 Train 2M30 was formed by two-car *diesel multiple-unit* number 165026 (figure 11). This unit was built in 1990, and was fitted with *automatic train protection* (ATP) equipment when new. *Train protection and warning system* (TPWS) equipment was fitted to the unit in 2001.

Staff involved

12 The driver of train 2M30 joined British Rail in 1991 as a trainee guard/driver, and became a driver in 1992. He has been based at Aylesbury depot for the whole of his service. He had not previously been responsible for a signal passed at danger (SPAD) incident. Other aspects of his service record are discussed at paragraph 95.

13 The signaller at Greenford joined British Rail in 1987, and had 23 years' experience at Greenford signal box. He had not previously been involved in any incidents affecting the safety of the line.

Rail equipment involved

Train Protection and Warning System (TPWS)

14 Signals GE55 and GE50 are both equipped with TPWS equipment, which is intended, at those two signals, to apply the brakes of any train which fails to stop at the signal when required to do so (ie when the signal arm is in the horizontal position (at danger)). Train 2M30 was fitted with on-train TPWS equipment, compatible with the TPWS equipment at the signals. If the TPWS system applies the brakes of a train, the driver is required by the rule book to report the event to the signaller immediately[2], and may be subject to disciplinary action and remedial training once the incident has been investigated by the railway company. For a description of the method of operation of TPWS, and the reasons why it is fitted, see appendix C.

Global system for mobile communication (railway) (GSM-R)

15 The Greenford area is equipped with the GSM-R radio system. This is replacing the National Radio Network and Cab Secure Radio[3] systems across the national network, and will provide a total communication system for railway operations.

16 GSM-R is intended to be a secure platform for voice and data communications between railway operational staff, including signallers and drivers. It was brought into full operation on the southern half of the national rail network, including the Greenford area, in 2013 after the equipment had been fitted to signal boxes and trains: the GSM-R equipment at Greenford had been commissioned in May 2012 (see paragraph 116). The signaller's GSM-R equipment in Greenford signal box consists of a touch-screen terminal with keyboard, and an external microphone and handset for voice calls. Further details of the radio coverage and operation in the Greenford area are in paragraphs 105 to 110 and appendix D.

External circumstances

17 The weather on 20 March 2014 was dry, mild and overcast. External circumstances did not play any part in the incident.

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[2] Unless the activation occurs on the approach to a buffer stop, in which case the driver must move forward to the normal stopping point and then tell the signaller what has happened (Rule Book, module S7, section 6.2).

[3] The National Radio Network was used throughout the railway system for emergency calls between trains and control offices. The Cab Secure Radio system was used in areas where passenger trains were operated by a single person, to provide a link between signallers and train drivers.

Events preceding the incident

18 The driver booked on for duty on 20 March 2014 at Aylesbury depot at 06:13 hrs. He took a train out of the carriage sidings to Aylesbury station, and took it into passenger service at 06:44 hrs, driving to London Marylebone (via High Wycombe), arriving at 07:54 hrs. He moved that train to the sidings at Marylebone, and then drove another train, empty, from Marylebone to Wembley depot, arriving at 09:17 hrs.

19 He had a rest period until 10:22 hrs, when he took over the train which was later involved in the Greenford incident. He drove it empty from Wembley to South Ruislip, arriving at 10:47 hrs. He changed ends and then drove it in passenger service as the 10:57 hrs from South Ruislip to Paddington (train reporting number 2V35), where it arrived in platform 14 at 11:27 hrs. The train was also crewed by a guard on this journey.

20 The driver moved to the opposite end of the train, and opened up the cab and activated the controls at the west end ready for departure. In doing this he encountered a condition (see paragraph 70) which meant that the 'TPWS temporary isolation/fault' indicator in the cab began to flash. He started the train, the 11:36 hrs service to West Ruislip (reporting number 2M30), with this indicator still flashing. The train departed from Paddington on time and was due to call at South Ruislip at 12:01 hrs, and arrive at West Ruislip at 12:06 hrs. Although this was a scheduled passenger service, there were no passengers on the train on that day.

21 Train reporting number 6M22, the 08:51 hrs freight service from Cricklewood to Calvert, was timetabled to run over the branch line from West Ealing to Greenford, and thence through Northolt Junction and on towards High Wycombe. If running on time, it would pass Greenford at 11:21 hrs, 30 minutes before train 2M30 was timetabled to pass. However, on 20 March 2014 it passed Acton Main Line 33 minutes late at 11:25 hrs and Greenford at about 11:45 hrs, the signaller at Greenford having cleared the signals for it to enter the single line towards Northolt Junction.

Events during the incident

22 Train 2M30 ran normally as far as signal GE57, which was at danger. When the signaller at Greenford saw on the diagram in the signal box that train 2M30 was approaching signal GE57, he pulled the lever to operate that signal, to permit the train to proceed towards signal GE56. He did not operate any further signals because the line towards Northolt was occupied by train 6M22. In these circumstances, although the lever has been operated, signal GE57 remains at red until the *track circuit* on the approach to it has been occupied for a period of time which was intended to be 43 seconds (but was actually 120 seconds because of a fault, see paragraphs 112 to 114)[4]. This arrangement is intended to ensure that an approaching train has stopped, or nearly stopped, and is therefore properly under control, before the signal clears.

[4] This control is called approach release from red. If the train passes the signal before it has changed from red to a proceed aspect, TPWS should intervene and apply the brakes to stop the train.

23 On arriving at signal GE57, the driver of train 2M30 sent a 'waiting at signal' text message to the signal box using the GSM-R system, in accordance with the rules. The signaller responded to this by sending a 'wait' message back to the train. When signal GE57 cleared to yellow, indicating that the train could proceed although the next signal was likely to be at danger, the driver started the train and increased speed to 30 mph (48 km/h). The next signal, GE56, was clear when the train passed it (see paragraphs 44 to 61 for a discussion of when this signal was cleared), and the driver increased speed to 36 mph (58 km/h). He then braked to bring the train's speed down to 19 mph (31 km/h) as it passed the signal box and ran over the junction onto the single line, to comply with the permanent speed restriction of 25 mph (40 km/h) which applies over the junction. While he was doing this, the train passed GE55 and GE50 signals, which were both at danger.

24 At the time, the signaller was dealing with the departure of train number 2G25, the 11:46 hrs service from Greenford to Paddington via Ealing. After it had left, on time, he restored the signals to danger behind it. As he was doing this, he saw train 2M30 pass signal GE55 at danger, and approach the signal box. The signaller was initially confused by what was happening, and checked that he had not pulled the lever to operate signal GE55. By this time the train was passing the signal box and approaching signal GE50, which was also at danger.

25 The signaller knew that signal GE55 was fitted with TPWS. He stated that he expected this equipment to stop the train before it reached signal GE50, which he could clearly see at danger in front of him (figure 3). However, the train did not stop, and continued onto the single line.

Figure 3: Greenford signaller's view of signal GE50 and the single line towards Northolt Junction (South Ruislip)

Events following the incident

26 The signaller moved to the GSM-R terminal in the signal box (figure 4), with the intention of using the radio to call the driver of train 2M30. He could not see the train on the list shown on the terminal, which is intended to display all the trains within the area controlled from the signal box (see paragraph 106), so he concluded that if he sent an emergency call, it would not reach train 2M30. Instead, he sent an emergency alarm to Marylebone signalling centre, and then contacted the signaller there by telephone to explain what had happened. The signaller at Marylebone was able to contact the driver of train 2M30 using GSM-R, and sent a 'stop' message to the train. The driver, on seeing the message, stopped the train 1 mile 86 yards[5] (1.69 km) beyond Greenford signal box.

27 The train was held where it had stopped while Chiltern located a replacement driver, who arrived at the train, along with a driver standards manager, at 13:15 hrs. There were no passengers on train 2M30, and no other trains had needed to use the line during this period. Train 2M30 moved off at 13:35 hrs, and was taken to Wembley depot. The driver was removed from duty, and tested by Chiltern for drugs and alcohol, in accordance with railway industry procedures for action following an incident. The results of these tests were clear.

28 Network Rail notified the RAIB of the event around 15:00 hrs. Examination and testing of the TPWS equipment, both on the ground and on the train, was carried out by Network Rail and Chiltern under the supervision of the RAIB, and completed by 21:00 hrs.

[5] The point at which the train stopped has been established as being at 8 miles 1054 yards (milepost mileage from Paddington).

The investigation

Sources of evidence

29 The following sources of evidence were used:

- witness statements;
- data from the on-train data recorder (OTDR);
- recordings from the forward-facing closed circuit television (FFCCTV) equipment fitted to unit 165026;
- CCTV recordings of platform 14 at Paddington;
- site photographs and measurements taken by the RAIB;
- tests carried out by the RAIB on the unit involved;
- a reconstruction of the event using train 2M30 on 26 March 2014;
- reports prepared by Network Rail at the RAIB's request on the details of the configuration of the radio system involved in the incident; and
- a review of previous RAIB investigations that had relevance to this incident.

Key facts and analysis

Background information

Signalling at Greenford

30 Greenford signal box has a mechanical lever frame, which controls both semaphore and colour light signals (figure 4). All the semaphore signals are of the lower quadrant type, in which the arm is horizontal when at 'danger', and moves downwards to between 45º and 60º below the horizontal to indicate 'clear'.

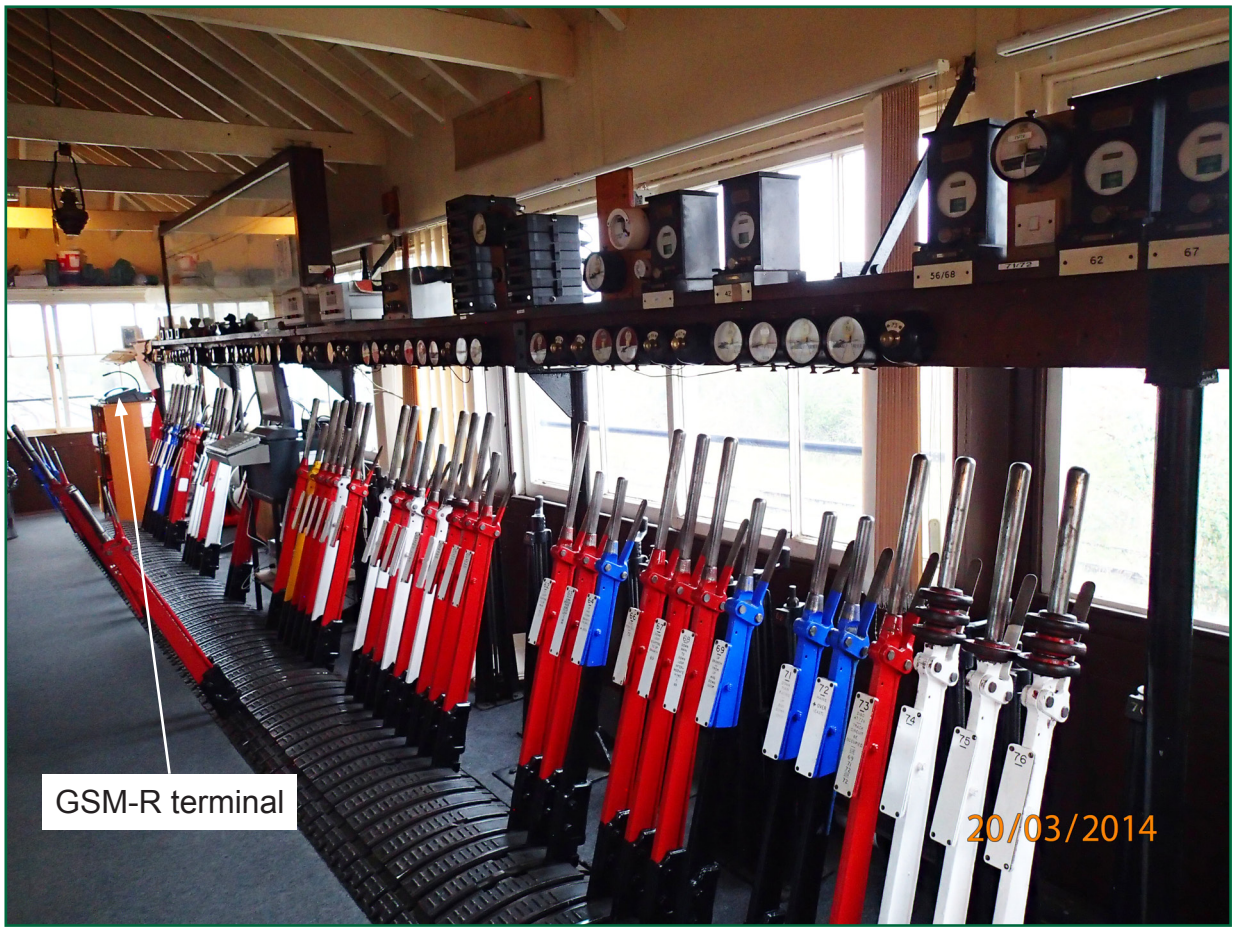

Figure 4: interior of Greenford signal box, showing lever frame.

31 Figures 5 to 8 show the signals concerned in this incident, displaying the same aspects as they were when train 2M30 passed them on 20 March 2014. For trains approaching on the direct route from Paddington, the first signal controlled by Greenford signal box is GE57 (figure 5), a three-aspect colour light 2329 yards (2130 metres) from the signal box. Beyond the signal, the line is straight for the whole distance through Greenford to South Ruislip.

32 The next signal is at Greenford East Junction, and consists of two arms on a bracket placed to the left of the line (figure 6). The signal for movements towards Greenford West Junction, GE56, is the higher of the two arms. These signals are 763 yards (698 metres) from the signal box.

Figure 5: signal GE57 showing yellow (caution). The signal was incorrectly plated G57 at the time of the incident, but this has since been corrected.

Figure 6: Greenford East Junction, showing signals GE68 (left) and GE56 (right)

33 The route to Greenford South Junction and Ealing diverges to the left. The next signal is GE55, visible in the distance in figure 6 and in the foreground of figure 7, which is 72 yards (66 metres) from the signal box. This signal protects the junction with the line from Ealing, which converges from the left beyond the signal box, about 130 yards (119 metres) beyond signal GE55.

Figure 7: Signal GE55, with Greenford signal box and signal GE50 in the distance

34 After passing the signal box, signal GE 50, 70 yards (64 metres) from the box, controls entry to the single line (figures 3 and 8). The signal is jointly controlled by Greenford signal box and Marylebone signalling centre (where it is known as ME65), and to allow a train onto the single line, the signallers at Greenford and Marylebone must co-operate to clear this signal, thus confirming that the single line is clear and that there is no train approaching it from the opposite direction. The entrance to the single line is also protected by trap points, which divert trains into a dead-end if they are not set for the single line (figures 3 and 8). The interlocking requires the trap points to be set for the dead-end before a train can enter the single line from the Northolt Junction end, so that if a train were to pass signal GE50 at danger in those circumstances, it would be diverted and derailed, but a head-on collision would be avoided. However, when two trains are following each other in the same direction towards Northolt Junction, there is no requirement for the trap points to be set for the dead-end. If the signaller had set the trap points for the dead-end before train 2M30 approached on the 20 March 2014, and the driver had not noticed this, the train would have been derailed after passing signal GE50 at danger.

Figure 8: signal GE50 and the start of the single line, showing the trap points.

Identification of the immediate cause[6]

35 **Train 2M30 passed onto the single line without stopping at either of the previous two signals, which were at danger.**

36 Evidence from the FFCCTV equipment installed in the cab of train 2M30 shows that signals GE55 and GE50 were at danger when the train passed them.

Identification of causal factors[7]

The causes of signals GE55 and GE50 being passed at danger

37 There are two factors which caused, or may have caused, the driver not to react to the sight of signals GE55 and GE50 at danger, as he approached them:

- he may have been misled into thinking that both signals were clear by the action of the signaller in clearing signal GE56 when train 2M30 was more than 200 yards (183 metres) from it; and
- he had not been required to stop at signal GE55 and/or signal GE50 in the recent past.

38 A further factor is that the TPWS equipment did not intervene to stop the train as it passed signals GE55 and GE50 at danger.

39 Each of these factors is now considered in turn.

[6] The condition, event or behaviour that directly resulted in the occurrence.

[7] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

The driver's observation of signals GE55 and GE50

40 The driver did not react to signals GE55 and GE50 at danger.

41 The driver drove the train past two signals at danger and did not react or make any attempt to stop the train. After the incident, the signaller told the driver that he had passed the two signals at danger. The driver disputed this, and only when he was later shown the FFCCTV from his train did he accept that he had made an error.

42 Evidence from the OTDR indicates that the train passed signal GE55 while being braked, at a speed of about 22 mph (35 km/h), and GE50 at a constant 19 mph (31 km/h), and it then accelerated to 36 mph (58 km/h) after entering the single line section.

43 The signals were clearly displayed, in the horizontal position, and in full view of the driver for over 30 seconds as the train approached them. However, the driver has stated that he believed that these signals were in the clear position, and that his attention was concentrated on checking the position of the points leading to the single line as his train approached them. Drivers are not normally required to look out for the position of points[8].

Clearance of signal GE56

44 The signaller cleared signal GE56 when the train was more than 200 yards (183 metres) from it. This was a probable causal factor.

45 The RAIB has sought to understand why the driver did not register that signals GE55 and GE50 had not been cleared for his train to proceed onto the single line.

46 It is probable that the driver did not register the position of either signal because he had formed a mental model that convinced him that his train had been given clear signals to pass through the Greenford area and onto the single line. The principal contributor to this mental model is most likely to have been that the signaller cleared signal GE56 (the signal preceding signal GE55) while the train was still some distance away from it.

47 In UK signalling practice, a train that is travelling on a running line will not be permitted to approach a signal which is at danger (meaning 'stop') without receiving a preliminary warning, or caution signal. This is to provide the driver with the opportunity to control the train so that it will be able to stop before reaching the signal which is at danger. This warning can take one of three forms:

- a semaphore *distant signal* in the horizontal (caution) position (or in the form of a warning board with a picture of a semaphore arm on it);
- a colour light signal showing a yellow aspect; or
- delayed clearance of a preceding stop signal (see paragraphs 50 to 53).

48 Where multiple-aspect colour light signals are in use, the standard sequence of signal aspects will provide a caution (yellow) signal on the approach to a stop signal. On the approach to signal GE57, the first signal controlled by Greenford, warning is given by a yellow aspect in signal SN405, a three-aspect colour light.

[8] Except after being authorised by the signaller to pass a signal at danger, in which case the driver must, if possible, make sure that any points etc are in the correct position (Rule Book, module S5, section 4.1).

49 Signal GE57 can only clear to green if all the subsequent signals controlled by Greenford are at clear. It is fitted with a feature known as approach release from red, which delays the clearance of that signal from a red to a single yellow aspect, when the signaller is unable to clear all signals in the down direction through the Greenford area (paragraph 22). This feature works automatically when the signaller operates the lever controlling the signal, and is intended to ensure that the train's speed has been reduced on approach to signal GE57, because there is no clear safe distance (known as an overlap) beyond the next signal ahead[9] (GE56).

50 The next three signals (GE56, GE55 and GE50) are semaphore stop signals worked mechanically. As signals GE55 and GE50 do not have an associated distant signal, delayed clearance is required because this is the only way that the specified warning that the next signal might be at danger can be given to the driver (paragraph 47). Delayed clearance is carried out by the signaller in accordance with the requirements of the railway Rule Book. Module TS1, 'General Signalling Instructions' (directed to signallers), says:

> ***Section 4.5 Clearing a stop signal when the next signal is at danger***
>
> *If you cannot clear a stop signal, you must not clear any associated signals on the approach to it until the train has stopped or nearly stopped at each signal in turn.*

51 The corresponding rule addressed to drivers is in module S7 'Observing and obeying fixed signals', and says:

> ***Section 2.21 Train stopped or nearly stopped at a signal at danger***
>
> *If you have stopped or nearly stopped at either of the following types of signal at danger and that signal changes to a proceed aspect or indication, you must be prepared to stop at the next stop signal worked by the same signal box.*
>
> - *A colour light signal that cannot display a yellow aspect.*
> - *A semaphore signal.*

52 This is a very long-standing rule that is intended to ensure that, where it is not possible to signal a train into the next section of track to proceed on its journey, it is fully under control as it moves through an area of closely spaced signals leading to the signal controlling entry to the next section (in this case, signal GE50 controlling entry to the single line section to Northolt Junction).

53 The driver of train 2M30 was warned that signal GE57 was likely to be at danger by a single yellow at the previous signal, SN405. The train was brought to a stand at signal GE57, and the driver says that he understood that this indicated that the next signal, GE56, was also likely to be at danger. When signal GE57 cleared, he started his train and accelerated to 30 mph (48 km/h) in anticipation of being stopped at signal GE56.

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[9] At the time the Greenford signalling reached its present state, this control was required by the Railway Inspectorate through the Requirements of the Minister of Transport for Passenger Lines, 1950, paragraph 13 (HMSO 1955, available at http://www.railwaysarchive.co.uk/documents/MoT_Requirements1950.pdf). More recently, HMRI's 'Railway Safety Principles and Guidance Part 2B Guidance on Signalling' (1996) made reference to this form of control at paragraph 30(c), and currently, the equivalent requirement (and details of how to implement it) is to be found in Network Rail's company standard NR/L2/SIG/11201 'Signalling Design: Module B7 Interlockings – General', at section 3.2.

54 The signaller at Greenford was intending to hold train 2M30 at signal GE55, while the single line ahead was occupied by train 6M22. For 2M30 to reach signal GE55, it first had to be signalled past signal GE56. To apply the provisions of the rule book quoted above (paragraph 45), the signaller needed to know when the train was 'stopped or nearly stopped' at signal GE56 before he could clear it.

55 The information that the signaller at Greenford has about the position of trains approaching on the down main line is limited. The train's position relative to signal GE56 cannot be established by looking from the signal box, because the signal is 763 yards (698 metres) away, and at the time of the incident it was concealed from the signal box by vegetation (the tree which is visible behind the signal in figure 6). The signaller must rely on the indications on the illuminated diagram in the signal box (visible above the lever frame in figure 4), which show which track circuit the train is occupying (figure 9).

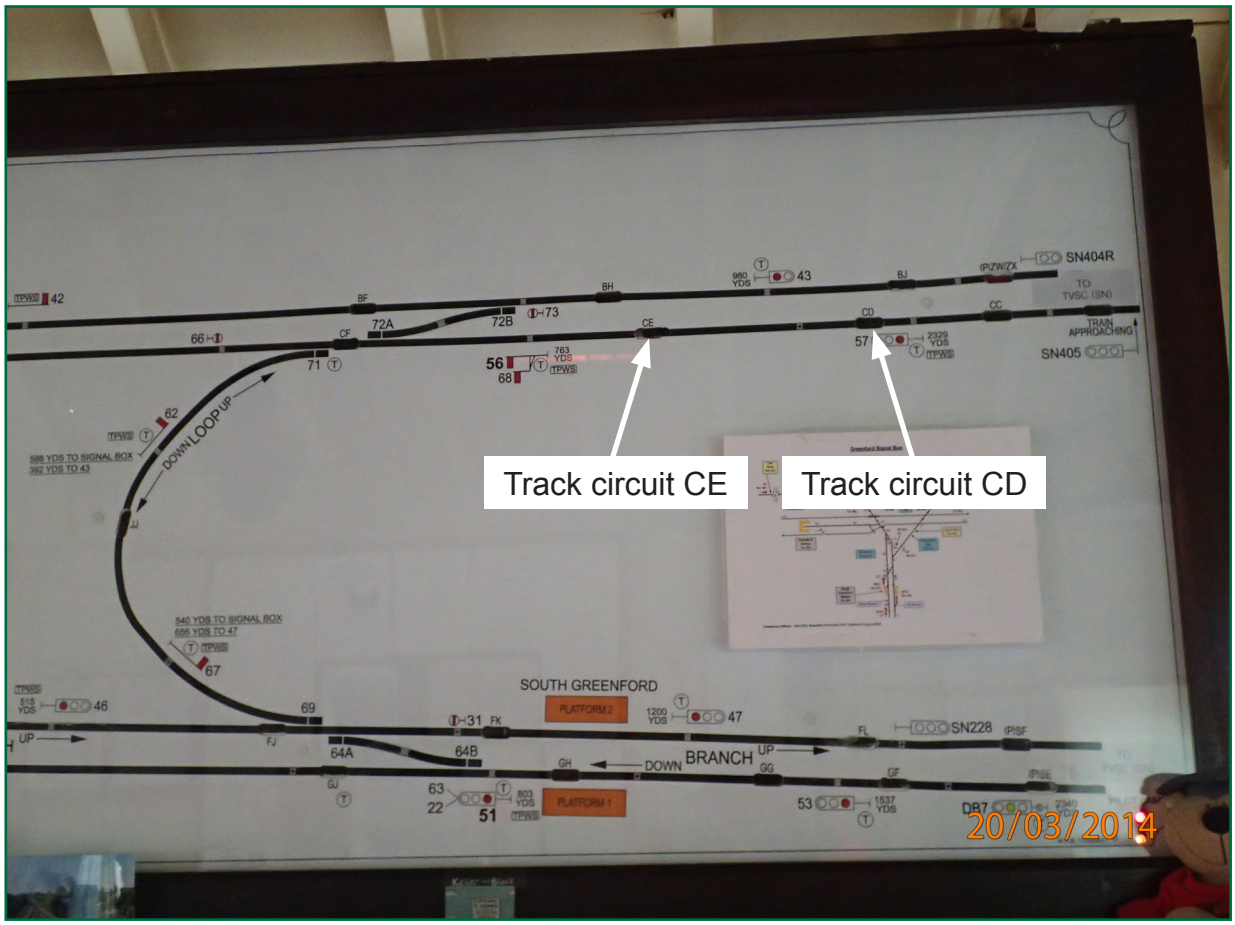

Figure 9: Signal box diagram at Greenford (part), showing down main line approach

56 There are two track circuits indicated between signals GE56 and GE57: CD and CE. The two signals are 1566 yards (1432 metres) apart. Track circuit CD extends for 422 yards (386 metres) beyond signal GE57, and track circuit CE covers the remaining 1144 yards (1046 metres).

57 The signaller stated that when a train, which had been cautioned at signal GE57, was moving towards signal GE56, it was his practice to wait an estimated one minute after the lights on the diagram showed that it had moved off CD track circuit before he pulled the lever to clear signal GE56. In the case of a two-coach train moving at a constant 30 mph (48 km/h), this would mean that the front of the train would be about 214 yards (196 metres) from the signal when it was cleared (in practice, the train should be slowing down to stop at the signal and would be further away from it).

58 Historically, to facilitate compliance with this requirement, mechanical signal boxes have been provided with a 'berth' track circuit 200 yards (183 metres) long on the approach to the first stop signal (the home signal). Occupation of this track circuit provides a reference point for the signaller to use when clearing such signals, on the basis that an approaching train can be judged as under control, and therefore considered to have been 'stopped or nearly stopped', in accordance with the Rule Book requirements (paragraph 50), if the signal is cleared a short while after occupation of the track circuit. The signaller's stated practice of waiting for one minute after the train moved off CD track circuit before he cleared signal GE56 was broadly equivalent to the historic practice (ie he would clear the signal when the train was about 200 yards (183 metres) away from it). However, because the signaller was not able to judge the position of the train visually (because of the distance of the train and signal GE56 from the signal box), it was important that he allowed the whole of this time to elapse before clearing the signal.

59 Witness evidence indicates that there were no formal instructions in Greenford signal box about how long it was appropriate to wait before clearing signal GE56, and it was something that each signaller at Greenford had developed for themselves, based on experience. There are very few trains which use the down main line, and they travel slowly (for many years there has been only one timetabled train each day, now train 2M30, which is allowed 25 minutes to cover the ten miles (16 km) from Paddington to South Ruislip, at an average speed of 24 mph (39 km/h)). Witness evidence indicates that the signallers did not regard the moment at which signal GE56 was cleared in this situation as particularly important. Managers had assessed the signallers at Greenford on their compliance with the rules related to delayed clearance by reference to other signals (because of the infrequency of trains on the line on which this incident occurred). Until this incident, there was no evidence that the signallers may not have been applying the rule correctly at signal GE56.

60 Evidence from the OTDR of train 2M30 indicates that the train accelerated from the stop at signal GE57 at a steady rate to reach 30 mph. This speed was maintained constant until after the train had passed signal GE56. The driver stated that when he first saw signal GE56, it was already clear. It is not possible to establish from the FFCCTV on the train when signal GE56 was cleared, because the camera resolution is insufficient.

61 During the investigation, RAIB observed the running of train 2M30 when the same signaller was on duty in the signal box. He had been asked to signal the train in the same way as he did on 20 March. On the day of the test, the signaller cleared signal GE56 when the train was approximately 650 yards (594 metres) away from it (figure 10). The RAIB has calculated that this was approximately 30 seconds after the train moved off CD track circuit.

Figure 10: View of signal GE56 at clear, from 650 yards (594 metres) away

62 If the signaller had in fact operated the signals in the same way on 20 March, and only waited for 30 seconds before clearing signal GE56, the driver of 2M30 may not have realised that the clearance of signal GE56 had been delayed, if he had first noticed its position only after it was cleared, when the train was about 650 yards (594 metres) from it. This may have created the belief in his mind that the rest of the Greenford signals would also be clear for his train.

The driver's experience of operations through Greenford

63 **The driver had not been stopped at Greenford in the recent past.**

64 The driver's roster took him to Paddington five times in the 48 week roster cycle, or approximately once every ten weeks. In the months leading up to the incident he had driven over the route on 26 November and 18 December 2013, and had a 'refresher' cab ride on 5 March 2014. He stated that on all those occasions his train had had clear signals through Greenford. It has not been possible to confirm this.

65 This may have contributed to his belief that he would have a clear run through Greenford on 20 March, despite the stop at signal GE57.

The lack of intervention by the TPWS

66 **The TPWS equipment did not intervene to stop the train when it passed signals GE55 and GE50 at danger.**

67 The TPWS equipment is described in appendix C. Both signals GE55 and GE50 are fitted with TPWS train stop equipment. This is designed to trigger an emergency brake application on a train which passes those signals while they are at danger, but evidence from witnesses and the data recorder on the train indicate that no intervention took place on 20 March 2014, and train 2M30 was able to continue unchecked.

68 The RAIB observed tests on the TPWS equipment, both at the signals at Greenford, and on unit 165026 at Wembley depot, on the evening of the day on which the incident occurred. These tests showed that all the equipment was working correctly.

69 However, there is a feature of the design of the TPWS equipment fitted to the class 165 trains, which is relevant to what happened on 20 March 2014. In common with other multiple-unit trains, the class 165 unit is equipped with a driving cab and a TPWS receiver at each end, and only the TPWS receiver associated with the leading cab is active during a journey.

70 If a unit stops with the inactive TPWS receiver at the trailing end of the train over an active track-based trigger loop, it is not then possible to set up the TPWS in that cab. This is relevant at terminus stations such as Paddington where the driver shuts down the leading cab on arrival and goes to the other (hitherto trailing) end in order to commence the return journey. The TPWS circuitry is not designed to deal with a continuous signal from a trigger loop. In these circumstances, when the driver prepares the cab for the return journey, the TPWS will self-isolate, and this will be indicated to the driver by a yellow flashing light (labelled TEMP. ISOLATION / FAULT) on the TPWS control panel in the cab (figure 12).

71 Although it is still possible for the driver to release the brakes and move the train normally, the TPWS will not operate if the train overspeeds, or passes a signal at danger. The yellow temporary isolation/fault light will continue to flash until the end of the journey, when the driver shuts down the controls in the cab.

72 There were therefore three factors which contributed to the TPWS non-intervention at signals GE55 and GE50:

- the train stopped at Paddington on its inward journey with the rear cab over a TPWS trigger loop;
- when the driver set up that cab in preparation for the return journey, he did not respond correctly to the yellow flashing light; and
- the design of the TPWS meant that it self-isolated in these circumstances.

These are now considered in turn.

Position of the train at Paddington

73 **The train stopped on arrival at Paddington with the rear cab over a TPWS trigger loop.**

74 The daily Chiltern service to and from Paddington is scheduled to use platform 14. This is the shortest of the main line platforms at the station, and can accommodate seven-coach trains.

75 No stopping marks (signs indicating to drivers where they should stop a train) are provided in platform 14. Network Rail's Sectional Appendix for the Western Route includes a local instruction for Paddington station:

> *Working of DMU trains into Nos. 13 and 14 Platform lines. Drivers of DMU trains running into these platform lines must draw their trains up to the stop block.*

Drawing up to the stop block (also known as the buffer stop) implies stopping as close as possible to it. Drivers are instructed, during their training, that in such cases, they should stop the train about six feet (two metres) away from the stop block.

76 Train 2V35/2M30 was formed of a diesel multiple unit (DMU), and so was subject to this instruction. However, the RAIB understands the purpose of the instruction is so that long trains will be drawn up to the stop block to avoid overhanging the end of the platform (which would prevent the use of adjacent platforms). This was not a consideration for a short train such as 2V35/2M30, but although the driver was not aware of the instruction, he stated that he believed that he had stopped about ten feet (three metres) from the stop block. CCTV evidence from the station indicates that this was not the case (see paragraph 79).

77 Terminal platforms on Britain's national network are equipped with TPWS, which is designed to ensure that the speed of trains approaching the stop block is kept below 10 mph (16 km/h). The equipment is generally located with the trigger loop 55 metres (plus or minus two metres) from the stop block[10], and will cause a brake application if a train passes over it at 10 mph (16 km/h) or more.

78 If a two-coach class 165 train (which is 46 metres long) is stopped two metres away from the stop block in platform 14 at Paddington, the rear of the train will be clear of the trigger loop for the TPWS associated with the stop block (figure 11).

Figure 11: Two-car class 165 drawn up the stop block in platform 14 at Paddington, showing TPWS trigger loop clear of west end cab

[10] Network Rail standard RT/E/S/10138 issue 3 'TPWS – Transmitter loop requirements and positioning', section 10.2

79 However, if a driver stops further away from the stop block, the rear (west end) cab of a two-coach train may come to rest over[11] the TPWS trigger loop, which is permanently energised. Evidence from the station CCTV at Paddington indicates that on 20 March, train 2V35 (which formed 2M30 on its return journey) stopped about eight metres from the stop block, placing its west end cab over the loop.

The setting up of the cab

80 **The driver took no action in response to the yellow flashing fault light displayed by the TPWS equipment.**

81 Information for drivers about the TPWS system is provided in the RSSB document RS522 'AWS and TPWS Handbook'. At the time of the incident, issue 1 (June 2012) of this document was in force, and it had been issued to (and signed for by) all Chiltern drivers as part of their issued Rule Book.

82 The Handbook describes the operation of the system, and section 2.2.2 illustrates the train equipment control panel (figure 12). The meaning of the indications given by the yellow lamp is explained thus:

> ***Temporary isolation / fault indicator***
>
> *The yellow temporary isolation / fault indicator gives three indications:*
>
> - *Off* — *TPWS state is normal*
> - Flashing — A fault has been detected in the train TPWS equipment
> - On (steady) — The train TPWS equipment has been temporarily isolated.

Figure 12: TPWS control panel in unit 165026

[11] The zone in which the TPWS receiver should pick up a signal, over a loop on the approach to a buffer stop, is 300 mm long (GE/RT8030 issue 2 Appendix D, which applied to the type of equipment at Paddington).

83 The driver had been trained on the use of the TPWS system when it was first introduced, in 2000. The training material issued by Chiltern at that time ('Chiltern Railways Drivers Manual Issue April 2000') gave instructions for setting up the system at the beginning of each journey. It explained that, when a driver setting up the cab moves the master switch away from the 'off' position, the TPWS train equipment undergoes a self-test process. At the end of this process, the *Automatic Warning System* (AWS) warning horn sounds and the driver should then '*press and release the TPWS cancel button. This should silence the warning horn, and extinguish all other indicators.'*

84 The training material went on to list possible fault conditions that may be detected during the self-test process, including:

> *If pressing and releasing the TPWS Cancel Button silences the horn but the Temporary Isolation/Fault indicator flashes, then there is a fault with the Train Stop and/or Overspeed Sensor functions (though the AWS will function normally). The driver must report the fault and select TPWS Temporary Isolation.*
>
> ***Note 1:*** *A unit may enter traffic with the Train Stop and Overspeed Sensor functions Temporarily Isolated so long as the AWS function remains operative.*
>
> ***Note 2:*** *If possible, the driver should avoid opening up the cab when the train aerial is standing directly over a Train Stop loop. In this circumstance it is possible that pressing and releasing the TPWS Cancel Button at the end of the self-test will not release the brake. In this case the driver should select Temporary Isolation in order to move the train. Temporary Isolation should be reset as soon as possible thereafter to restore full TPWS operation. Either this or change ends and move off the TPWS loop.*

85 This training material represented Chiltern's understanding of the TPWS system's characteristics and the operating rules that were applicable at the time it was produced. However, by 2014 various aspects of it were inadequate, or no longer correct.

86 The flashing yellow Temporary Isolation/Fault indicator, following the self-test process, actually indicated that the TPWS had already self-isolated. It did not mean that the brakes could not be released. The driver of train 2M30 on 20 March saw the yellow flashing light when he tried to set up the cab of unit 165026 at Paddington. However, he thought that the TPWS would still function normally (see paragraph 97), so he took no action. Chiltern's processes for managing driver competence are discussed in paragraphs 93 to 100.

The design of the TPWS system

87 **The TPWS equipment on the train self-isolated if an attempt was made to set it up while standing over a loop.**

88 The version of TPWS used by Chiltern is made by one specific manufacturer and known as 'Mark 1', and was the first design of this equipment to be widely fitted to trains in the UK, in the period 2000-2001. It is a characteristic of this version of TPWS that it cannot be successfully powered up if the receiver on the train is standing directly over an active loop on the track. The RAIB carried out a test with the train involved in this incident which confirmed that this was the case, and that in this situation a flashing yellow light in the Temporary Isolation/Fault indicator would be displayed to the driver.

89 Since the introduction of TPWS, the system has progressed, and several of the unsatisfactory features of the Mark 1 system have been designed out of more recent versions which are now available for retro-fitting to existing trains. Following its investigation of a SPAD incident at Purley on 18 August 2006 (RAIB report 27/2007), the RAIB recommended that Railway Group Standards should be amended to mandate that in-cab TPWS should specifically identify a TPWS activation associated with a SPAD, and prevent the use of the driver's reverser key to reset TPWS once activated. This recommendation was not adopted for existing trains, but the relevant standard (GE/RT8030) has since been modified to make these functions mandatory on new trains entering service from December 2012.

90 The Mark 3 version of train-borne TPWS equipment from the same manufacturer is physically interchangeable with the Mark 1 version. It has improved functionality which prevents the driver resetting the system immediately after a TPWS intervention takes place. In addition to this, and various other features, the unit can now be powered up when the train is standing over an active loop.

91 Current Railway Group Standards require new trains to be fitted with Mark 4 TPWS. This provides additional information to the driver about the cause of a TPWS intervention, has various other upgraded features, and will be compatible with the *European Rail Traffic Management System* (ERTMS). However, the version that is available for retro-fitting is larger than Mark 1 equipment and not physically compatible with it, making it difficult to fit to existing trains.

92 The Office of Rail Regulation (ORR) believes that it is reasonably practicable to upgrade TPWS equipment on existing trains, and is encouraging train operating companies and rolling stock owners to do so. This incident would have been prevented if the train had been fitted with Mark 3 or Mark 4 TPWS. Mark 3 and Mark 4 TPWS also addresses the risk associated with drivers re-setting the TPWS and restarting their train without authority following an intervention (paragraph 90).

Identification of underlying factors[12]

Driver management

93 The driver management process within Chiltern Railways did not address the driver performance issues which contributed to this incident.

94 The driver was familiar with the route through Greenford, although he only drove over it relatively infrequently (paragraph 64). Greenford is now the only area where Chiltern drivers encounter semaphore running signals (other than trains departing from some platforms at Banbury).

95 The driver had been the subject of action plans in the past to address problems that Chiltern's driver managers had identified with his driving technique. Some of these had arisen from incidents (a station overrun in 2007 and a failure to call at a station in 2008). Others had been as a result of analysis of OTDR information, downloaded at random by driver managers as part of Chiltern's competence management process rather than because of any incident. Problems identified, as described in the records kept by Chiltern, included:

- 16.12.03: braking issues identified and an additional assessment scheduled.
- 15.01.04: braking issues identified and an additional assessment scheduled.
- 27.04.04: DRA[13] not correctly used at Marylebone. Heavy braking identified.
- 14.08.08: running brake test not carried out. Heavy braking issue identified.
- 03.08.09: DRA not used correctly at Marylebone. Heavy braking identified. Another assessment scheduled.
- 15.09.09: heavy braking noted. DRA and running brake tests compliant.
- 21.10.10: no running brake test.
- 10.07.13: insufficient reduction in speed on running brake test.

Following each of these occasions, the driver behaved correctly during an assessment by a driver manager who travelled with him to observe his driving technique. However, the recurrence of these issues over several years suggests that the action plans have not been effective in permanently changing the driver's behaviour. In the RAIB's view, none of the problems identified during this period gave the driver managers any warning that the driver was likely to act in the way that he did on 20 March 2014.

[12] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

[13] Driver's Reminder Appliance: a red button in the driving cab which, when pressed, is latched in and illuminated and prevents the driver from applying power. It is required by the Rule Book to be used when trains are waiting at signals, and in some other circumstances.

96 Witness evidence indicates that many Chiltern drivers understood that the yellow flashing light indicated that the TPWS had self-isolated because the train was standing over a loop, and that the remedy for this was to move it a short distance and repeat the process of opening up the cab. This information, a slight but significant variation on the advice in the training material (paragraph 84) had emerged in the light of experience and had been passed by word of mouth between drivers over the 14 years that TPWS had been in use on parts of the routes that Chiltern serves[14], but it had never been formally briefed by Chiltern to its drivers.

97 The driver of train 2M30 on 20 March saw the yellow flashing light when he tried to set up the cab of unit 165026 at Paddington. He states that he thought this meant that the train was over a loop, but that the TPWS would still function normally, so he took no action. He was aware that the Rule Book prohibited him from driving the train in passenger service if the TPWS was not functioning. He believed that he had encountered this situation on a few previous occasions, and had dealt with it in the same way. His knowledge of this aspect of the TPWS system had not been explored or assessed by driver managers at Chiltern since he had first been trained on it. Although driver managers had observed and assessed his ability to set up the cab, they did not test his knowledge of this particular situation, which did not arise during his assessments. Chiltern's driver management process (and the audits of the process carried out as part of Chiltern's safety management system) had not identified this as a potential gap in the understanding of its drivers.

98 The use of simulators to give drivers practice in dealing with unusual events and situations that are not encountered frequently, and to assess their reactions and ability to deal with out-of-course events, has been standard practice in the management of drivers in train operating companies in Britain for over ten years. Chiltern has one driving cab simulator, located at Aylesbury depot, but in the past this has only been used for training new recruits, and has not been part of the company's ongoing competence management system.

99 Non-technical skills have been defined as the cognitive, social and personal resource skills that complement technical skills and contribute to safe and efficient task performance. Examples of non-technical skills that are important for train drivers are conscientiousness, concentration, communication, rule compliance and workload management.

100 Research into the non-technical skills required by train drivers was carried out by RSSB in 2011-12 (project T869). An abstract of the project is available at http://www.rssb.co.uk/research-development-and-innovation/research-and-development/research-project-catalogue/T869. In March 2013, RSSB published guidance[15] to duty holders on best practice for competence management. This included guidance on integrating non-technical skills into the competence management system. At the time of this incident, Chiltern had just begun to develop processes for doing this.

[14] The main Chiltern route between Marylebone and Aynho Junction was fitted with Automatic Train Protection equipment by British Rail in the early 1990s. However, this equipment has never been operational on the line through Greenford.

[15] RS100 issue 1 'Good Practice Guidance on Competence Development': RSSB, London, 2013.

Factors affecting the severity of consequences

The train was not immediately stopped by means of the radio system

101 Shortly after train 2M30 passed signal GE50 at danger, it entered the single line at Greenford West Junction and proceeded towards Northolt Junction. The train travelled for a further one mile and for more than two minutes before the signaller at Marylebone contacted the driver and told him to stop. There was a GSM-R terminal in the signal box at Greenford. The actions of the signaller and the design of the GSM-R installation at Greenford are discussed in the following paragraphs.

The actions of the signaller

102 **The signaller at Greenford did not use the GSM-R system to contact the driver of train 2M30.**

103 The signaller at Greenford had been trained to use the GSM-R radio system, and when he saw train 2M30 pass the two signals at danger, he intended to use the system to send a 'stop' message to the train driver.

104 He found, when he looked at the GSM-R terminal in the signal box, that train 2M30 was no longer shown on the list of trains on the screen (paragraph 26). He therefore concluded that neither a direct message to the train, nor a 'railway emergency call' to all trains in the area, would reach the driver of train 2M30. He decided to send an emergency alarm to Marylebone signal box (by operating a plunger on the shelf above the levers in the signal box), and followed this up with a telephone call. The Marylebone signaller was able to use the GSM-R system to make a railway emergency call to send a 'stop' message directly to train 2M30, and the driver responded to this and brought the train to a stop. However, this whole process took about two minutes, so that the train travelled over one mile before it was stopped.

The design of the GSM-R system

105 **The configuration of the GSM-R system caused the description of train 2M30 to disappear from the terminal at Greenford soon after the train passed the signal box.**

106 The reason why the signaller was unable to see train 2M30 on the terminal was related to the way the GSM-R system had been designed and installed at Greenford. Network Rail has investigated the coverage and configuration of GSM-R in the Greenford area. The detailed findings of this investigation are described in appendix D.

107 The way the GSM-R had been implemented at Greenford meant that trains approaching on the down main line were displayed on the list of trains on the GSM-R terminal in Greenford signal box as soon as they entered the area controlled by the signal box, on the approach to signal GE57. They remained displayed on the terminal until they had passed signal GE50, but they could then disappear from the train list as soon as they had gone about 200 yards (183 metres) past that signal, or up to three minutes later (because of the way the GSM-R system collects train position data: see appendix D). After this time they would only appear on the train list at the Marylebone signalling centre. On 20 March 2014, train 2M30 seems to have disappeared from the train list at Greenford at the earliest possible moment.

108 This feature complied with Network Rail's design standards for the implementation of GSM-R. However, the design does not appear to have taken into account the possible need for a signaller to contact a train which had passed the last signal controlled from Greenford, and was proceeding on its journey.

109 In such a case, Network Rail has confirmed that a railway emergency call would in fact have been received by train 2M30. However, the signaller was not aware that this would have been the case, and there was nothing in the training that he had been given which would have suggested that such a thing was possible.

110 Since the incident, Network Rail has changed the configuration of the GSM-R system at Greenford (paragraph 131).

Observations[16]

Delays at signal GE57

111 **The timer for the approach release on signal GE57 was incorrectly set.**

112 Before this incident, signallers at Greenford had noticed that trains appeared to be being detained at signal GE57 whenever it was used to check the speed of trains approaching the area. However, they believed that this was intentional, and had not reported it as a fault to Network Rail's maintenance organisation.

113 Signal GE57 is designed to remain at red until a train is closely approaching it if any of the signals in the route towards South Ruislip (GE56, GE55 and GE50) is at danger, or if a route is set towards the East Curve. The intention (as described in the electrical locking control tables for the signal box) is that in these conditions track circuit CC on the approach to the signal should be occupied for 43 seconds before signal GE57 will change from a red to a yellow aspect.

114 Following the incident on 20 March 2014, Network Rail staff tested the signalling at Greenford and found that the timer was set to 120 seconds, rather than 43 seconds. The delay arising from this condition may have made it more difficult for the signaller at Greenford to estimate the position of trains approaching signal GE56, because he was not aware that they would be stationary for such a long period before starting to move from the signal. Since the incident, the timer has been reset to the correct value.

Training and briefing of signallers at Greenford

115 **The signaller's training on GSM-R had not equipped him adequately to deal with emergency situations.**

116 The signaller had been trained by Network Rail on the use of the GSM-R system. This training had taken place in November 2011, about six months before GSM-R was brought into use at Greenford. The training had covered the use of the railway emergency call facility, but there had been no opportunity to practise emergency calls in a 'live' signal box rather than the classroom. GSM-R was commissioned at Greenford in May 2012, and in the period of almost two years that the system had been available for use (it was fully implemented as the principal system for communicating with train drivers by July 2013 (paragraph 16)), the signaller had not experienced an emergency call from a train, nor had he been required to make an emergency call to a train.

[16] An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the accident but does deserve scrutiny.

117 Witness evidence indicates that the signaller (in common with many of his colleagues) was apprehensive about using the railway emergency call facility, believing that it would result in a 'stop' message going out to many trains over a wide area. The risk of this happening is one of the reasons why there was no opportunity to practise the use of the railway emergency call on a 'live' railway. In fact, the configuration of the system at Greenford meant that, at the time that the signaller was considering sending an emergency call, there were, in addition to train 2M30, two other trains (6M22 going towards South Ruislip, and 2G25 going towards Ealing) that might have received such a call.

118 The signaller did not fully understand how the railway emergency call system worked. He abandoned his attempt to use it, and chose instead to send an emergency alarm to the adjacent signal box, and followed this up with a telephone call.

Previous occurrences of a similar character

119 On 16 January 2013, a passenger train passed a semaphore signal at danger at Norton-on-Tees West, County Durham, and passed over a level crossing that was open to road traffic. The train continued on its journey, and was not stopped until it had travelled about 3.5 miles (5.6 km) beyond Norton-on-Tees West.

120 The RAIB's investigation into this incident (bulletin 03/2013, published 30 May 2013) found that the driver of the train may have been focusing on the yellow light of the distant signal which was mounted below the stop signal, and therefore did not react to the red light in the stop signal. The train was following a diversionary route, and the driver had last worked over it about a month before the incident. He had no recollection of ever being stopped at the signal on previous journeys.

121 The signaller at Norton-on-Tees West became confused about what was happening when he saw the train passing the signal at danger, and his response also confused the signaller at the next signal box, Norton-on-Tees South. By the time the confusion was resolved, the train had passed Norton-on-Tees South and was continuing its journey. It was stopped by signals at Bowesfield, the next signal box on the route.

122 There were no recommendations made as a result of this investigation, although RAIB did identify four learning points for the railway industry, relating to the training and competence management of drivers and signallers. None of these were directly relevant to the incident at Greenford.

Summary of conclusions

Immediate cause

123 Train 2M30 passed onto the single line without stopping at either of the previous two signals which were at danger (**paragraph 35**).

Causal factors

124 The causal factors were:

a. The driver did not react to signals GE55 and GE50 at danger (**paragraph 40, no recommendation**).

b. The TPWS equipment did not intervene to stop the train when it passed signals GE55 and GE50 at danger (**paragraph 66, Learning point 2**).

c. The train stopped on arrival at Paddington with the rear cab over a TPWS trigger loop (**paragraph 73, Recommendation 1**).

d. The driver took no action in response to the yellow flashing light displayed by the TPWS equipment (**paragraph 80, Recommendation 1**).

e. The TPWS equipment on the train self-isolated if an attempt was made to set it up while standing over a loop (**paragraph 87, Recommendation 1, Learning point 2).**

125 It is probable that the following factors were causal:

a. The signaller cleared signal GE56 when the train was more than 200 yards (183 metres) from it (**paragraph 44, see paragraph 132, Learning point 1**).

b. The driver had not been stopped at Greenford in the recent past (**paragraph 63**).

Underlying factor

126 The driver management process within Chiltern Railways did not address the driver performance issues which contributed to this incident (**paragraph 93, Recommendation 1**).

Factors affecting the severity of the consequences

127 The signaller at Greenford did not use the GSM-R system to contact the driver of train 2M30 (**paragraph 102**).

128 The configuration of the GSM-R system caused the description of train 2M30 to disappear from the terminal at Greenford soon after the train passed the signal box (**paragraph 105, Recommendation 2**).

Additional observations

129 Although not linked to the incident on 20 March 2014, the RAIB observes that:

a. The timer for the approach release on signal GE57 was incorrectly set (**paragraph 111, see paragraph 132**).

b. The signaller's training on GSM-R had not equipped him adequately to deal with emergency situations (**paragraph 115, Recommendation 3**).

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

130 On 24 March 2014 Chiltern issued a briefing notice to its drivers on 'Checking and Responding to TPWS Indications on Cab Mobilisation', describing how the TPWS should behave when a driver is setting up the cab, highlighting the meaning of the flashing yellow light, and setting out the action to take if the flashing or steady yellow light appears.

131 Network Rail has modified the configuration of the GSM-R radio system at Greenford, so that trains travelling between Greenford and Northolt Junction will appear on the train list on the terminal in Greenford signal box for the whole of the time that they are on the single line.

132 Network Rail has adjusted the timer on the approach release for signal GE57 to its designed value of 43 seconds, and cut back the vegetation which obscured the view of signal GE56 from the signal box (although this was not likely to have been directly linked to the causes of this incident) (paragraph 125a).

Learning points

133 The RAIB has identified the following key learning points[17]:

1 At locations where the delayed clearance of signals is used to warn train drivers about the state of the line ahead, signallers must be confident that they know enough about the position and speed of the train to judge accurately the moment when the signal should be cleared. This may mean waiting until they are certain that the train has stopped (paragraph 125a).

2 Train operators are reminded of the need to assess periodically whether it is reasonably practicable to upgrade on-train TPWS equipment to address known shortcomings in the Mark 1 equipment identified in this investigation (such as the equipment self-isolating when a cab is opened with the receiver directly over an active loop, and the readiness with which it can be reset after an intervention). Such upgrades should be planned and take place during maintenance interventions, as part of life extension works, or in a phased programme (paragraph 124e).

[17] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Recommendations

134 The following safety recommendations are made[18]:

1 *The intent of this recommendation is that Chiltern Railways should improve the way in which its drivers are trained and managed, to reduce the risk that they will not respond appropriately to unusual events.*

Chiltern Railways should conduct a review of its driver management processes to confirm that the training and briefing given to drivers is comprehensive as regards the equipment and systems that drivers use, and that assessment of drivers covers the identification of, and response to, TPWS fault warnings as well as drivers' response to other unusual or emergency situations, and make changes in accordance with the findings of the review. As part of its review, Chiltern Railways should consider whether there is a role for more regular use of its driving cab simulator in the assessment of its drivers' competence, to achieve a more systematic approach, and whether it has adequate systems in place for periodically reviewing and revising its competence management processes and training material (paragraphs 124c, 124d, 124e and 126).

This recommendation may be applicable to other train operating companies.

continued

[18] 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 Regulation to 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.raib.gov.uk.

2 *The intent of this recommendation is that Network Rail should improve the robustness of the GSM-R radio system, in respect of signallers' ability to contact train drivers in an emergency.*

Network Rail should conduct a review of its implementation of GSM-R, particularly in respect of its configuration where signal boxes which have no GSM-R train describer feed adjoin signal boxes that automatically send train description data to GSM-R, and in areas of enhanced risk such as the entrances to single lines. The review should cover the visibility of trains on signallers' terminals as trains traverse signalling boundaries. Changes should be implemented where necessary so that signallers are able to directly contact all trains that are within, or leaving, their area of control, and are aware that although trains may no longer be shown on the terminal, it may still be possible to contact them by use of a railway emergency call (paragraph 128).

3 *The intent of this recommendation is that Network Rail should improve the training given to signallers on the use of GSM-R, so that they are able to use it effectively in an emergency situation.*

Network Rail should review and modify as necessary the training given to signallers in the use of GSM-R, so that signallers are given adequate opportunity to become familiar with the use of railway emergency calls, by practice, simulation or any other appropriate means (paragraph 129b).

Appendices

Appendix A - Glossary of abbreviations and acronyms

ATP	Automatic train protection
AWS	Automatic warning system
DMU	Diesel multiple unit
DRA	Driver's reminder appliance
FFCCTV	Forward facing closed circuit television
GSM-R	Global system for mobile communications (railway)
ORR	Office of Rail Regulation
TPWS	Train protection and warning system

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.

Automatic train protection	A communication and control system which utilises lineside equipment to transmit permissible speed and signal aspect information to trains. Since the signalling system tells the train how fast it may proceed at any given point, the system is capable of taking control from the driver and applying the brakes automatically should the driver attempt to exceed the safe speed.*
Colour light	Signal which conveys movement authorities to train drivers by means of coloured lights.*
Diesel multiple unit	A train consisting of one or more vehicles (semi-permanently coupled together) with a driving cab at both ends, whose source of power is a diesel engine.
Distant signal	A signal only capable of displaying a proceed aspect or caution aspect. Its purpose is to alert the driver to the fact that, when it is displaying caution, the next signal may be showing a stop aspect.*
Down	The direction away from London, and the line used by trains travelling in that direction.
European Rail Traffic Management System	A standardised system of rail traffic control which supplements or replaces the existing conventional fixed signalling system. Drawing together aspects of Train Protection Warning System (TPWS), Automatic Train Protection (ATP) and other systems, the physical implementation is called European Train Control System (ETCS).*
Interlocking	Controls fitted between points and signals that prevent the signaller from setting conflicting routes.*
Semaphore	Mechanical signals generally consisting of moveable arms, the shape, disposition and attitude of which (eg raised or lowered) all carry meaning.*
Track circuit	An electrical or electronic device used to detect the absence of a train on a defined section of Track using the rails in an electric circuit.*
Train protection and warning system	An automatic system intended to reduce the risks arising from trains passing signals at danger and travelling too fast over speed restrictions and on the approach to terminal platforms: see appendix C for details.
Trap points	A set of points intended to derail rail vehicles in the event of their unauthorised movement.

Appendix C - Train Protection and Warning System (TPWS)

1 In the period immediately before and after the privatisation of British Rail (BR), in the years 1990 to 1999, the principal safety risk on the network arose from trains passing signals at danger (SPADs), with the possibility of colliding with other trains or with buffer stops[19]. This risk had been addressed since the early 1950s by the Automatic Warning System (AWS), which provided an audible and visual warning to a train driver on passing a signal showing a cautionary (yellow or double yellow) aspect, and applied the brakes automatically if this warning was not acknowledged promptly[20].

2 However, it was recognised that the protection provided by AWS was limited, because it relied on the driver reacting appropriately to the AWS warning, and reducing the train's speed accordingly. With a view to establishing the best method of reducing the risk that a driver might fail to do this, BR had implemented two pilot schemes of Automatic Train Protection (ATP), on the Great Western Main Line between Paddington and Bristol/Bristol Parkway, and on the Chiltern line between Marylebone and Aynho Junction. ATP provides full supervision of the driver's actions, and intervenes to apply the brakes if the train's speed is greater than the calculated safe speed for the current situation.

3 These two systems remain in use, but extending either of them to the rest of the network was not considered reasonably practicable, and in the mid-1990s the industry developed a cheaper solution which was intended to address a large proportion of the risk from SPADs, by stopping a train which passes a signal at danger before it reaches a point at which it could collide with another train. This solution also enforces observance of speed restrictions, and controls the speed at which trains approach buffer stops.

4 This is the TPWS system, which uses pairs of electrical loops placed between the rails. One pair is placed at the signal itself, and, at some signals deemed to be higher risk, another pair is placed at a calculated distance on the approach to the signal which will permit an approaching train to be stopped within the overlap of the signal (based on the line speed, gradient and braking curve of the trains using the line). The loops are activated if the signal is showing a stop aspect.

5 The pair of approach loops are set between 4 and 36 metres apart. When the train passes over the first, or arming, loop, an electrical timer on board the train is switched on to detect the time which elapses while the train covers the distance between the arming and trigger loops. If the detected time indicates that the train is travelling too fast, an immediate emergency brake application is initiated.

6 The second pair of loops are placed adjacent to each other, at the signal. If the train passes over both of these when the signal is at danger the brakes are immediately applied.

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[19] A buffer stop is treated as a signal for the purposes of TPWS installation.

[20] The Great Western Railway had introduced this form of protection on its main lines between 1906 and 1939, but it was not widely adopted by other railway companies until after nationalisation in 1948. The occurrence of various accidents had led to the extension of AWS to provide similar protection at severe permanent and temporary speed restrictions, from the 1970s onwards.

7 If the TPWS intervenes to apply the brakes for any reason, the driver is required by the rules to immediately contact the signaller[21], and report the event. This will trigger an investigation of the incident by the driver's employer, and may result in remedial training and reassessment of the driver's competence and/or disciplinary action.

[21] Except if the train was approaching buffer stops.

Appendix D - GSM-R at Greenford

1 This description of the operation of the GSM-R system at Greenford is adapted from Network Rail's investigation into the events of 20 March 2014. A general description of the GSM-R system can be found at http://gsmr-info.com/.

2 GSM-R point to point voice calls and GSM-R messaging within the Greenford signal box area are routed according to the GSM-R radio cell the train radio is connected to at any given time. This is referred to as Location Dependent Addressing (LDA) and is required because the train describer at Greenford does not send train describer berth stepping data to GSM-R, a condition which is common for mechanical signal boxes. The GSM-R system therefore has to operate in LDA mode while trains are in the Greenford East area of control. Greenford East interfaces with Marylebone Area Signalling Centre south panel to the northwest and Thames Valley Signalling Centre (TVSC) Acton workstation to the south and southeast. Both Marylebone and TVSC provide train describer stepping data to GSM-R and therefore this data is used by the GSM-R system, in preference to the GSM-R cell being used, to accurately determine the position of trains in these adjoining areas, and route calls and messages accordingly. This is referred to as Enhanced Location Dependent Addressing (ELDA).

3 GSM-R emergency calls are always routed only using GSM-R cell data. This allows these critical calls to be invoked rapidly, without having to cross-reference the train describer data.

4 When trains with GSM-R radios registered for their journey approach the Greenford area from the Marylebone South and TVSC Acton areas, they are normally using ELDA. When the train clears the last train describer berth on either the Marylebone South or TVSC Acton areas, on approach to the Greenford area of control, the GSM-R system will change the train to operate in LDA mode. The GSM-R system will then immediately poll the train radio requesting it to respond so that its current GSM-R serving cell can be determined.

5 The GSM-R system polls all uncorrelated train radios nationally (ie those not correlated with the relevant train describer stepping data) every three minutes. The train that has just entered the Greenford area will therefore be polled next when the following three minute poll is timed, and every three minutes thereafter. This will continue until the train correlates with train describer stepping data, ie it enters an area operating ELDA, or the train radio is de-registered. While trains are operating in LDA mode, calls and messages from drivers to signallers are routed according to which signallers' terminal is the nominated terminal for the cell the call originated from.

6 Greenford is the nominated signallers' terminal for cell 2128 only (figure 13). The coverage of cell 2128 corresponds closely to the control area of Greenford signal box: it extends approximately from North Acton to Northolt (mile post 4 to milepost 8¾) on the main line, and as far as Castle Bar Park (milepost 7½) on the Ealing branch.

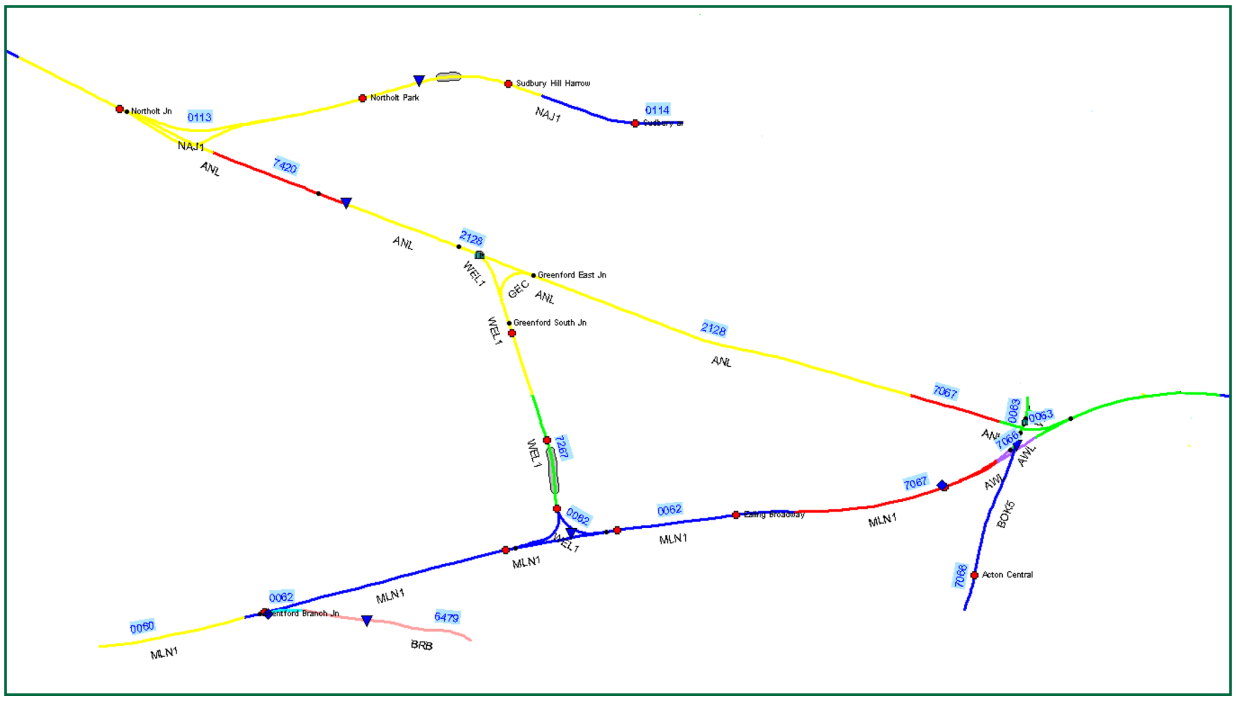

Figure 13: Greenford area, showing GSM-R cell coverage boundaries (courtesy of Network Rail)

7 At the fringes of the Greenford control area, the GSM-R system is programmed with the first track berths of the adjoining train describer areas for Marylebone South and TVSC Acton. As described above, when trains exit an ELDA area, the transition to LDA mode on the GSM-R system occurs almost immediately as soon as the last train describer berth step information is received and the train radio in question is polled for its cell. However, for trains exiting the Greenford area and going from LDA to ELDA, the transition is not as immediate.

8 When a train leaves the Greenford area and travels into the Marylebone South area, the GSM-R system will register this change at the next three minute poll when the train describer berth step information held by the GSM-R system associated with the Marylebone South control area matches the train's head code. At this point the train will change from LDA to ELDA mode and the train head code will only be displayed on the Marylebone South signaller's terminal.

9 On the morning of 20 March 2014, train 2M30 was seen to have disappeared from the Greenford GSM-R signallers' terminal train list a very short time after it passed Greenford signal box travelling towards South Ruislip. Investigation of the GSM-R system configuration showed that the LDA configuration for the Greenford signallers' terminal was in accordance with the design.

10 However, the first train describer berth in the GSM-R system associated with the Marylebone South control area was berth 0067. This train describer berth is linked to track circuits occupying nearly the entire length of the single line between Greenford and South Ruislip and begins adjacent to BB track circuit just to the west of signals GE41 and GE45 (figure 14).

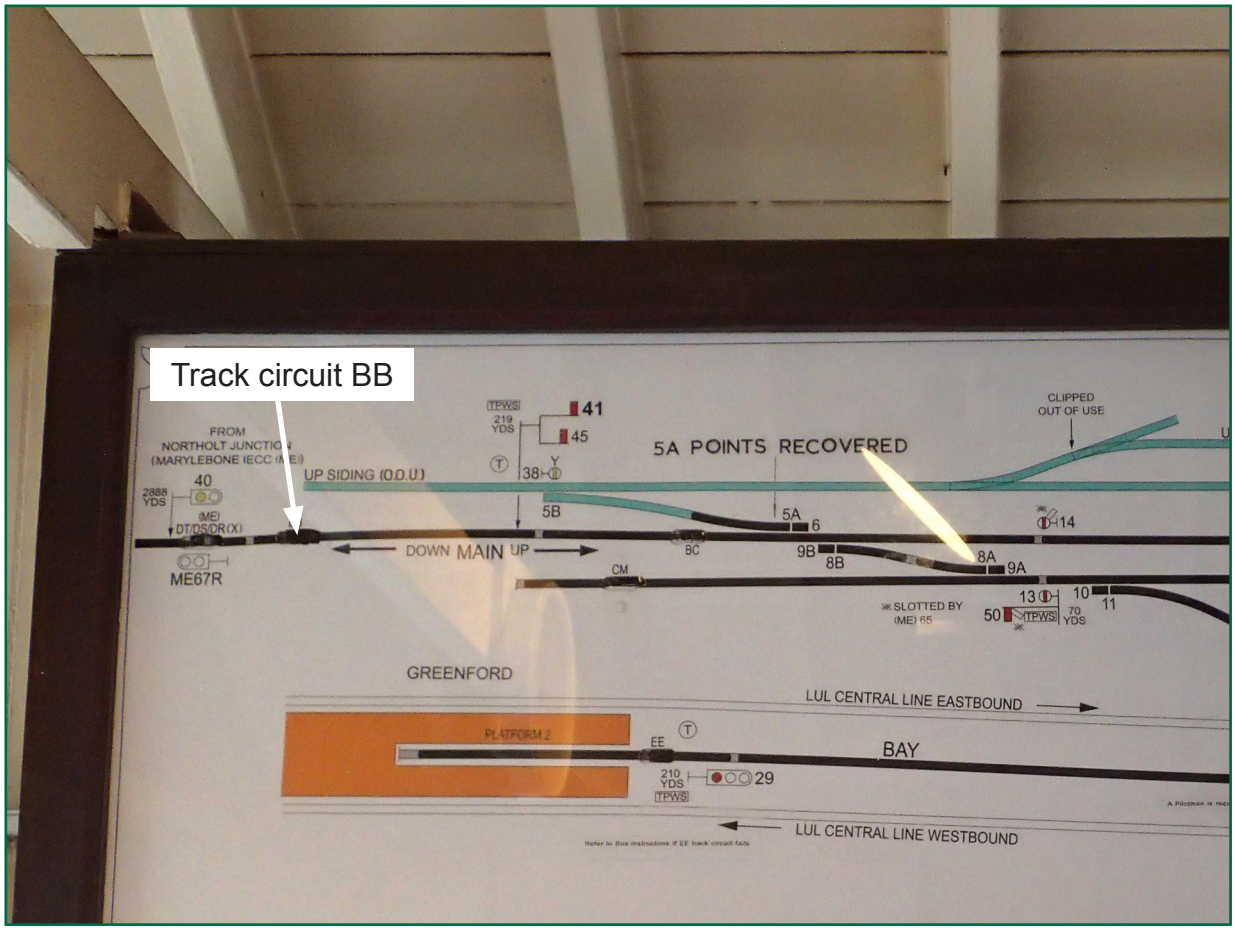

Figure 14: Part of Greenford signal box diagram, showing the line to Northolt Junction

11 The effect of including berth 0067 in the ELDA configuration for Marylebone South was that as soon as the next three minute GSM-R poll occurred, the GSM-R system correlated the train radio to Marylebone South in ELDA mode and only displayed it on the Marylebone South signaller's terminal. Depending on exactly when the three minute poll of the train radio occurred, this would have made train 2M30 disappear from the Greenford GSM-R terminal when the train was a relatively short distance past the signal box on the single line.

12 Railway Emergency Group Calls are routed using cell based information only. The Greenford group call area includes cells 2128, 7420, 7067 and 7267 (figure 13). This extends the area covered to Old Oak Lane and Northolt Junction (milepost 3½ to milepost 10) on the main line, and to Drayton Green (milepost 7) on the Ealing branch, and means that a Railway Emergency Call (REC) initiated by the Greenford signaller will reach all trains served by the four cells above regardless of whether they are operating in LDA or ELDA mode. On the day of the incident, had the signaller initiated a REC, 2M30 would have received the call. However, the signaller had no means of knowing this.

13 The implementation of GSM-R at Greenford was in compliance with Network Rail's design standards. However, this did not take account of the likely need for the signaller at Greenford to contact a train which had passed the last signal controlled from the signal box and was continuing on its journey.

14 Since the incident, Network Rail has modified the configuration of the GSM-R system at Greenford by removing train describer berth 0067 from the Marylebone South GSM-R ELDA configuration. This has the effect of making the single line section an LDA area in GSM-R terms. Trains travelling from Greenford towards South Ruislip now remain in LDA mode and remain on the Greenford signaller's terminal train list until the train enters train describer berth 0071 at South Ruislip, when ELDA mode is again established following the next three minute GSM-R train radio poll. When the train enters cell 7420 at approximately milepost 8½, the train, still in LDA mode, will also be displayed on the Marylebone South signaller's terminal.

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