Rail Accident Investigation Branch

Rail Accident Report

Passenger door open on a moving train near Desborough 10 June 2006

Department for Transport

Report 31/2007
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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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Passenger door open on a moving train near Desborough, 10 June 2006

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Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given by Midland Mainline, Bombardier Transportation, Faiveley Transport and Schaltbau to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain the following glossaries:

- acronyms and abbreviations are explained in Appendix A; and
- technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B.

5 All mileages in this report are measured from the zero point at London St Pancras.

Summary of the report

6 At 11:34 hrs on Saturday 10 June 2006, a passenger on train 1D17, the 10:30 hrs London St Pancras to Sheffield service, reported to on-board staff that an exterior door was open, in the first class portion, while the train was moving. The train was formed of a class 222 Meridian unit, number 222 009.

7 The door opened just north of Kettering. The train was finally brought to a stand at Desborough summit, 5 miles 79 *chains* north of Kettering station, Figure 1.

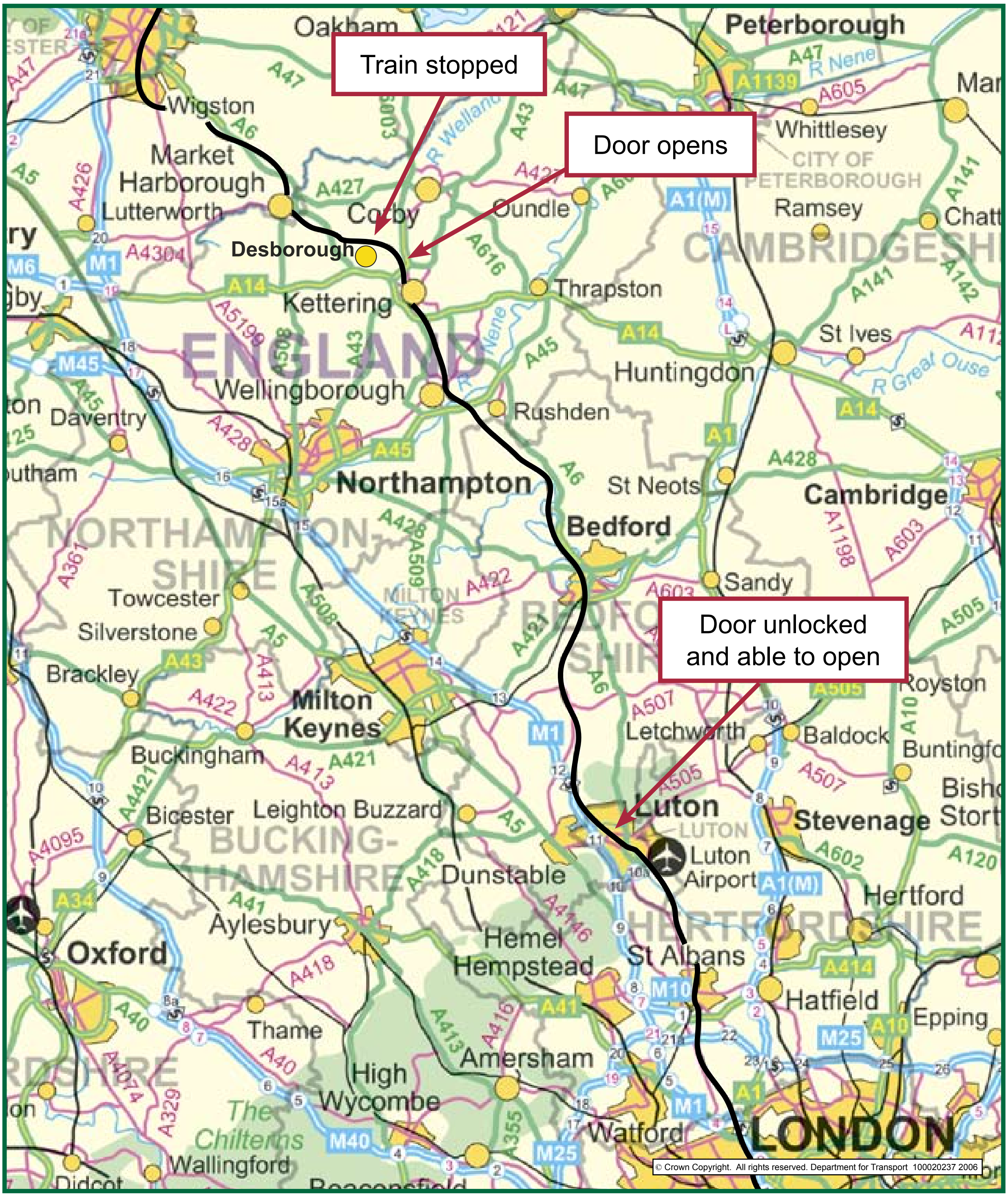


Figure 1: Extract from Ordnance Survey map showing location of the key events associated with the incident

8 As intended by the design, when the door opened, the train's brake applied automatically. However, the driver initially overrode this as, to him, the indications in the cab were ambiguous and he was uncertain what had happened.

9 When the driver realised that the train was 'in danger', he made a controlled brake application to stop at the next signal. The train travelled for about five minutes with the door open before the driver braked the train to a stand.

10 The door was closed and secured, and the train continued to the next station, Market Harborough. The passengers were safely detrained. The train was taken out of service and continued forward to Etches Park depot, Derby, for investigation.

11 The immediate cause of the incident was that the door had become, and remained, both unlocked and without a closing force from the *door motor* (subsequently referred to as being un-motored) in response to the detection of a malfunction of the microswitch used to detect the status of the door lock (the *door lock switch* (DLS)). This occurred during the initial stages of the door opening sequence at Luton station, earlier in the journey; it resulted in the door being left able to open.

12 The DLS malfunction resulted in the door's control unit (the *electronic door control unit* (EDCU)) identifying a specific locking fault (an 'EM/DLS error'). The cause of the door being both unlocked and un-motored is attributed to the way in which the EDCU controlled the door motor when this fault was detected.

13 The following factors were considered to be contributory:

- the unintended change of the door motor current limit, as part of a recent EDCU software upgrade, leading to conditions which prevented the *falling latch* (in the locking mechanism) engaging with the *locking hook*;
- the presence of a foreign particle which resulted in the DLS becoming jammed;
- the lack of an overt indication from the on-train computer (the *train management system* (TMS)) to the train manager (or driver) that a door lock fault had occurred at Luton station;
- the EDCU not motoring the door closed when the train started to depart from stations;
- the lack of a *level 3* anomaly indication from the TMS to the driver when the door opened;
- the '*pass comm/door activated' light* being ambiguous because it gives the same indication for different reasons;
- the driver not noticing that the '*door close/locked' light* extinguished when the door came open as it was difficult to observe when driving;
- none of the passengers, who observed the open door, then operating the *Passenger Communication Apparatus* (PCA) *emergency brake handle*; and
- the driver overriding the emergency brake and not stopping the train immediately when he became aware that there was a door open.

14 There were no injuries or material damage as a result of the incident or its outcome. However, the state of the door after departure from Luton – and when it finally opened north of Kettering – presented a real and unprotected risk to those on board the train.

15 Recommendations can be found in paragraph 233. They relate to the following areas:

- review and modification of the algorithm used to control the door;
- procedures for specification, development and verification of train and door system software;
- a review of the design of the DLS and the associated manufacturing process;
- fault alarms from the TMS and their treatment by the on-board staff;
- improvements to the training of on-board staff;
- the ergonomics of indication lamps in the driver's cab and the PCA emergency brake handles; and
- a review of the operational rules relating to PCA, power operated doors and use of the emergency brake override.

Summary of the incident

16 At 11:34 hrs on Saturday 10 June 2006, a passenger on train 1D17, the 10:30 hrs London St Pancras to Sheffield service, reported to on-board staff that an exterior door was open in the first class coach (vehicle 60249) while the train was moving. The train was formed of a class 222 Meridian unit, number 222 009 (see Figure 2).

Figure 2: The train and (inset) door involved in the incident

17 The door became unlocked and able to open as result of a locking fault which occurred at 10:52 hrs when the train stopped at Luton station (30 miles 19 chains). The door came open at 11:31 hrs, two minutes after departing from Kettering station (72 miles 1 chain) while the train was travelling at 79 mph (127 km/h).

18 There was no obvious indication – such as a visual or audible alarm – to the on-board staff of the locking fault at the station stop at Luton or afterwards. To the driver, the indications in the cab, when the door opened north of Kettering, were ambiguous.

19 The train travelled for about five minutes with the door open, and it was only secured closed after the driver finally brought the train to a stand. Following this, the train went forward to Market Harborough (82 miles 74 chains) where the service was terminated and the passengers detrained.

20 There were no injuries or material damage as a result of the incident.

The parties involved

21 The train is owned by the rolling stock leasing company HSBC Rail (UK) Limited and operated by Midland Mainline Limited, a franchise run by National Express Group PLC. It carried three on-board staff: the driver, train manager and a *customer host*.

22 The train was designed and constructed by Bombardier Transportation. The passenger door system was designed and constructed by Faiveley Transport.

23 The track infrastructure is owned by Network Rail which also operates the signalling equipment.

Location

24 The incident occurred on the Midland main line that runs from London St Pancras to Nottingham, Derby and Sheffield.

25 The initial door fault, where the passenger door became unlocked and able to open, occurred when passengers requested it to open at a scheduled stop at Luton station (30 miles 19 chains). The train made further scheduled stops – with the door in this condition – at Bedford (49 miles 65 chains), Wellingborough (65 miles 11 chains) and Kettering (72 miles 1 chain) stations.

26 The door opened just north of Kettering with the train finally coming to a stand at signal LR195 (78 miles) near Desborough summit.

The train and its crew

Class 222 Meridian trains

27 Class 222 Meridian trains are *diesel electric multiple units* (DEMU) capable of 125 mph (200 km/h) operation. They were designed and built by Bombardier Transportation to meet requirements specified by Midland Mainline Limited and others for use on passenger franchise services to and from London St Pancras.

28 Her Majesty's Railway Inspectorate (HMRI) carried out an initial assessment of the trains under the Railways and Other Transport Systems (Approval of Works, Plant and Equipment) Regulations 1994 (ROTS) and issued a letter of 'no objection to concept'. However, the approvals process under ROTS was never completed, because of new arrangements introduced by the Railways (Interoperability) (High-Speed) Regulations 2002 (HSI).

29 HMRI authorised the class 222 trains into service under the HSI Regulations following an assessment by a *Notified Body* and submission of a technical file documenting conformity with relevant standards. HSBC Rail (UK) Limited appointed Atkins Rail as the Notified Body.

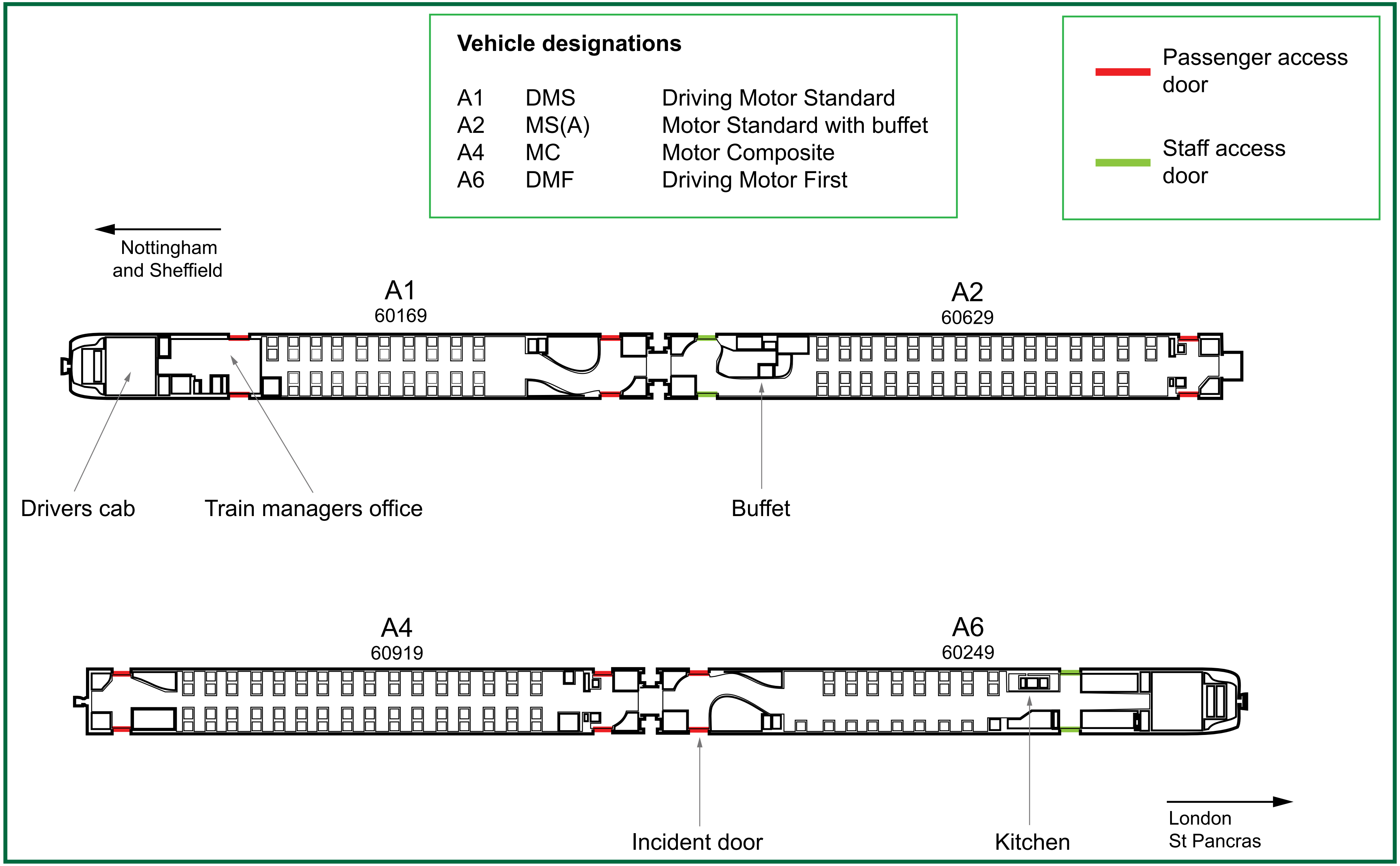


Figure 3: Train formation unit 222 009

30 The first of the class 222 trains was accepted by Midland Mainline on 14 May 2004 and entered service on 31 May 2004. Unit 222 009 was the second train to be accepted – on 28 May 2004. It also entered service on 31 May 2004.

31 The trains can be marshalled into a variety of car formations. Unit 222 009 is formed of four cars. Figure 3 shows the train formation, vehicle designations, numbers, and pertinent features.

32 The trains are fitted with electrically operated exterior doors, two on each vehicle side. On *intermediate vehicles*, they are located in the two *intermediate end vestibules*. On driving vehicles, they are located in the intermediate end vestibule and also toward the cab-end of the passenger area: in the kitchen area on the first class vehicle and next to the train manager's office on the standard class. The doors are a single leaf *slide-and-plug* design. Most of the doors are designated for passenger access use. However, some are for staff use only – these have different controls. The location of each door and type is shown in Figure 3. The door which opened (the incident door) was on the west side of the train; this is also identified on Figure 3.

33 An on-board computer system, the TMS, monitors the condition of the train's electrical and electronic systems. It logs fault and alarm events (*anomalies*) the reports of which are available to the driver, train manager and maintenance staff through touch screens located in each driving cab and additionally at designated train manager positions in each vehicle (the screen provided in the train manager's office is also fitted with a key pad). Anomalies are classified according to whether they are applicable to the driver, train manager or maintainer. Each anomaly is allocated a severity level (paragraph 94).

34 Class 222 trains are derived from the earlier class 220 Voyager trains which Bombardier Transportation supplied to Virgin Trains for their cross-country services. However, there are a number of key differences between the class 222 and 220 trains with the class 222s having:

- additional control functionality for *selective door operation* (SDO); and
- a difference in the manner in which anomaly information is presented to the driver on the TMS.

35 Class 222 Meridian trains are almost identical to the class 222 Pioneer trains operated by Hull Trains.

<u>The driver of train 1D17</u>

36 The driver of train 1D17 (subsequently referred to as the driver) was based at the Midland Mainline's Derby depot and had 27 years experience as a railway employee. He was subject to both a two year continuous competence assessment cycle and a five-yearly fitness assessment process by Midland Mainline - all in accordance with *Railway Group standard* GO/RT3251. He was issued with a certificate of competence on 17 March 2005 that was valid until 16 March 2007, and prior to the incident on 10 June 2006, his most recent reassessments - in which he was successful - were as follows:

- rules – 16 March 2006;
- train handling – 3 January 2006; and
- medical – 16 June 2003.

37 The driver was first passed as competent in *route knowledge* for the Midland main line on 11 November 1992. The most recent recertification of route knowledge prior to the incident was on 16 March 2006.

38 The driver received training from Midland Mainline on the class 222 Meridian trains (paragraphs 121 to 123) and was assessed on these on 13 April 2005, with satisfactory results.

The train manager of train 1D17

39 The train manager was based at the Nottingham depot and was initially passed as competent as a guard in 1984. He was subject to a two-yearly cycle of competence reassessments and six-yearly cycle of fitness reassessments by Midland Mainline – both in accordance with Railway Group standard GO/RT3255. His most recent competence assessment was on 6 September 2005 when he was judged to be competent for a further two years. His last medical reassessment was on 31 July 2003 when he was passed fit for normal duties.

40 The train manager's safety responsibilities included train dispatch procedures at stations, including the closure of train doors.

41 Following training (see paragraphs 124 and 125), the train manager took the assessment on class 222 Meridian trains on 5 May 2004 and was judged, by Midland Mainline, competent.

The customer host of train 1D17

42 The customer host on board train 1D17 had worked for Midland Mainline for three years and had attended the two-day conversion training course on class 222 Meridian trains (see paragraph 126). She passed the course on 24 June 2004.

43 Customer hosts receive a day's refresher training every two years which is tested by written questionnaire. They are not subject to regular medical assessment. Prior to the incident, the customer host last received refresher training on 3 May 2005.

Events preceding the incident

44 On 10 June 2006, the driver booked on duty at Derby at 07:02 hrs. He then drove unit 222 009 as *empty coaching stock* from Derby Etches Park depot to Nottingham where it was to form train 1B12, the 08:07 hrs service from Nottingham to the terminus station at London St Pancras. From St Pancras, unit 222 009 was to form the 10:30 hrs service to Sheffield, reporting number 1D17.

45 The train manager and the customer host for trains 1B12 and 1D17 booked on at Nottingham at 07:37 hrs and 07:47 hrs respectively.

46 The train manager checked the TMS at Nottingham and found an anomaly logged affecting the seat reservation system. The driver attempted to clear this by shutting down the train's engines and then restarting them, but this was unsuccessful. This was the only anomaly reported to be present on the TMS.

47 When also at Nottingham, the customer host found that she could not open the internal door in the kitchen area on the first class coach.

48 The train departed from platform 4 at Nottingham at 08:11 hrs and subsequently called at Beeston, Loughborough, Leicester, Market Harborough, Kettering, Wellingborough, Bedford and Luton stations before arriving at London St Pancras at 10:04 hrs. At all of these stations, apart from Bedford, the train doors were made available for use on the east side of the train. Bedford was the only station where the train doors were made available for use on the west side (the side of the incident door). The incident door was used at Bedford without any irregularity.

49 The turnaround at London St Pancras where the train reversed direction was uneventful, and train 1D17 departed a minute early at 10:29 hrs. The train proceeded to Luton station, its first scheduled stop, where it arrived at 10:51 hrs. The incident door was now adjacent to the platform, and this was also the case at the stations that followed: Bedford, Wellingborough and Kettering.

Events during the incident

50 At 10:52 hrs at Luton, the CCTV system on the train recorded a group of passengers, wishing to alight, make a request to open the door. The door failed to respond. They had to alight by another door.

51 Both a 'door service failure' and a 'lock fault' were logged on the TMS but, because of their classification, these were not made immediately apparent to either the driver or the train manager. (The 'door service failure' is required to be displayed only as a level 2 anomaly for the train manager and maintainer (paragraph 94), and not be displayed at all to the driver. Level 2 anomaly reports for the train manager are provided for information purposes only. The train manager duties do not require him to regularly check the TMS for their presence or to immediately respond to them (paragraph 189). The 'lock fault' is required to be displayed only as an anomaly for the maintainer). The on-board staff were therefore unaware of any fault or the need to take precautionary action, such as manually locking the door out of service.

52 As a result of the response to the detected fault, the door had become unlocked; no closing force was demanded from the door motor to hold the door closed. The *safety loop* (paragraph 80) on the train was not cut; as a result, no on-train protection system was activated which could have prevented the train departing (paragraph 157).

53 As he was not made aware that there was anything untoward, the train manager authorised the train to depart.

54 As the train accelerated, and the *low speed signal* de-energised, the *pneumatic door seal* inflated as intended. The seal initially provided a gripping force which held the door in place. However, its deflation and inflation at each station stop – again as intended – was to gradually prise the door leaf out of the carbody (paragraph 199) making the opening of the door increasingly inevitable.

55 Train 1D17 departed from Luton at 10:53 hrs and arrived at Bedford, the next booked station stop, at 11:07 hrs. The CCTV on the train showed that passengers attempted to board the train by using the incident door, but again it did not respond.

56 The train then made scheduled stops at Wellingborough and Kettering stations at 11:18 hrs and 11:27 hrs respectively. At both stations, the CCTV on the train showed passengers attempting to enter the train through the incident door, but it continued not to respond.

57 Train 1D17 departed from Kettering at 11:29 hrs and just beyond Kettering North Junction, at 11:31 hrs when the train was travelling at 79 mph (127 km/h) the CCTV showed that the door came fully open.

Events following the incident

58 Immediately before the door came open, the driver heard the sound of electrical contacts operating behind him, and this was followed by an *enhanced service brake* application. The driver also saw that the yellow 'pass comm/door activated' light had illuminated warning that either a PCA emergency brake handle (these devices are provided throughout the train to enable passengers to alert the driver of an emergency – their operation results in opening a voice communication channel to the driver and the train brake applying) had been pulled or a passenger door had unlocked (eg through the operation of an *egress handle*) and possibly opened. The driver also checked the TMS for any displayed indications of anomalies, but none were apparent.

59 The driver did not observe whether or not the blue 'door close/locked' light was extinguished on the *driver's desk*. This light illuminates when all the train doors have been properly closed and locked. A door coming open in traffic would cause this light to extinguish.

60 The driver was unable to establish what the cause of the brake application was and pressed the emergency brake override button to prevent the train stopping at an inconvenient location. This caused the 'pass comm/door activated' light to extinguish and the driver was able to increase the speed of the train.

61 The emergency brake override button is a round, yellow, mushroom-headed button that can be operated by the driver's foot and may be used to cancel an enhanced service brake which has resulted from one of the following:

- a PCA emergency brake handle has been pulled; or
- a passenger door has unlocked (eg because an egress handle has been operated).

62 When pressed once, the enhanced service brake application is overridden for thirty seconds. If pressed repeatedly within this period, the enhanced service brake application may be overridden indefinitely.

63 About thirty seconds after releasing the emergency override button, the enhanced service brake applied for a second time, and the driver pressed the emergency brake override button again in order to prevent the train stopping and allow the train to increase speed. The train manager, who had been in his office behind the cab, came to join the driver to understand what was happening. A third enhanced service brake application then occurred, and the driver pressed the emergency brake override again allowing the speed of the train to increase – to 78 mph (126 km/h).

64 While the train was increasing speed again, the train manager was contacted by the customer host through the *crew call system*. The customer host told the train manager that a passenger had reported that a door was open in the first class portion of the train. The train manager told the customer host to pull one of the PCA emergency brake handles which are located throughout the train. These are painted red and provided with a notice underneath that reads: 'alarm, pull the handle, penalty for improper use'. The train manager was with the driver at the time of this call and so the driver first became aware that an exterior door might have been open.

65 The customer host made two unsuccessful attempts to pull the handle. By the second attempt the train was slowing anyway because, by then, the driver realised he had a problem with an exterior door (paragraph 64). At the time, the customer host thought that the braking was due to her pulling the handle.

66 The driver and the train manager worked together in an attempt to verify the passenger report in the light of apparently contradictory indications presented to them in the cab – particularly the lack of any information on the TMS to clarify the meaning of the illuminated ‘pass comm/door activated’ light. At the driver’s request, the train manager opened the cab doors to check whether any orange lights on the outside of the train were illuminated – illumination indicates that an exterior door is open. The train manager found that there was an orange light illuminated on the west side of the train; it then became evident to the driver that there was a problem with an exterior door.

67 The driver then made a controlled brake application to bring the train to a controlled stop at signal LR195. While doing so, two further enhanced service brake applications occurred, which the driver overrode on both occasions by pressing the emergency brake override button. The train was brought to a stand at 11:36 hrs.

68 The train manager walked back through the train and found that a door on vehicle 60249 was wide open. After the train had stopped, the door was closed manually and locked by on-board staff, and the train went forward to Market Harborough where the service was terminated, the passengers detrained, and the train taken out of service. Midland Mainline notified the RAIB of the incident at 12:04 hrs. The empty coaching stock ran to the maintenance depot at Etches Park, Derby with the RAIB’s agreement.

69 The detailed sequence of events following the train’s departure from Kettering was confirmed by a download from the train’s *on train monitoring recorder* (OTMR) – see Appendix D.

Consequences of the incident

70 There were no injuries or material damage as a result of this incident.

71 The train ran in service, at speeds up to 79 mph (127 km/h) with a passenger door that was wide open, and this situation existed until the train braked to a stand five minutes from when the door first opened.

72 The potential existed for someone to fall from the train – CCTV shows an adult passenger with children and another adult passenger walking past the open door.

Overview of key events

73 Figure 4 shows a diagrammatic overview of the key events associated with the incident and its consequences.

74 The full sequence of events identified by the investigation is included in Appendix E.

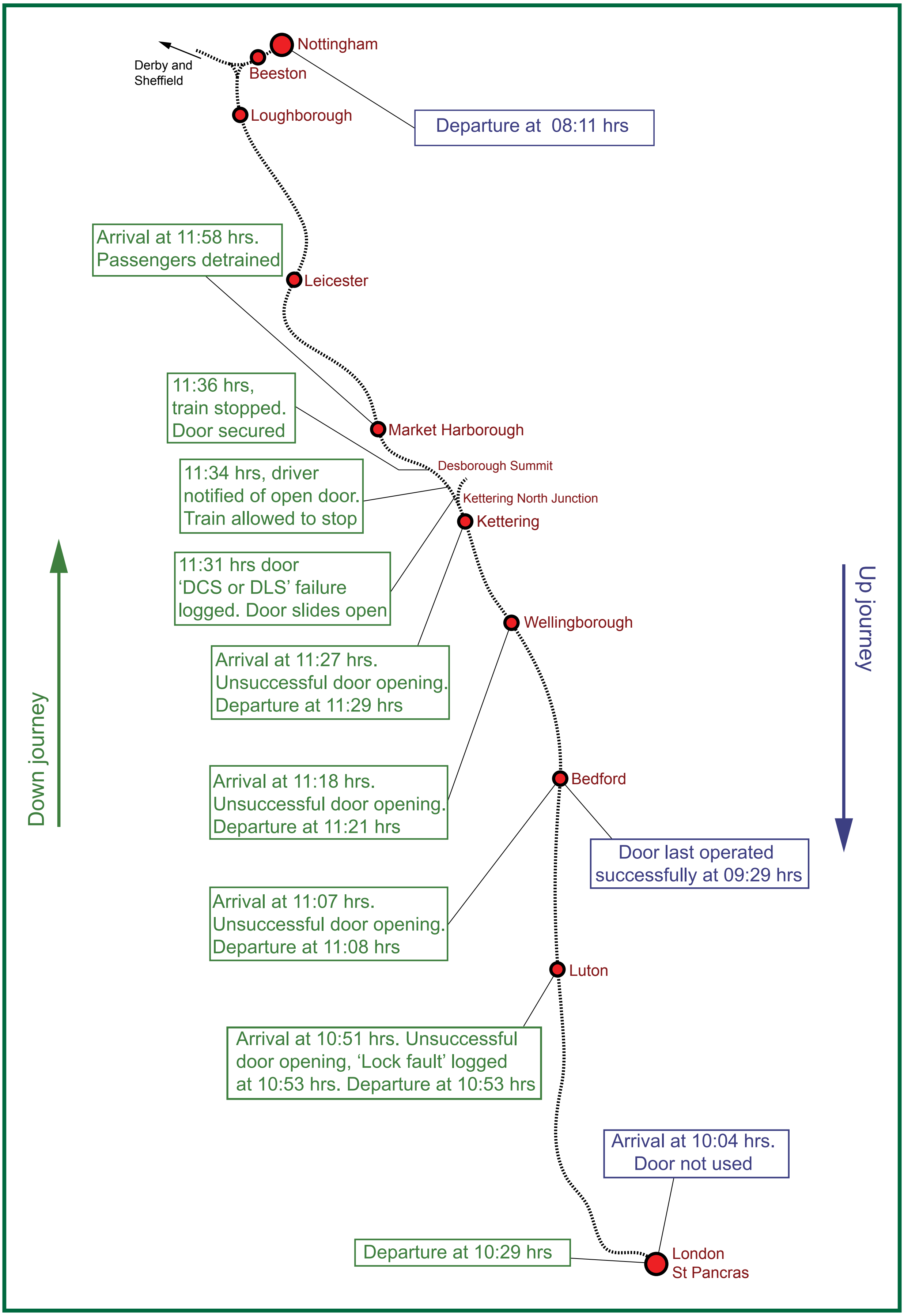


Figure 4: Overview of key events

The Investigation

Investigation process

75 The investigation considered:

- the cause of the door opening; and
- the handling of the incident.

76 The key evidence considered included:

- on-train CCTV recordings;
- data logged by the OTMR, the TMS and the EDCU;
- findings from evidential testing: including on-vehicle and rig testing of the door functions, wiring tests, and laboratory testing of the *door lock assembly* (DLA);
- documentation relating to the design and operation of the door system;
- witness statements from key parties involved; and
- details of training given to on-board staff.

Key facts

Railway infrastructure

77 There was no evidence that the railway infrastructure contributed to the incident in any way.

The door system

78 Figure 5 shows an overview of the doors system and its associated connections.

79 Each door comprises the following main equipment:

- Door leaf and associated parts. This is fitted to the door *portal*; the associated parts include the door motor, a *guidance and stabilisation system*, and a pneumatic door seal. A pin, fitted at mid-height on the door leaf (the *door leaf pin,* see Figure 5), is used as part of the locking arrangement;
- The DLA; see Figures 5 and 6. This is fitted to one of the *vertical door stanchions*; it includes the locking mechanism which engages with the door leaf pin to lock the door (paragraphs 81 and 82). Also mounted are the detection switches used to indicate that the door is closed (*door closed switch* (DCS)) and locked (door lock switch (DLS));
- The EDCU; see Figure 5. Fitted above the door, this contains the processor circuits that control and monitor door operation. Supplementary relay circuits are included for safety critical functions;
- Relay control box (known as the *MADD box*, see Figure 5). Fitted on the DLA, this contains additional door control relay circuits; and
- Local door control panels. Fitted adjacent to the door, these include the passenger 'open' and 'close' pushbuttons (see Figure 5) and other related equipment (eg microphone, loudspeaker and indication lamps).

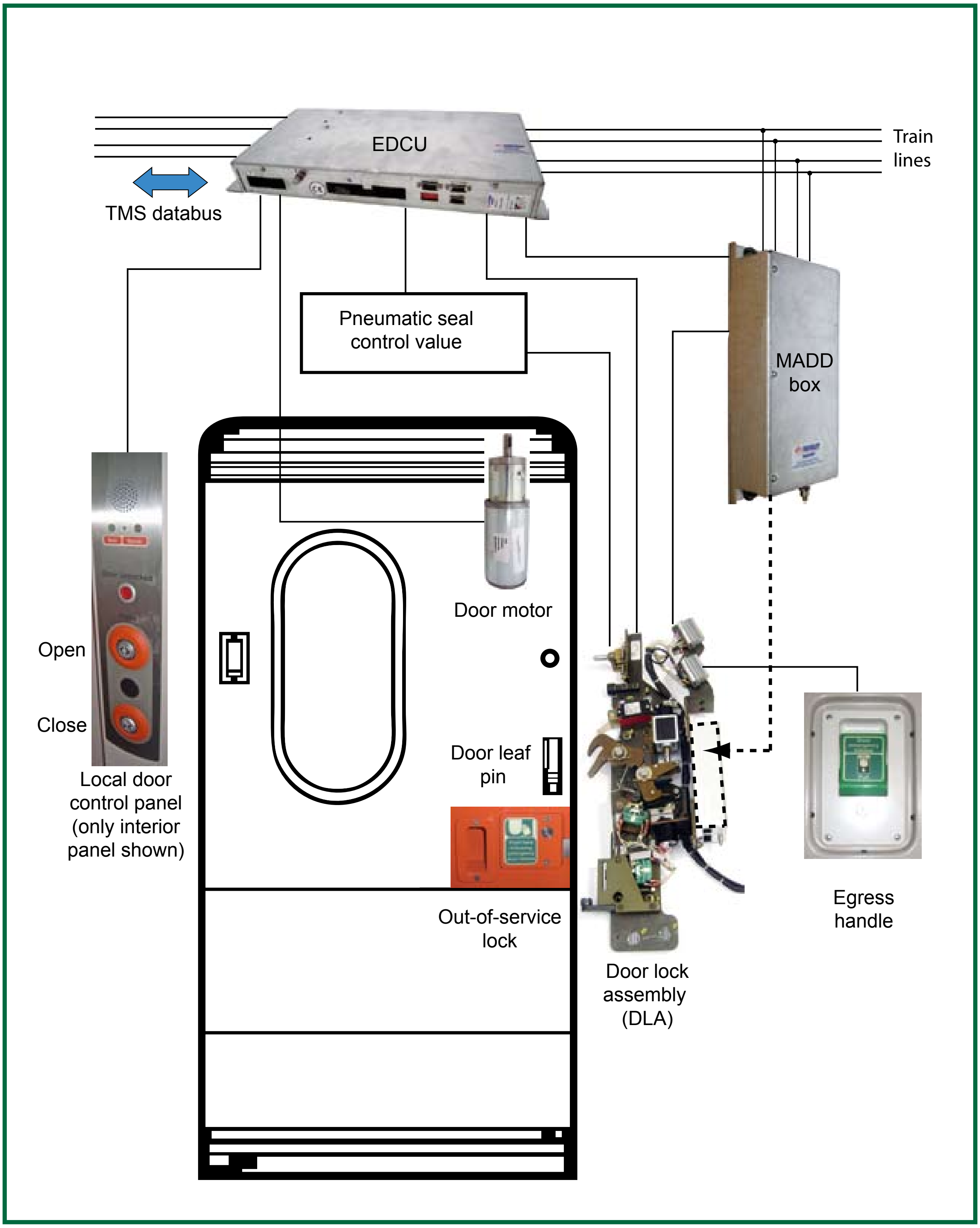


Figure 5: Overview of the door system and its associated connections

80 Wires running the length of the train (*train lines*) carry *control signals* to the doors from the driving cab and locations used by the train manager. Other train lines are used to monitor the status of the door; these include the safety loop (indicates that all doors are closed and locked) and the *emergency loop* (indicates that no egress handle (paragraph 91) or PCA emergency brake handle has been operated). Control and monitoring information is also exchanged between the TMS and the EDCU (eg for door relay status and fault messages) via a *databus* connection.

Locking arrangement

81 The principal parts of the DLA and its interface with the door leaf are shown in Figures 6 and 7.

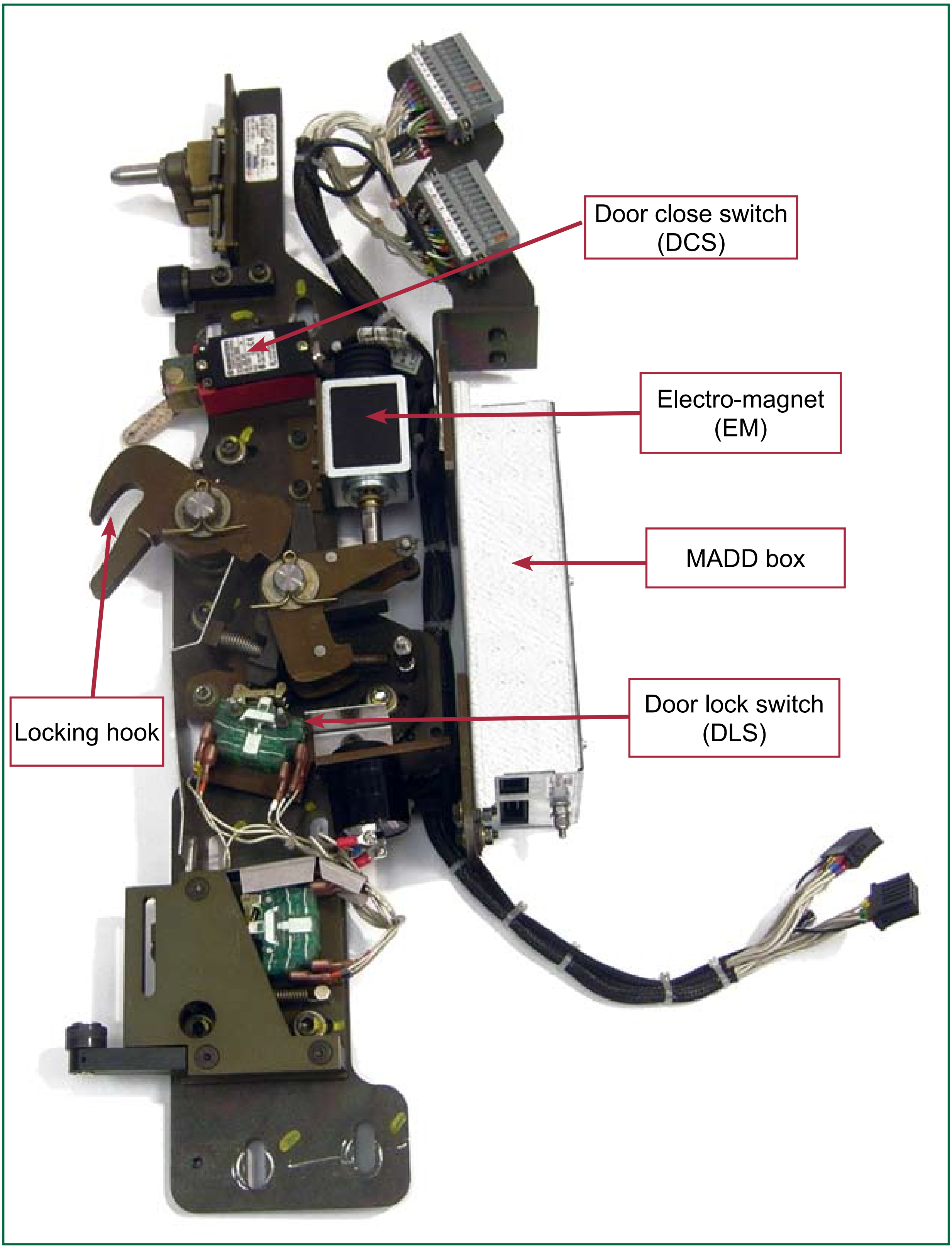


Figure 6: Door lock assembly

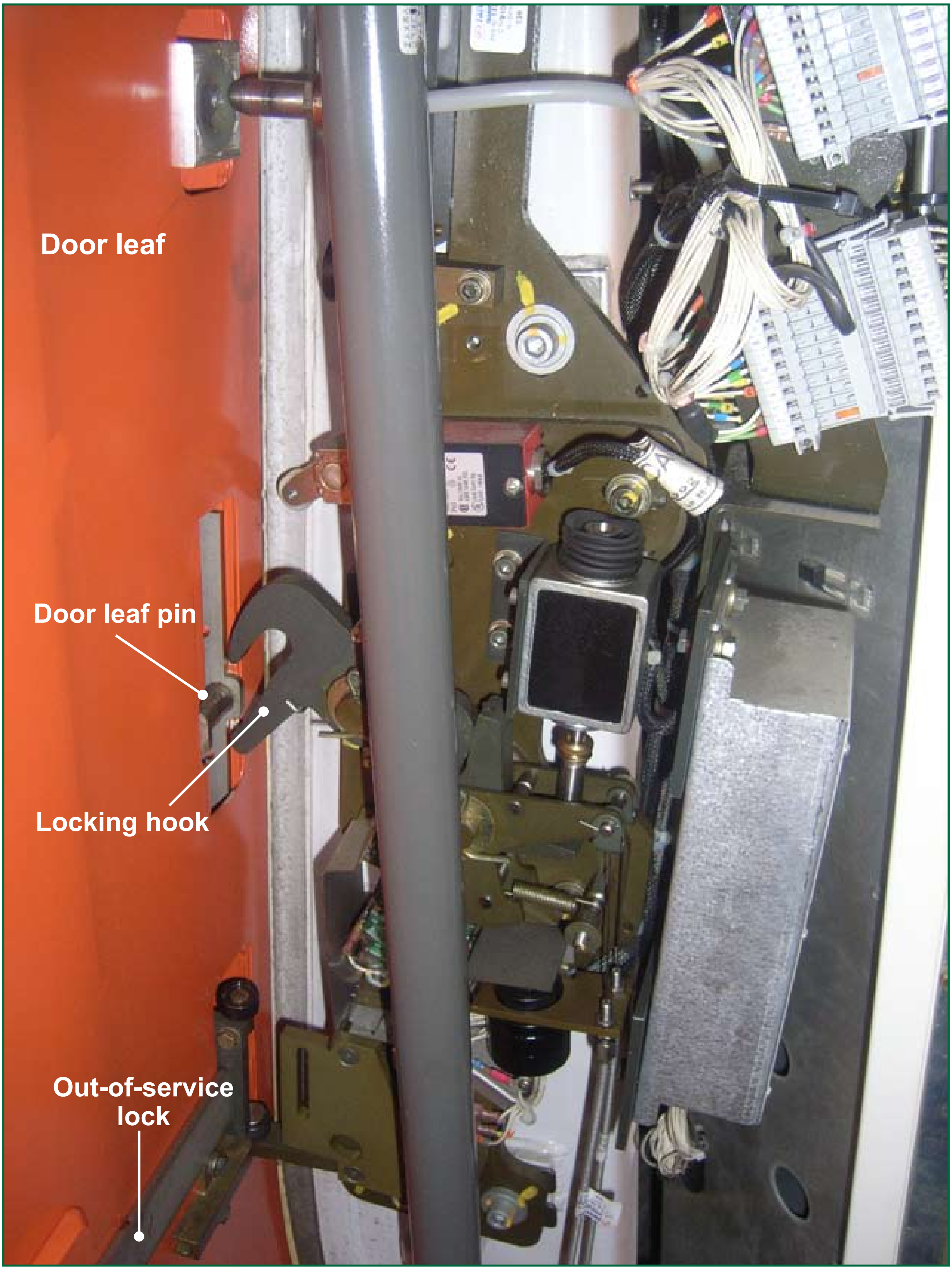


Figure 7: Door lock assembly showing its relationship to the door leaf (shown with door unlocked and unplugged)

82 The door is in the locked state when the door leaf pin is held in place by the locking hook; see Figure 8. The locking hook can rotate, but when locked, it is held in place by the falling latch locating in the *engagement slot* (engagement). Locking detection is provided by the DLS. When deactivated (natural condition), an unlocked door state is indicated; the *switch plunger* (which opens and closes the electrical contacts) is raised. When the falling latch engages in the locking hook, the switch plunger is depressed and the opposing contacts made. The DLS is activated and a locked state is indicated. The door is unlocked by the *electro-magnet* (EM); when activated, it presses on the falling latch, rotating it out of the engagement slot.

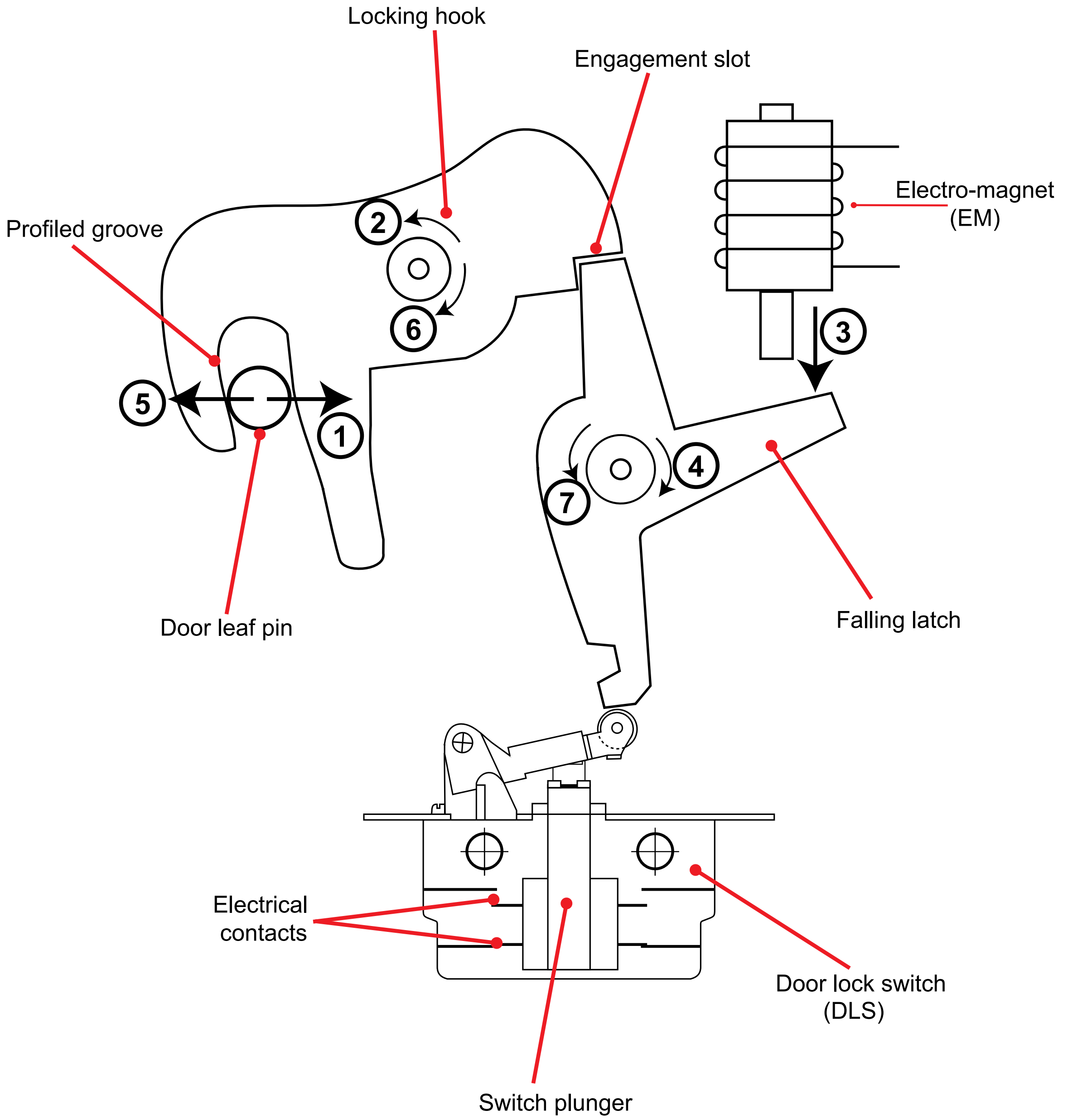


Figure 8: Door locking mechanism (shown in locked state) - annotation on diagram refers to description given in paragraphs 85 - 89

Normal operation

83 When the train is moving, the door system is in a quiescent state; it is locked by the locking hook but no current is applied to the motor to hold it closed.

84 To open the door, the driver first selects the side and number of vehicles on which opening is to be permitted. He then gives an authorisation signal to the train manager who sends the necessary *door release* signal. Relay circuits use these commands, together with an indication of low speed from the brake control system, to decide if door opening conditions are safe. The EDCU then lights an indicator on the local door control panel to show that the door can be opened.

85 When the passenger presses the 'open' push button, the EDCU initiates a further sequence of control commands. Referring to Figure 8, first a current is applied to the door motor to close the door; this pulls the door leaf pin to the right (1) – toward the portal – rotating the locking hook (2) and relieving any force on the top of the falling latch and the engagement slot. Unlocking is then initiated. The electro-magnet is energised (3), forcing the falling latch to rotate clockwise (4) and disengage from the locking hook; the locking hook is now only held in place by the door leaf pin.

86 When the DLS detects disengagement the safety loop is cut, providing an indication to the train (paragraph 80) that the door is unlocked; simultaneously, the EDCU applies a current to the door motor to open the door. The door leaf pin moves outward (5) and leaves the profiled groove in the locking hook. The locking hook is spring biased and rotates clockwise (6) so that the door leaf pin can re-enter the profiled groove when the door is next closed.

87 As the door opens, the DCS (which acts on the door leaf) deactivates. The electro-magnet is de-energised after a fixed time period (configurable in the range 2-5 seconds) and the falling latch is released. This is also spring biased and it rotates anti-clockwise (7) to rest against the locking hook (it cannot enter the engagement slot because of the now clockwise orientated position of the hook). Figure 9 shows the door locking mechanism in this unlocked state with the door leaf pin free of the locking hook.

88 When the door is fully open the EDCU cuts the current to the door motor.

89 The command to close the door can be from a variety of sources: eg use of the dedicated train crew controls, pressing the local passenger door 'close' push button, or, automatically, after the lapse of a pre-determined time period. On receiving the command, the EDCU applies a closing current to the door motor and the door leaf pin re-enters the profiled groove in the locking hook (paragraph 86). The EDCU continues to command the door motor to drive the door closed. Again referring to Figure 8, the door leaf pin is pulled toward the portal (1), rotating the locking hook anti-clockwise (2); as the engagement slot becomes aligned, the falling latch is able to engage. When the DLS detects that the door is locked, and the DCS detects that it is closed, the EDCU cuts the current to the door motor.

Out-of-service lock

90 A key operated *out-of-service lock* on the door leaf can be used by on-board staff to lock the door out of service in the event of malfunction. It is shown on Figure 5. The lock operates a microswitch on the DLA which bypasses the other detection switches.

Egress handle

91 An egress handle, shown on Figure 5, is provided at each door to enable it to be mechanically unlocked and manually opened in the event of an emergency.

92 The handle disengages the falling latch from the locking hook by means of a cable operated unlatching mechanism.

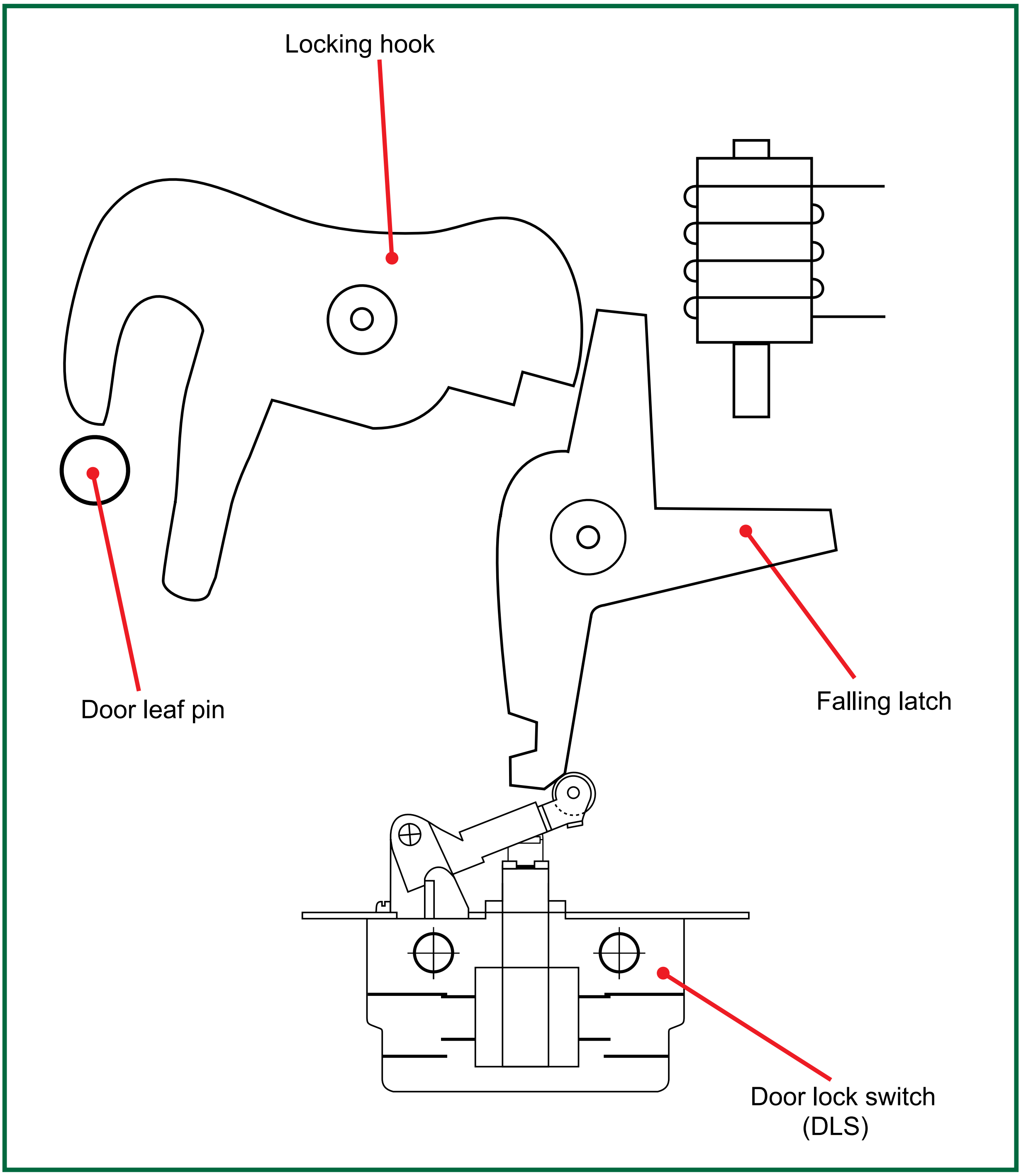


Figure 9: Door locking mechanism in unlocked state

93 Its operation opens the emergency loop (paragraph 80). This results in an automatic brake application and the opening of a voice communication channel to the driver. In this regard, its operation is similar to that of the PCA emergency brake handle (paragraph 58).

<u>Train Management System</u>

94 Prior to the introduction into service of the class 222 trains, Midland Mainline held a series of review meetings with Bombardier Transportation to decide what severity level should be assigned to each anomaly (paragraph 33) - HSBC Rail (UK) Limited attended these. As a result, one of three levels of severity was allocated to each anomaly. The meetings also decided whether the indication of each anomaly on the TMS was to be made to the driver, the train manager, the maintainer or to more than one of them. A summary description of each level is shown in Figure 10.

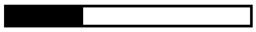
Severity Level	Representation on touch screen	Description
1		Warning – minor problem
2		Degraded function – major problem
3		Alarm – Safety affected or service critical

Figure 10: Summary description of TMS anomaly reports

95 During the design process for the trains (and prior to HMRI issuing the 'no objection to concept' – paragraph 28), Midland Mainline and HMRI agreed that in the driving cab, the TMS screen would normally be blank unless an indication of a level 3 anomaly occurred. This was to minimise the possibility of the driver being distracted, when, for example, approaching a signal at danger, and marked a change in philosophy compared with the earlier class 220 Voyager trains which, at the time, were reported to be frequently displaying 'anomaly' information on the TMS screen in the driving cab.

96 Level 3 anomalies for the attention of the driver are indicated by an illuminated yellow push button 'TMS level 3 fault' located above the touch screen in each driving cab. They also give rise to an audible warning. The driver must press the push button to acknowledge the anomaly and to silence the audible warning.

97 Level 3 anomalies for the attention of the train manager are indicated by a warning tone over the train's public address system.

98 Many level 3 anomaly indications are given to both the driver and train manager: such as, where a PCA emergency brake handle has been operated, where an egress handle has been pulled, or where doors have failed to lock or close (when in the station). Level 3 anomalies that are indicated just for the attention of the driver relate to engine, transmission, suspension and braking defects. Level 3 anomalies indicated just for the attention of the train manager typically relate to on-train equipment including heating and ventilation, catering, and the call-for-aid facility in the passenger toilet.

<u>The design of the driving cab</u>

99 The class 222 driving cab has a wrap-around driver's desk, with the driver's seat located toward the centre of the cab. It is based on the cab design of the class 220 Voyager fleet; it was, though, modified to suit Midland Mainline's specific requirements (particularly in respect of accommodating *5th percentile* females and *95th percentile* males) and to take account of the findings of design and human factors reviews. Drivers' representatives were also invited to study a mock up of the proposed cab and to provide comments on it.

100 No concerns were raised during the reviews regarding the design of the 'pass comm/door activated' light or the 'door close/locked' light.

101 Figure 11 shows the layout of the driver's desk and identifies the key features.

<u>Cause of the door opening</u>

102 The following key sources of evidence were used to investigate the underlying technical reasons for the door opening unexpectedly, and why this had been possible when the train was moving.

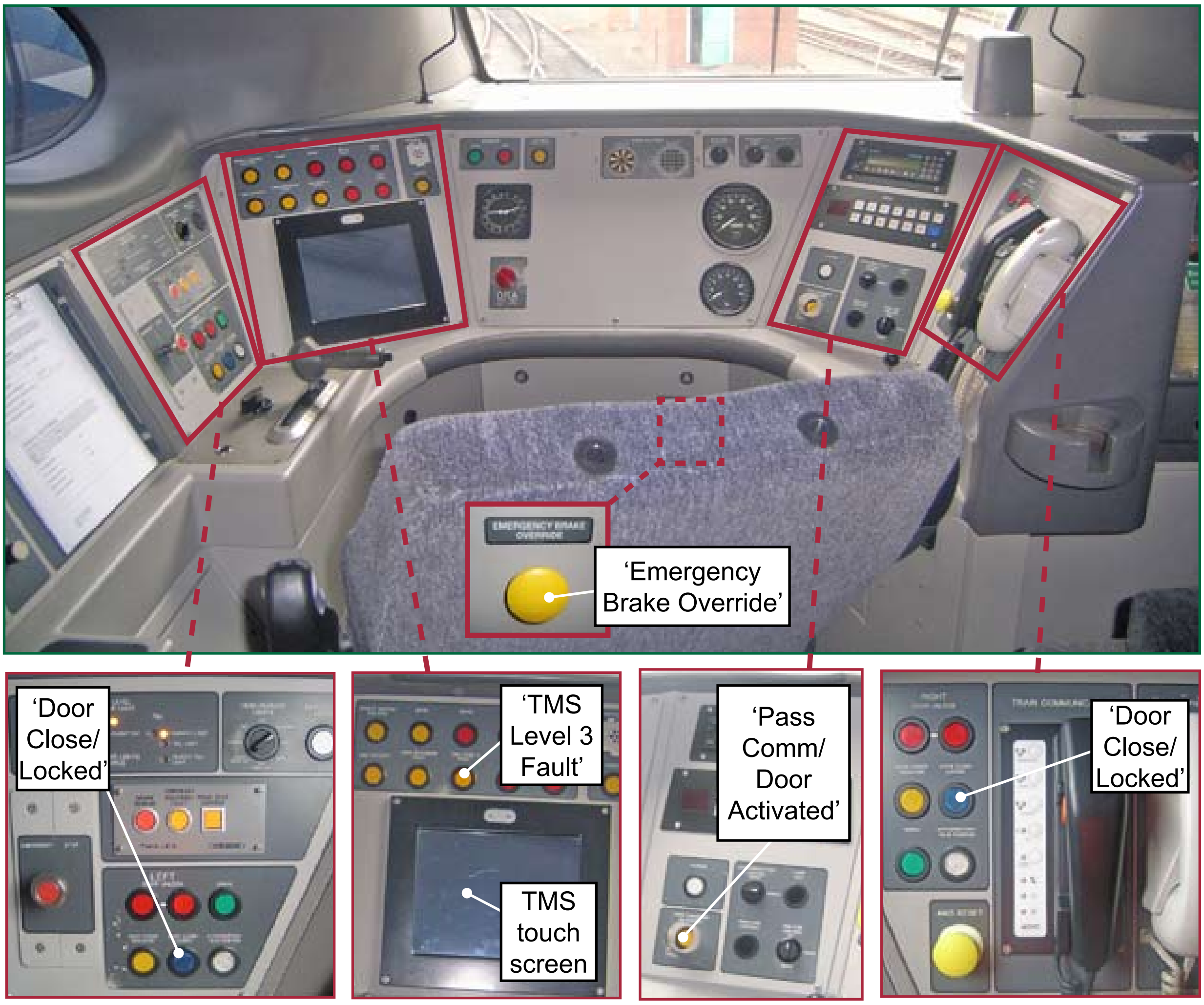


Figure 11: Class 222 driver's desk

On-train data records and recordings

103 The door was within the view of a CCTV camera located in the train *vestibule*. Images were available for the journey to and from St Pancras. They showed how the door controls had been used and how the door had responded. They showed that passengers attempted to use the door at Luton on the *down* journey – but that it did not open – and that the door was last successfully operated at Bedford on the *up* journey. They also showed the movement profile of the door when it opened (including the opening time) and the status of key ancillary functions (eg the *footstep light*). The images are time stamped.

104 The OTMR records the status of key vehicle functions and how the train is operated; this includes details of the train speed, brake application and selected train anomalies. A post-incident download of the OTMR was made on 10 June 2006 at Etches Park depot. This information was used to identify the event time sequences.

105 Passenger door system status event and fault information is logged by the TMS; the information is time stamped. The TMS logs were downloaded after the incident, when the train was in quarantine in Etches Park depot. Several door related anomalies were logged. In sequence, these included:

- ‘door service failure’ and ‘lock fault’ anomalies for the incident door when the train was at Luton station on the down journey;
- ‘DCS or DLS failure’ and ‘all doors closed car contradiction’ anomalies when the train was north of Kettering (around the time the door was observed to open);
- a ‘passenger alarm’ event after the train had been brought to a stand following the incident (this correlates with the train manager demonstrating the use of the PCA emergency brake handle to the customer host); and
- also after stopping, a series of anomalies arising from attempts to secure the door. This includes an egress handle operation (there was no record of this being operated before the train stopped).

106 The TMS uses EDCU information and the state of the DLS and DCS to establish door status (‘closed and locked’, ‘closed’, ‘open’ or ‘intermediate’) and fault conditions. It was established that:

- as no fault was logged at Bedford station on the up journey, the door was working normally at that point;
- as a ‘door failed to close’ fault was not recorded after the ‘lock fault’ at Luton was logged at 10:52 hrs, the TMS detected the door as being ‘closed and locked’; and
- because, when the door finally opened, the logged ‘DCS or DLS failure’ was followed by an ‘all doors closed car contradiction’ (this is generated when it cannot be detected that all the doors on the train are closed), the door was not being powered.

107 The EDCU logs additional door fault information. There is no time stamp, but timing can be established by correlation with the TMS record. The EDCU was also downloaded when the train was in quarantine. The following were logged:

- an ‘EM/DLS error’, corresponding to the ‘lock fault’ logged on the TMS at Luton; and
- a ‘door closed switch/DLS contradiction’ (this is generated when the door is detected open, but the DLS indicates a locked condition) corresponding to the ‘DCS or DLS failure’ north of Kettering.

Evidential testing

108 The following outlines the key testing undertaken in support of the investigation.

109 Bombardier have a standard prescribed post-incident door test. This test, undertaken on 10 June 2006, found nothing untoward with the operation of the door or its mechanical condition.

110 Testing of the footstep light showed that it was working after the incident; if commanded, it would have illuminated (paragraph 143).

111 Functional testing of the TMS showed how it responded to various simulated electro-magnet and the DLS faults. This was used to correlate the fault record to the physical operational state of the door.

112 Functional testing confirmed that, in all significant aspects, the door (when configured as it was on 10 June 2006) performed in accordance with the original type test specification.

113 Testing of the associated vehicle wiring showed that it had been installed in accordance with design documentation and that there were no faults which could have led to errors with controlling signals.

114 Functional testing of the egress handle showed that there was no evidence (for instance, by correlation of the fault information generated with that recorded at the time of the incident) that egress handle operation contributed to unlocking the door.

115 Tests were undertaken, on both a test rig (at Faiveley Transport's factory) and a number of service train doors, to investigate the response of the door to a simulated DLS malfunction occurring during a normal door open sequence. These showed that, after unlocking, and the detection of an 'EM/DLS error', it could not be assured that the falling latch would engage in the locking hook (as a result of the foul condition shown in Figure 12(b)). The tests also showed that the pneumatic door seal would continue to inflate and deflate when the low speed signal was de-energised (train moving) and re-energised. This caused the door leaf to be pushed out of the door portal incrementally.

116 Laboratory testing of the DLA was undertaken to understand its behaviour and to identify any issues contributing to the incident. Initial tests showed that the wiring was in accordance with design documentation and that there were no faults which could have led to errors with the controlling signals. The tests identified nothing untoward – at room or elevated ambient temperatures - with the mechanical operation of the falling latch, locking hook or the DLS switching characteristic which would explain an 'EM/DLS error'.

117 The DLS was then removed from the DLA and a small foreign body (particle) was observed to be inside the switch. The DLS was dismantled and the particle removed. Chemical analysis showed the particle and the switch to be of different materials.

118 Inspection showed that the particle was too large to have got into the DLS after assembly. Locations were identified within the DLS where the particle, if located, could cause the microswitch to jam.

<u>Technical documentation and other information</u>

119 The investigation considered the following key documents and specifications:

- Faiveley Transport specification E 082 710.SRS 'System Requirement Specification – Passenger Access Doors'. This defines the functional requirements for the door system and the associated EDCU software. It includes the detection criteria for faults, the method of cancellation and the system response in the event of non-cancellation. Issue H is applicable to the EDCU software version that was installed on the incident door.
- Faiveley Transport specification E 082 710.SATS 'System Acceptance Tests Specification – Passenger Access Doors'. This defines testing requirements for verifying individual functional requirements detailed in E 082 710.SRS.
- Faiveley Transport document NT E147700.002 'Passenger and Staff Access Doors – Operator Related Documentation'. This defines the operating instructions for the door system. It includes advice on corrective action in the event of malfunction.

<u>Handling of the incident</u>

<u>Training of the driver, train manager and customer host on class 222 'Meridian' trains</u>

120 The class 222 Meridian trains were commissioned by Bombardier Transportation from a depot at Crofton, near Wakefield. Bombardier staff trained Midland Mainline's instructors, and the training material given was adapted by Midland Mainline for the conversion courses that were delivered to drivers, train managers and customer hosts.

121 The training for drivers consisted of five days in the classroom followed by eight days practical training on class 222 trains. The final day included an assessment consisting of 22 questions, following which drivers were issued with a certificate of competence if successful. The training included, amongst other aspects, use of the TMS, and operation of the doors and cab equipment. Continued competence is assured by means of a two-yearly assessment cycle.

122 Drivers were issued with a Drivers' Manual on the first day of training. This consisted of extracts taken from the Operations Manual produced by Bombardier Transportation and provided the main source of information for drivers on the class 222s covering practical issues, including faults and failures.

123 Drivers did not have the opportunity to practice their response to faults and failures on a simulator.

124 The conversion training for train managers was a ten day course that consisted of a mixture of practical and classroom based training. The practical training included how to respond to incidents and matters such as door operation, PCA emergency brake handle operation and use of the TMS. Train managers were assessed both during the course and on the final day of training.

125 Training material was issued to train managers during the training course, but they were not issued with relevant extracts of the Operations Manual. Sections of the manual which are relevant to both train managers and to customer hosts were still to be issued at the time of the incident. This was to be done following a rewrite of the manual into a form suitable for issue to the staff concerned (including drivers). At the time of writing this report there was no date planned for the issue of the revised manual.

126 Customer hosts received a two day conversion course covering catering and on-board safety issues such as the location of fire extinguishers and ladders and other safety equipment. Their training did not include practical application of PCA emergency brake handles.

Actions required of drivers and guards (train managers) in the event of an emergency

127 The requirements relating to the correct response to emergencies arising during a journey are laid down in the Rule Book, Railway Group standard GE/RT8000. The use of the emergency brake override is not however explicitly covered. Clauses relevant to the circumstances arising from a door opening in service are described in the paragraphs below.

128 Clause 10.11 of module TW1, 'Preparation and movement of trains – General', deals with passenger communication apparatus and states that if an emergency brake application is not automatically made when the warning alarm sounds, the driver must:

- if possible, contact the person who has operated the apparatus;
- ask the person why they have used the PCA;
- take the necessary action;
- if necessary, bring the train to a stand at the first suitable location.

The driver is required to stop the train immediately if he has reason to believe that the train may be 'in danger', or if the PCA has been operated as the train is leaving a station.

129 Clause 20.2 of module TW1 contains instructions to drivers and guards when their train is put 'in danger'. It requires that if the driver or guard sees something which could put the safety of the train 'in danger', they must stop the train immediately. If possible, the driver must avoid stopping the train on a viaduct, in a tunnel, or in any other place where it might be difficult to deal with the emergency.

130 Clause 5.1 of module TW2, 'Preparation and movement of multiple-unit passenger trains', covers incidents involving exterior power-operated doors. Drivers and guards are required to immediately lock and label out of use a power-operated door if:

- a door closes other than through normal operation;
- the train starts with someone or something trapped in the door;
- the train starts with a door staying open when it should be shut;
- a door comes open during the journey.

In such circumstances, the driver must tell the signaller immediately, not move the train until instructed to do so and carry out the instructions given by the signaller.

131 Clause 1.2 of module TW5, 'Preparation and movement of trains – Defective or isolated vehicles and on-train equipment', contains requirements on drivers to report defective on-train equipment. Clause 1.2 (a) lists defects where the train must be stopped immediately and the signaller advised; clause 1.2 (b) lists defects where the driver is required to stop the train at the first convenient opportunity (defined as the next scheduled station or other stopping point on the journey, or when stopped at a signal showing a stop aspect) before telling the signaller. The list of defects in clause 1.2 (b) includes a defect in the PCA.

Use of the Train Management System by on-board staff

132 Drivers and train managers are not issued with specific instructions about when they should interrogate the TMS.

133 Drivers are discouraged from using the TMS when the train is moving because of the potential for distraction (paragraph 95). Under normal circumstances therefore the TMS in each driving cab remains blank during a journey and, normally, will only display if requested to do so following the reporting of a level 3 anomaly that also gives rise to an audible alarm which the driver must cancel.

134 The TMS screen in the driving cab will display at the start of a journey when the driver inserts his key or at any other point during the journey if the driver chooses to look by touching the screen (such as when the train is stopped at a station).

135 TMS screens are also located in each vehicle and train managers are able to use these, at their own discretion, to see what faults are recorded. Train managers will also see what anomalies have been recorded by the TMS when they initially set the system up before the start of a new journey. The train manager has various duties on the train (eg collecting tickets and dealing with passenger questions), however, they do not include the need to regularly interrogate the TMS in order to check whether new anomalies have been reported. If an anomaly requires the attention of the train manager, the TMS will report it as level 3, and give an audible alert on the public address system (paragraph 97).

136 Customer hosts only use the TMS in conjunction with using the public address system. They are not responsible for interpreting anomalies that have been logged.

Analysis

Identification of the immediate cause

137 The investigation identified two principal mechanisms for the door opening during train movement:

- the EDCU had commanded the door to unlock and then power open; or
- the door had become unlocked by some other means and had then opened of its own accord.

138 Post-incident inspections and functional testing on 10 June 2006 did not indicate any obvious immediate fault regarding the condition or operation on the door (paragraph 109). There was therefore no evidence that a catastrophic mechanical failure had occurred which had resulted in the door opening.

139 Three possible mechanisms were identified for the door becoming unlocked and then, when moving, remaining unlocked:

- the EDCU had initiated a normal door opening sequence when train was moving; or
- the egress handle had been operated at some stage; or
- a malfunction of the DLS - during a normal opening sequence at Luton - had left the door in a 'dormant' unlocked state, but detected locked.

Testing and analysis was undertaken to evaluate which of these three mechanisms were relevant.

EDCU initiated door opening sequence

140 The EDCU controls the door opening using a combination of software commands and hard-wired relay circuits. One credible fault is a software error which allows the EDCU to initiate a door opening sequence autonomously.

141 The supplementary relay circuits (paragraph 79) are designed to protect against this by ensuring that certain conditions are present (eg low speed, presence of a door release command from the on-board staff) before an opening current can be applied to the door motor.

142 The probability of a software error occurring at the same time as a relay circuit failure, given the simplicity and hence reliability of the circuit, is considered so small that the risk of a multiple failure of the EDCU causing the motor to open the door can be ignored.

143 The following evidence indicates that other failures, which require a combination of errors, did not cause the door to open under power of the motor:

- CCTV recordings indicated that the door leaf moved slowly and smoothly, taking more than ten seconds to open fully and without any evidence that its *obstacle detection* system had been activated. During normal operation, the door takes approximately five seconds to open fully. If the obstacle detection system identifies an obstruction it would cause door leaf movement to pause.
- The CCTV did not record evidence of the local 'open' pushbutton being pressed immediately prior to the door opening.
- An analysis of the anomaly information logged by the TMS and the EDCU showed it to be inconsistent with the door being driven by the motor.

- CCTV recordings showed that the footstep light was not illuminated when the door opened (paragraph 110). The EDCU would have illuminated the light if the door had been commanded to open.
- Testing showed that the train wiring associated with the door was in accordance with the intended design and free of electrical fault; tests also showed the door to operate in accordance with its functional specification.

144 The possibility of a door open command sequence initiating – when moving – which unlocked the door but did not power the motor, can be discounted from the fault information recorded on the TMS and EDCU. This is further confirmed by the fact that the local 'open' pushbutton was not pressed (paragraph 143) prior to the door opening.

Egress handle operation

145 An egress handle is provided at each door so that it can be manually unlocked and opened in an emergency. The handle unlocks the door by mechanically disengaging the falling latch from the locking hook; it also activates an associated microswitch and opens a voice communication channel to the driver. Operation is logged by the TMS. The handle needs to be reset (by a key) after each use.

146 It is possible that operation of the egress handle, at any time, could have left the door unlocked but closed.

147 A combination of CCTV and TMS data recordings shows that the door last operated successfully (ie without fault) at Bedford station on the up journey. As the DLS would have correctly moved from its 'locked' state and back to its 'unlocked' state, there is nothing to suggest that the egress handle operation (or a malfunction of it) had interfered with the locking mechanism.

148 Similar evidence shows that the door failed to open (for the first time) at Luton station on the down journey. There is no CCTV or TMS data recording to show that the egress handle was operated at, or before, this time, or between then and when the door opened north of Kettering. The TMS first logged an egress handle operation at 11:50 hrs, however, this correlates with its use by the on-board staff after the incident and when the train had stopped.

149 Furthermore, for the egress handle to have caused the door to open when the train was moving, an additional fault with the low speed signal would have been required. There was no evidence to suggest this.

150 The above discussion and post-incident testing, which demonstrated that egress handle operation would not explain the recorded TMS and EDCU fault messages, shows that egress handle operation did not cause the door to open.

DLS malfunction

151 A potential credible failure mode is that a DLS malfunction occurred between leaving Bedford, on the journey up to London, and arriving at Luton, when the door first failed to open on the down journey.

152 The following evidence supports this:

- the on-board CCTV showed that the door operated satisfactorily at 09:29 hrs on the up journey at Bedford;
- the 'lock fault' logged by TMS at 10:52 hrs when the door failed to open on the down journey at Luton (paragraphs 50, 51 and 105); and
- the associated 'EM/DLS error' recorded on the EDCU (paragraph 107).

153 The EDCU logs an 'EM/DLS error' during a door opening sequence if, in less than 3 seconds after energising the electro-magnet, it fails to detect that the DLS has correspondingly changed state. A malfunction of the DLS would explain both the logging of the 'EM/DLS error' and the failure to detect a door which had become unlocked.

154 A malfunction of the electro-magnet could also result in an 'EM/DLS error'. However, given its relatively simple design, and that it appeared to operate normally both before and after incident, its malfunction is an unlikely source. Furthermore, a malfunction of the electro-magnet would not have resulted in an undetected unlocking of the door.

155 After identifying an 'EM/DLS error', the EDCU puts the door into a degraded mode of operation. The intended response is to cut, simultaneously, the current to the electro-magnet – allowing the falling latch to attempt to engage with the locking hook – and the door motor. There is evidence from the functional testing undertaken to support that this response occurred when the 'EM/DLS error' was logged. Post-incident tests were conducted to assess the combined effect of these actions. They showed that there was a significant probability that, in practice, the falling latch would not engage (paragraph 115).

156 It is credible therefore, that the door was in an unlocked state because of the EDCU's response to the 'EM/DLS error'. The door would have become unlocked as part of a normal passenger demanded opening sequence. It would have remained unlocked because the falling latch failed to engage when the EDCU identified a DLS malfunction and cut the current to the electro-magnet. It remained unmotored, because as part of the automatic fault management process, the EDCU simultaneously cut the current to the door motor.

157 Because the DLS failed in a way that indicated the door was locked, the safety loop was not cut. Protection systems on the train - which may have prevented it departing from the station - were therefore not activated.

158 Because no current was applied to the door motor, there was no significant retaining force on the door leaf (except that from the inflatable seal - see paragraph 199) to counteract any external effects trying to slide the door leaf open.

<u>Identified cause</u>

159 Neither an EDCU initiated opening sequence nor did an egress handle operation caused the door to open while the train was moving.

160 The observed events can, however, be fully explained by the manifestation of a DLS malfunction, the response to which led the door to become and remain unlocked, and also unmotored. It is likely that this occurred during the normal door opening sequence at Luton station and is identified as the immediate cause of the incident – the door being left able to open. No other mechanisms were identified which explain how the door opened.

Identification of causal and contributory factors

<u>Causal factors relating to the door being able to open</u>

161 The microswitch design used for the DLS has a service history of over 30 years and is widely used in safety critical circuits. A number of potential failure modes (eg welding of contacts or jamming due to external clamping forces on the switch case) could result in the observed malfunction – normally open contacts conducting as if they were closed. Protection features are therefore needed to mitigate the risk of a DLS malfunction.

162 In the door design, protection is inherently provided by the falling latch which, when not acted on by the electro-magnet, naturally rotates toward the locking hook and, if it is correctly aligned, enters the engagement slot and physically locks the door (paragraph 82). However, post-incident tests identified circumstances where engagement does not always occur (paragraph 115).

163 Figure 12 shows the relationship between the falling latch and the locking hook. With reference to Figure 12(a), to ensure engagement of the falling latch in the locking hook, the door leaf pin must move in towards the carbody – to the right (1). This rotates the hook anti-clockwise (2), in order that the engagement slot is aligned so that the falling latch, rotating under spring bias (3), can enter (4). If the pin does not move sufficiently far enough, a foul condition results and the falling latch cannot engage, Figure 12(b).

164 The door leaf pin is rigidly fixed to the door leaf. It moves in toward the carbody as the door motor drives the door closed; an increase in motor current increases the closing force, and improves the opportunity of engagement.

165 Resistance preventing the door leaf closing against the portal (eg an obstruction or a pressure difference) forces the door leaf pin away from the carbody and reduces the opportunity for engagement.

166 The EDCU commands the door to be driven and held closed during the normal closing sequence in order to ensure reliable falling latch engagement (paragraph 89). Development testing was used to determine the motor current needed; this considered worst case operating scenarios (eg standing on *canted track*).

167 The door is also driven closed during the initial part of the open sequence. This relieves forces acting on the top of the falling latch, reducing wear and ensuring the falling latch can rotate when the electro-magnet energises (paragraph 85).

168 On the up journey, the door opened and closed at Bedford; no problem was reported. There was therefore sufficient capability in the door motor for the EDCU to drive the door, overcome any prevailing resistance, and ensure that the falling latch could engage. Functional testing showed that the motor was working correctly after the incident.

169 When the 'EM/DLS error' was detected, the EDCU response was to stop normal operation of the door and to call alternative software control algorithms – entering it into a degraded mode of operation. Nevertheless, as the motor had sufficient capability at Bedford - and there is no evidence to suggest that resistance was significantly higher at Luton (or on any other immediately previous occasion when the door had successfully locked) – the EDCU should have been able to control the door motor so that engagement could also be assured in this particular circumstance. The commands given by the EDCU did not result in falling latch engagement; issues contributing to this are discussed in paragraphs 171 to 177.

170 The manner in which the EDCU controlled the door motor when – as result of the 'EM/DLS error' – the door was put into a degraded mode of operation, is causal to the door becoming unlocked and able to open (un-motored) at Luton station.

Contributory factors relating to the door being able to open

EDCU software

171 The software in the EDCUs on the Meridian fleet was upgraded between 27 March and 14 April 2006. This raised the EDCU configuration to revision I, its status at the time of the incident. Service problems had been experienced with the indication given on the 'door/closed locked' lamps on the train manager's control panels – on occasion they gave a different indication to that displayed in the driver's cab. The ECDU software upgrade was implemented to remedy this.

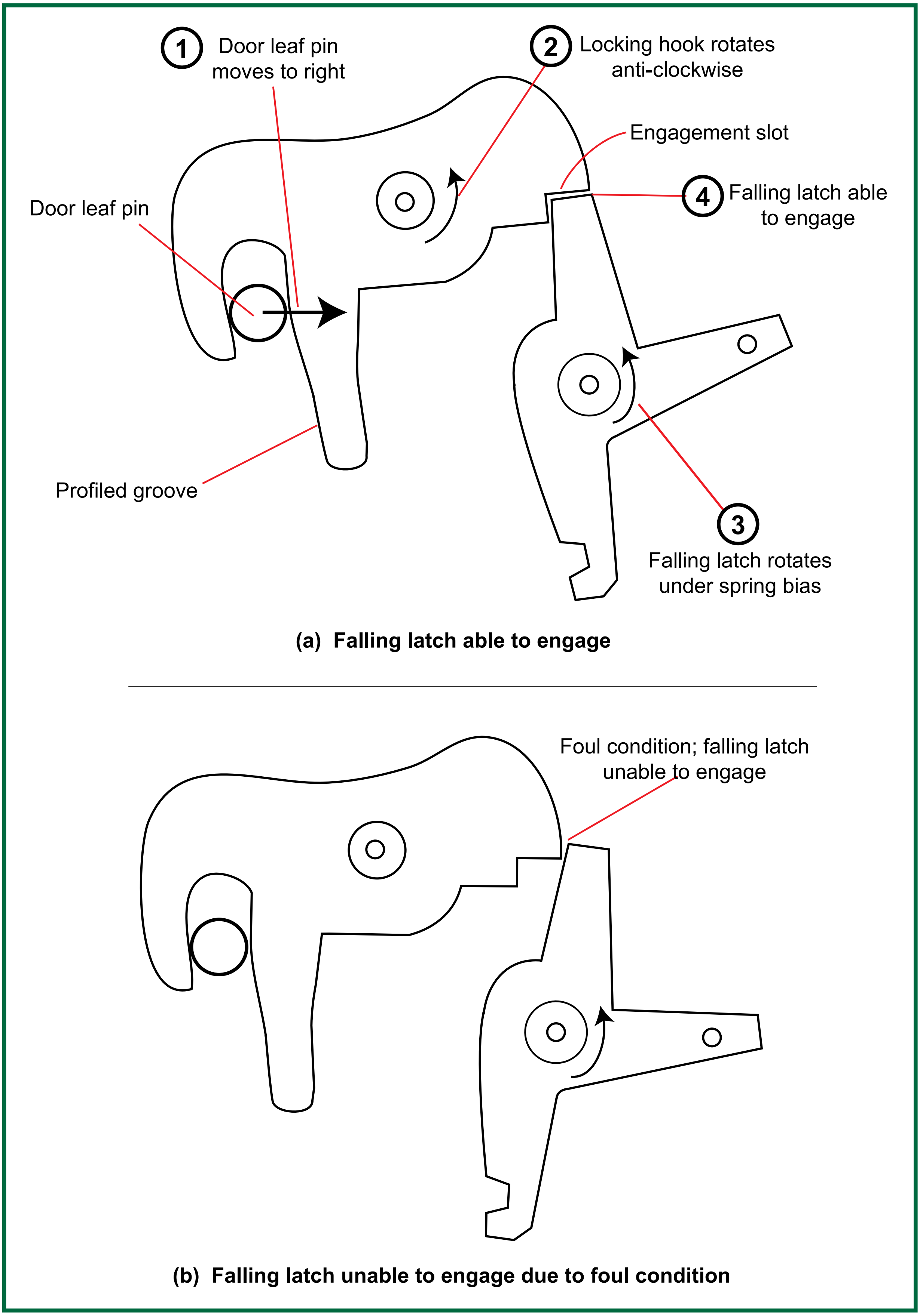


Figure 12: Relationship between the locking hook and the falling latch - annotation in diagram refers to description given in paragraph 163

172 The EDCU software comprises two parts: the '*application system*' (AS) and the '*operating system*' (OS). The software upgrade included a change to the way in which the EDCU managed the door motor current. Changes were made to the OS to implement this, but no corresponding modification was made to the AS.

173 It was intended that a limit of 4.7A should apply to the door motor current. Development testing (paragraph 166) showed that 3.0A was needed for falling latch engagement; 1.7A was provided as an additional margin. However, the result of the implemented software changes was unintentionally to limit the current to 0.9A for certain operating scenarios. These scenarios include the operating conditions prevailing at the time of a 'EM/DLS error' detection.

174 The EDCU software design is such that, in responding to an 'EM/DLS error', the current is immediately cut to both the electro-magnet and the door motor. Hence, for the falling latch to engage, it has to be able to enter the engagement slot before relaxation of the motor current allows the locking hook to rotate to a position which is foul of its returning path, see Figure 12(b).

175 In practice, the movement of the locking hook is governed by the comparatively large inertia of the door leaf. Therefore the rotational speed of the locking hook is likely to be small and probably insignificant. However, as the closing force would be low due to the 0.9A motor current limit, the locking hook was probably in a position which fouled the path of the returning falling latch **before** the current was cut. If true, this alone would have prevented engagement.

176 Faiveley conducted tests to verify the software upgrade before changes were made to the class 222 fleet. These were designed to confirm that the primary functional intent of the modification had been correctly implemented. The various current limits were not checked; it was assumed that a deficiency in functional performance – for instance, an inability to lock during normal operational open and close cycles – would be evident if the current was insufficient. The particular sequence of abnormal events that would have led to the identification of the reduced current limit was not envisaged and therefore not included in the test specification. The software error thus went undetected.

177 The unintended change of the motor current limit as part of a EDCU software upgrade is contributory to the door becoming unlocked at Luton station.

DLS malfunction

178 A variety of factors could have caused the DLS malfunction. Evidence shows that a number of these can be disregarded:

- post-incident wiring and functional tests showed that the malfunction was not due to a fault (eg a false electrical feed) with the associated wiring;
- Schaltbau did not consider that, in their experience, the installation design used for the DLS presented any risk to its operation (eg external clamping forces which could cause it to jam);
- testing at elevated temperatures did not find a risk of jamming due to thermal expansion; and
- there was no evidence of welding of switch contacts.

179 Upon close examination, a small and mobile particle was found in the DLS. After dismantling the switch, the particle was examined chemically and physically. On microscopic examination the particle appeared to be of a plastic material, approximately 2.5 mm long and 1.2 mm wide, Figure 13. Its thickness, at its narrowest dimension, was 0.4 mm.

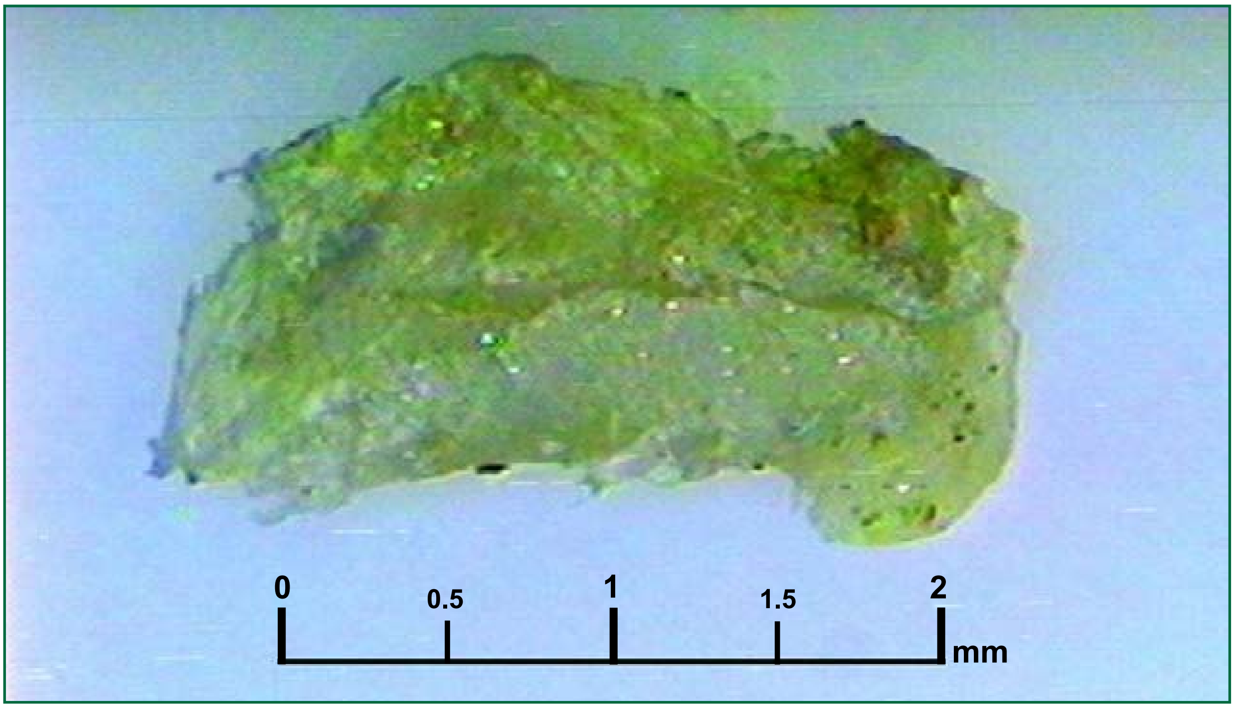


Figure 13: Particle found in the DLS

180 Chemical analysis showed the particle core to be of a different material to that of any of the switch components. However, surface analysis indicated chemical agents which are present elsewhere in the switch, notably the switch plunger.

181 The switch case is designed to prevent ingress of solid objects greater than 1 mm in size; this is tested by attempting to insert 1.0 mm diameter wire. In practice, the DLS prevented insertion of wires down to 0.3 mm diameter. Therefore, in view of its smallest dimension (0.4 mm), it is highly unlikely that the particle entered the switch after manufacture. Furthermore, because it is of a different material, it is not a part which had become detached from a component of the switch.

182 Precautions are taken to avoid contamination during manufacture; this includes washing components in de-ionised water. However, as clean room conditions are not used, it is conceivable that a foreign body could enter the switch during assembly. This is the most likely explanation for the presence of the particle.

183 The presence, on the surface of the particle, of chemical agents from the switch plunger, is evidence that there had been close contact between components normally free to move relative to each other. With the particle located on the plunger, the switch jammed in a manner which would explain the DLS malfunction.

184 The presence of the particle within the DLS is contributory to the door becoming unlocked at Luton station.

185 Schaltbau have no records of other switch malfunctions due to foreign bodies of this type.

Contributory factors relating to the door opening

186 The train was stationary at Luton when the EDCU logged an 'EM/DLS error'. If this fault had been identified to the train manager, there was an opportunity to lock the door out of use before departure. Alternatively, a command could have been made to motor the door closed as a precaution against it opening when the train was moving.

Use of the out-of-service lock

187 Faiveley specification E 082 710.SRS 'System Requirement Specification' states that to cancel an 'EM/DLS error' it is necessary to 'Close the door manually. Operate the (out-of-service) lock to isolate the door and reset it'. Faiveley document NT E147700.002 'Operator Related Documentation' similarly advises 'use of the out-of-service lock to isolate the door…' when such faults occur.

188 Operating the out-of-service lock requires manual intervention. The train manager is the only person who could be expected to do this.

189 The TMS is the only practical means of alerting the train manager of an 'EM/DLS error'. Although the fault indication was passed to the TMS, it was only classified as a level 2 anomaly indication for the train manager. To be aware of it in time he would have had to have reason to have been interrogating an on-board TMS screen while the train was in the station. The train manager's duties (eg ticket inspection) mean that he is not always in the close vicinity of a TMS screen; accordingly, there is no requirement for the train manager to check the TMS regularly for level 2 anomalies or lower. The train manager's duties include a responsibility for the safety of passengers on the train; they do not include the need to respond immediately to train anomalies which are classed as not being 'safety affecting' or 'service critical' (Figure 10).

190 If the 'EM/DLS error' had been classified as a level 3 TMS anomaly, an audible alarm on the public address would have alerted the train manager of its safety affecting nature and the need for acknowledgement on a local touch screen. This would have prompted the train manager to lock the door manually out of service before authorising departure.

191 No passenger reported a problem with the door at Luton, Bedford, Wellingborough or Kettering.

192 The fact that the detected 'EM/DLS error' was not a severity level 3 anomaly for the train manager (or driver) is contributory to the door remaining unlocked and able to open when the train was in motion.

Motoring the door closed when the train is moving

193 In addition to being left unlocked, the DLS malfunction resulted in no closing force from the door motor (paragraph 155). The provision of an active motor force could have mitigated the risk of the door subsequently sliding open when travelling.

194 Faiveley specification E 082 710.SRS states that, in response to an 'EM/DLS error', 'The door stays free (ie no motor force is applied) in its position if the train is at a standstill or powered on closing (ie closing force applied) if the train is running'. It was confirmed that, in accordance with this specification, when the train starts to move, and the low speed signal is lost, the EDCU should have motored the door closed.

195 The software logic requirements (in E 082 710.SRS) call for the generation of a door closing command when the train starts to move. However, if (as in this case) the DLS incorrectly indicates that the door is locked, this command is blocked so preventing a motor current being applied. This is a software requirement error that has existed since the initial design.

196 Faiveley developed a detailed System Acceptance Test Specification (SATS). This defined the testing needed to verify performance against the requirements in E 082 710.SRS. However, as it was assumed that the door would have been locked out of service (paragraph 187), no test sequence was included which would have revealed the requirement error.

197 The fact that the EDCU did not motor the door closed when departing from Luton is contributory to the door remaining able to open when the train was in motion.

Contributory factors relating to the severity of the outcome

198 After Luton, station stops were made at Bedford, Wellingborough and Kettering. There was no obvious indication to the on-board staff that the door was unlocked and able to open.

199 The pneumatic door seal would have initially helped to keep the door leaf in the portal. However, at each station the door seal was commanded to deflate and then re-inflate (on the presence and absence of the low speed signal). Rig tests showed that, on an unlocked door, this prises the door leaf incrementally out (paragraph 115).

200 Some two minutes after leaving Kettering the door had been sufficiently prised out of the portal for the DCS to activate. This is evidenced by the 'all doors closed car contradiction fault' logged on the TMS, a corresponding log of a 'DCS failure' on the EDCU and images recorded on the CCTV.

201 The activation of the DCS cut the train safety loop and the enhanced service brake was automatically applied. As the door was free to move, it did not decelerate with the rest of the train. It was therefore able to slide, taking just over ten seconds to open fully.

The driver's response to enhanced service brake applications

202 When the enhanced service brake application occurred following the cutting of the train safety loop, the only indication that the driver observed was the illumination of the 'pass comm/door activated' light (paragraph 58). This warning light does not distinguish as to whether the use of the PCA emergency brake handle or a door activation has caused it to come on. The driver did not therefore know what had happened. The driver reacted in a way that indicates he thought that there was a fault with the PCA given that there was no related TMS level 3 anomaly report and no communication channel established with any person who may have operated a PCA emergency brake handle. The driver therefore decided to cancel the brake application and proceed on the basis that he could stop at the 'first suitable location' in accordance with clause 10.11 of rule book module TW1 and clause 1.2 (b) of module TW5 (paragraphs 128 and 131).

203 The driver did not observe the 'door close/locked' light which would have extinguished when the door came open (while it cannot be established with certainty that the light extinguished, post-incident testing supports this as most likely). This would have provided an indication to him that the enhanced service brake application was caused by an exterior door coming open. However, the 'door close/locked' light is not in the driver's primary field of forward vision since its primary purpose is to give an indication of the state of the door when the train is stationary – it requires the driver to note the absence of a light that had been steadily illuminated previously. It is also a light that drivers are used to observing at station stops as part of the door closing procedure rather then when a train is moving.

204 The opening of the DCS contacts when the door opened caused the application of the enhanced service brake, but no anomaly at any level was logged on the TMS. If the TMS had reported a level 3 anomaly to the driver, he would have been required to acknowledge it and would have had information about the nature of the problem. It was originally intended that a level 3 anomaly would be displayed in the event of a door coming open. However, as part of the general desire to reduce potentially distracting information presented to the driver (paragraph 95), it was ultimately decided that this was not required. A door coming open would result in other indications: the automatic application of the train brake (paragraph 201) and the extinguishing of the 'door close/locked' light (paragraph 203).

205 The driver did not realise that a door had opened until he overheard the conversation between the customer host and the train manager; he then worked together with the train manager to verify the passenger report (paragraphs 64 and 66). The driver then made a controlled brake application - overriding the enhanced service brake - bringing the train to stand at the next signal fitted with a signal post telephone (paragraph 67).

206 On realising that an exterior door was open, the driver might (in accordance with rule book clause 20.2 of module TW1 (paragraph 129)) have stopped the train immediately (avoiding stopping on a viaduct, in a tunnel, or in any other place where it might be difficult to deal with the emergency). Clause 5.1 of rule book module TW2 also requires a door that has come open during the journey to be locked immediately.

207 The Rule Book is only specific in stating that the drivers of trains 'in danger' should avoid stopping 'on a viaduct' or 'in a tunnel'. There is no further guidance given on what constitutes 'any other place where it might be difficult to deal with an emergency', so it appears to be accepted practice by drivers to proceed to a signal with a signal post telephone where they can speak directly to the signaller. The alternatives of using the fixed radio equipment over the National Radio Network on the train (permitted by clause 3.5 of module TW1 of the Rule Book) or the company issued mobile telephone are not always reliable where there are areas of poor radio reception.

208 If the driver had stopped the train immediately on confirmation there was an open door, the duration of the hazard would have been reduced and the open door could have been dealt with more expeditiously. The driver may not, though, have been able to contact the signaller immediately as required by clause 5.1 of module TW2 if radio reception were poor.

209 From the above, it is possible to identify four contributory factors that affected the severity of the outcome of the incident:

a. the driver did not stop the train immediately when he became aware that there was a door open and the train was therefore 'in danger' (paragraph 205);

b. there was no level 3 anomaly report for the driver (or the train manager) on the TMS when the door opened (paragraph 204);

c. the driver did not notice that the 'door close/locked' light extinguished when the door came open as it was difficult to observe when driving (paragraph 203); and

d. the 'pass comm/door activated' light is ambiguous because the same indication is given for two different reasons (paragraph 202).

210 There had been no door opening incidents when moving, on the class 222 Meridian train fleet prior to 10 June 2006. In light of this, it is possible that the driver had not contemplated that there could be an open door when the enhanced service brake applied and the 'pass comm/door activated' light initially illuminated.

211 Since the sequence of events associated with the incident had not been anticipated, Midland Mainline had not given their staff any specific training on how they should have responded. This, together with the lack of guidance in the Rule Book regarding places where it might be difficult to deal with an emergency (paragraph 207), may have influenced the driver's decision to stop at a signal post telephone.

Passenger actions

212 Despite at least two passengers walking past the open door when the train was travelling at speed, neither used a PCA emergency brake handle to notify the driver and stop the train. This is a contributory factor affecting the severity of the outcome of the incident.

213 There may be a natural reluctance on the part of passengers to pull a PCA emergency brake handle for fear of pulling it in inappropriate circumstances, or for fear of being fined for improper use.

214 It was one of the passengers who had walked past the open door that brought its condition to the eventual attention of the on-board staff (paragraph 215).

Other factors for consideration

Actions of the customer host

215 When the passenger first advised the customer host that there was a door open in the first class coach, she initially thought that they were referring to the interior door between the first class saloon area and the kitchen as she had encountered a problem closing this at Nottingham (paragraph 47). While speaking to the train manager on the crew call system, it became clear that the passenger was in fact referring to an exterior door.

216 The train manager (present in the driver's cab at the time) told the customer host to pull a PCA emergency brake handle so that the train's emergency brake would apply, but despite two attempts, she did not succeed. The second attempt happened to coincide with when the driver applied the brake anyway; it gave the customer host the impression that the second pull of the handle had been successful and had caused the brake to apply.

217 If the customer host had successfully operated a PCA emergency brake handle, an alarm would have sounded throughout the train. Post-incident tests found no fault with the PCA emergency brake handle that was pulled.

218 Given the driver was already braking the train when the customer host attempted to pull a PCA emergency brake handle, it is considered unlikely that it would have made any material difference had she been successful in doing so.

Summary of the event chain

Causal Factors

219 Figure 14 is an overview of the most likely identified causal and contributory factors, showing their relationship to the incident and its outcome. It does not show possible causes which have been discounted as part of the investigation (paragraph 159).

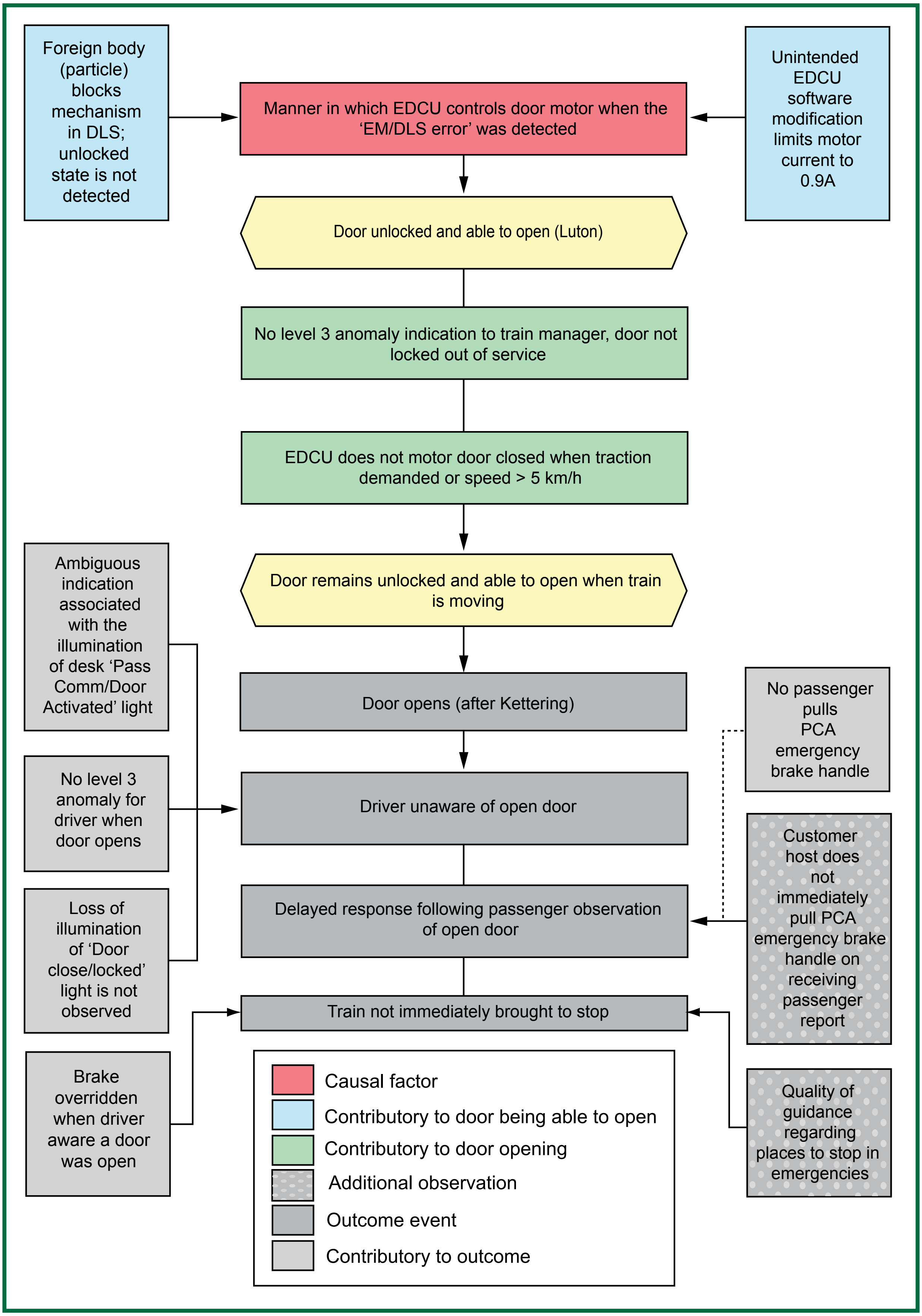


Figure 14: Overview of the identified causal factors

Conclusions

Immediate cause

220 The door became, and remained, both unlocked and un-motored in the response to the detection of a DLS malfunction. This occurred during the initial stages of the door opening sequence at Luton station; it resulted in the door being left able to open (paragraph 160).

Causal factor

221 The DLS malfunction resulted in the EDCU identifying an 'EM/DLS error'. The cause of the door being both unlocked and un-motored is attributed to the way in which the EDCU controlled the door motor when the fault was detected. The door had unlocked as part of the initial door opening sequence; it was not able to re-lock because the EDCU cut the current to the motor when the locking hook was in an orientation that prevented the falling latch being able to engage with it. Since the current remained cut, the door remained un-motored (paragraph 170, Recommendation 1).

Contributory factors

222 In addition, the following factors were considered to be contributory:

a. the unintended change of the motor current limit as part of a recent EDCU software upgrade, leading to the conditions which prevented the falling latch engaging with the locking hook (paragraph 177, Recommendation 2);

b. the presence of a foreign particle which resulted in the DLS becoming jammed (paragraph 184, Recommendation 3);

c. the lack of an overt indication from the TMS to the train manager (or driver) that a door lock fault had occurred at Luton station (paragraph 192, Recommendation 4);

d. the EDCU not motoring the door closed when the train started to depart Luton station (paragraph 197, Recommendations 1 and 2);

e. the lack of a level 3 anomaly indication to the driver from the TMS when the door opened (paragraph 209b, Recommendation 4);

f. the 'pass comm/door activated' light being ambiguous because it gives the same indication for different reasons (paragraph 209d, Recommendations 5 & 7);

g. the driver not noticing that the 'door close/locked' light extinguished when the door came open as it was difficult to observe when driving (paragraph 209c, Recommendations 6 & 7);

h. none of the passengers who observed the open door then operating a PCA emergency brake handle (paragraph 212); and

i. the driver overriding the emergency brake and not stopping the train immediately when he became aware that there was a door open and that the train was therefore 'in danger' (paragraph 209a, Recommendations 7 and 9).

Additional observations

223 The driver's decision not to stop the train immediately, and to continue to the next signal post telephone, may have been influenced by a lack of guidance: in the Rule Book or in the training given by Midland Mainline (paragraph 211, Recommendations 7 and 9).

224 The customer host was unsuccessful in attempting to operate the PCA emergency brake handle, but this made no material difference to the outcome of the incident (paragraphs 216 and 218, Recommendations 7 and 8).

Actions reported as already taken relevant to this report

225 On 12 June 2006, Midland Mainline issued a notice to drivers about the PCA giving guidance on the use of the emergency brake override button. The notice instructed drivers that they were to use the override only to allow a train to stop at a location where it would be safe to evacuate passengers in an emergency. All passenger communication or door activations were '..to be investigated at the first opportunity without causing risk to any parties'.

226 At the same time, Midland Mainline issued a National Incident Report (NIR 2159) under Railway Group standard GE/RT8250 to advise other train operators of the incident and the action taken.

227 Midland Mainline has submitted a proposal to the RSSB to change clause 10.11 of Rule Book Module TW1 in order to clarify when a driver should bring a train to a stand after using the emergency brake override following the use of the PCA emergency brake handle.

228 Midland Mainline has required all of its on-board staff to practice the use of the PCA emergency brake handle.

229 On 20 June 2006, a process was introduced to monitor – three times a day – TMS information on the Meridian fleet in order to identify the occurrence of locking faults. This monitoring has continued.

230 The EDCU software error resulting in the change to the door motor current limit was identified by 23 June 2006. A fleet modification, changing the software back to the previous version, was implemented within two days.

231 New versions of EDCU and TMS software have been developed in light of the incident. These have undergone a programme of testing culminating in a two-week trial on two Meridian trains. The revised software has now been installed on all class 222 trains operated by Midland Mainline and Hull Trains. The changes to the TMS have included:

- the provision of a level 3 anomaly indication so that the train manager is made fully aware of door lock faults; and
- the provision of a level 3 anomaly indication for the driver in the event of an unexpected door unlocking while the train is moving. The door motor also powers the door closed.

232 Faiveley have revised the system acceptance test specification. Additional test sequences have been defined and the need to check the motor torque included; the latter would have identified the unintended change to the door motor current limit as a result of the EDCU software modification.

Recommendations

233 The following safety recommendations are made[1,2]:

1 HSBC Rail (UK) Limited and operators of class 222 trains (as appropriate) should review, in conjunction with Bombardier Transportation UK and Faiveley Transport, the door control algorithm and implement any changes necessary to ensure that:

- when door locking is required, the falling latch engages with the locking hook in all normal and degraded operating scenarios (paragraph 221); and
- following the identification of a locking fault, real or otherwise, the motor is controlled so that the door is not left in an unrestrained condition (paragraph 222d).

2 Bombardier Transportation UK, Faiveley Transport and operators of class 222 trains (as appropriate) should review, in the light of the investigation findings, their processes for software specification, development, upgrading and verification. They should implement any changes necessary to ensure they identify and manage the risks due to performance errors occurring during fault conditions (paragraphs 222a and 222d).

3 Bombardier Transportation UK and Faiveley Transport (as appropriate) should require their supplier Schaltbau to review and, if necessary, upgrade its manufacturing process and switch design in the light of the evidence presented in this report with the objective of minimising the risk of foreign bodies being present (paragraph 222b)

4 HSBC Rail (UK) Limited, Bombardier Transportation UK and operators of class 222 trains (as appropriate), should review fault alarms and handling on class 222 units and implement any changes necessary to ensure that on-board staff are adequately warned and able to take the appropriate action (for instance, operation of the out-of-service lock or stopping the train) in the event of a door system failure. This should include the need for:

- the train manager to be aware of door locking faults before authorising train departure (paragraph 222c); and
- the driver to be aware of any door-related fault which may put the safety of the train 'in danger' (paragraph 222e).

continued

[1] Responsibilities in respect of these recommendations are set out in the Railways (Accident Investigation and Reporting) Regulations 2005 and the accompanying guidance notes, which can be found on RAIB's website at www.raib.gov.uk

[2] Midland Mainline is not included in these recommendations because it will no longer be the operator of rail services (or of class 222 trains) from London St Pancras to the East Midlands from November 2007.

5 HSBC Rail (UK) Limited and operators of class 222 trains (as appropriate) should review the design of the 'pass comm/door activated' indication light and the two conditions requiring it to illuminate. If necessary, improvements should be made to the general design of indications on class 222 trains to ensure that the driver is clearly aware of which condition has occurred (paragraph 222f).

6 HSBC Rail (UK) Limited and operators of class 222 trains (as appropriate) should review the ergonomics of the 'door close/locked' light to determine whether its conspicuity could be improved and therefore be more likely to be observed by drivers if a door opens when the train is moving (paragraph 222g).

7 Operators of class 222 trains should review the content of training courses and the assessment of drivers, train managers and customer hosts in the practical application of procedures relating to unexpected incidents that may occur while trains are running in service. This should include ensuring that on-board staff members have an adequate understanding of their roles and responsibilities, particularly with regard to the use of the emergency brake override (and where the train should be brought to a stand), the operation of the passenger communication alarm system, and the use of the TMS and other sources of fault and event indication (paragraphs 222f , 222g, 222i, 223 and 224).

8 HSBC Rail (UK) Limited and operators of class 222 trains (as appropriate) should review the ergonomics of the PCA emergency brake handle and, if necessary, make improvements to ensure that, when either passengers or on-board staff attempt to use it, it will successfully operate (paragraph 224).

9 RSSB should make a Proposal, in accordance with the Railway Group Standards Code, to clarify the various requirements of the Rule Book relating to PCA and power operated doors to ensure they minimise the duration of any hazard affecting the safety of a train. This should include conditions for the use of the emergency brake override (paragraph 222i and 223).

Appendices

Glossary of abbreviations and acronyms — Appendix A

AS	Application system
EDCU	Electronic Door Control Unit
EM	Electro-magnet
DEMU	Diesel Electric Multiple Unit
DCS	Door Close Switch
DLA	Door Lock Assembly
DLS	Door Lock Switch
HMRI	Her Majesty's Railway Inspectorate
HSI	Railways (Interoperability) (High-Speed) Regulations 2002
OS	Operating System
OTMR	On Train Monitoring Recorder
PCA	Passenger Communication Apparatus
ROTS	Railways and Other Transport Systems (Approval of Works, Plant and Equipment) Regulations 1994
RSSB	Rail Safety and Standards Board
SDO	Selective Door Opening
TMS	Train Management System

Glossary of terms

Appendix B

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

5th percentile	The value of a characteristic (eg the height of a human being) the magnitude of which is lower in 5 % of a given statistical population.
95th percentile	The value of a characteristic (eg the height of a human being) the magnitude of which is lower in 95 % of a given statistical population.
Anomalies	Term given to on-train fault and other event conditions which are monitored and recorded by the train management system.
Application system	Computer software design to perform a desired specific functional task.
Canted track	Track on which one rail is raised higher than the other.
Chain	A unit of length, being 66 feet or 22 yards.*
Control signals	Information transmitted to control the operation of electrical and other on-train systems.
Crew call system	That part of the voice communication system fitted to the train that enables on-board staff to communicate with one another while dispersed through the train. Three notes played over the public address system signify that a member of on-board staff is trying to contact another elsewhere in the train.
Customer host	A member of the on-board railway staff whose principal duties are the serving of refreshments to passengers.
Databus	A system which transfers data between various parts of a computer system.
Diesel electric multiple unit	A self-contained diesel-powered train where the diesel engines are located beneath each vehicle and the transmission system between the engines and the wheels is electric.
Door closed switch	Electrical switch used to detect that the door leaf is in its closed position relative to the door portal.
'Door close/locked' light	Lamp indicating that train doors are detected closed and locked.
Door leaf pin	Structural component on the door leaf which engages with the mechanism on the carbody used to lock the door in the closed position.
Door lock assembly	Sub-assembly that includes the mechanism on the carbody which is used to lock the door in the closed position.
Door lock switch	Electrical switch used to detect that the falling latch on the door lock assembly is in the locked position.
Door motor	Electrical motor used to drive the door leaf open and closed.

Door release	A control signal given by the on-board staff granting their permission for door operation.
Down	In the direction away from London.
Driver's desk	Console incorporating the controls and instruments used for driving the train.
Egress handle	Device used to open train doors in order to exit in the event of an emergency.
Electro-magnet	Electrical device used to exert a force and rotate the falling latch on the door lock assembly.
Electronic door control unit	Unit used to control and monitor the operation of an individual door.
Emergency loop	Electrical wire passing through the train used to detect the operation of an egress handle or PCA emergency brake handle.
Empty coaching stock	The term for a train of empty passenger coaches being moved from one place to another.*
Enhanced service brake	Train brake capable of achieving deceleration rates of greater than 9 % g.
Engagement slot	The part of the locking hook that the falling latch is designed to enter in order to lock the door.
Falling latch	Part of the door lock assembly used to secure the locking hook in position in order to lock the door.
Footstep light	Light used to illuminate the threshold of the doorway.
Guidance and stabilisation system	Mechanism used to support the door leaf and guide its sliding motion.
Intermediate end vestibule	The entrance area in the vicinity of a passenger door that is located at coupled end of the vehicle.
Intermediate vehicle	Vehicle of a multiple unit train (eg a DEMU) not having a driving cab.
Level 3	Name given to the class of fault or event conditions (anomalies), monitored and recorded by the TMS, which affect safety or are service critical.
Locking hook	Part of the door lock assembly used to retain the door leaf pin in order to lock the door.
Low speed signal	Control signal indicating the train speed to be less than a pre-defined threshold.
MADD box	A module within the door system containing electrical control relays, the name being abbreviated from the French term 'Module ADDitionale'.

Notified Body	An organisation with the delegated responsibility to audit the correct application of national standards under Technical Specifications for Interoperability regulations for railway schemes.*
Obstacle detection	Facility to detect the presence of objects in the path of a closing door.
On train monitoring recorder	A data recorder fitted to traction units collecting information about the performance of the train.
Operating system	Computer software used to generally control and integrate the various parts of a computer or computer-based control system.
Out-of-service lock	Key operated device used to manually lock the door and preventing its use in normal service.
'Pass comm/door activated' light	Lamp used to alert the driver to the operation of either a PCA emergency brake handle, or that a door had unlocked (for example though operation of the egress handle).
Passenger communication apparatus	On-train system provided to enable passengers to communicate with the driver in the event on an emergency.
PCA emergency brake handle	Device provided to enable passengers to alert the driver of an emergency.
Portal	Aperture in the carbody in which the door is fitted.
Pneumatic door seal	Device fitted to the door leaf which is inflated by air to seal the gap between the leaf and the portal.
Railway Group standard	A document mandating the technical or operating standards required of a particular system, process or procedure to ensure that it interfaces correctly with other systems, processes and procedures.*
Route knowledge	A driver's awareness of key features (eg signal and speed restriction locations) on a particular railway line.
Safety loop	Electrical wire passing through the train used to confirm that the doors detected to be are closed and locked.
Selective door operation	System used to limit the number of doors that are permitted to open - primarily when stopping alongside short platforms.
Slide-and-plug	Type of powered door system in which, during opening, the door leaf initially moves out and clear of the carbody side before sliding open.
Switch plunger	Moving part of DLS microswitch used to open and close the electrical contacts.
Train lines	Electrical wires which carry control signals along the length of the train.
Train management system	On-train computer system which monitors and records fault and other event conditions associated with the train's electrical and electronic systems.
Up	In the direction of London.

Vertical door stanchion	Vertical structural part of the door portal.
Vestibule	The entrance area in the vicinity of a passenger door.

Key standards current at the time — Appendix C

Railway Group standards:

GE/RT8000	Rule Book
GE/RT8250	Safety Performance Monitoring and Defect Reporting of Rail Vehicles, Plant and Machinery
GO/RT3251	Train Driving
GO/RT3255	Train Working – Competence and Fitness

Interpretation of OTMR after departing Kettering — Appendix D

Time	Action	Speed (km/h)
11:28:54 hrs	Train departed from Kettering station	N/A
11:31:05 hrs	Enhanced service brake applies when door comes open	127
11:31:16 hrs	Driver presses emergency brake override	82
11:31:21 hrs	Driver releases emergency brake override	68
11:31:54 hrs	Driver presses emergency brake override	80
11:32:00 hrs	Driver releases emergency brake override	72
11:32:32 hrs	Driver presses emergency brake override	101
11:33:32 hrs	Driver releases emergency brake override and makes a controlled brake application	126
11:34:03 hrs	Driver presses emergency brake override	85
11:35:22 hrs	Driver releases emergency brake override	40
11:35:54 hrs	Driver presses emergency brake override	21
11:36:11 hrs	Driver releases emergency brake override and train stops	0

Identified sequence of events **Appendix E**

The following has been established as the most likely explanation of the sequence of events leading to the incident and its outcome on 10 June 2006:

<u>*Bedford station (9:29 hrs, up journey)*</u>

1 This was the last occasion that the door was successfully used before it opened unintentionally near Desborough. Nothing untoward was logged or identified at this time (or previously) that could explain the observed events.

<u>*London St Pancras (10:04 to 10:29 hrs)*</u>

2 The train was berthed in platform 13 and prepared for the return down journey. The door was not adjacent to the platform and, therefore, not available for passenger use.

<u>*Luton station (10:52 hrs, down journey)*</u>

3 This was the next occasion that use of the door was required.

4 The doors were released by the train manager. Passengers wishing to alight pressed the 'open' pushbutton. The door failed to respond and passengers had to use another door.

5 The EDCU commanded the door motor to drive the door closed and relieve the pressure acting on the falling latch. The electro-magnet was then energised; the falling latch disengaged from the locking hook.

6 A foreign particle had caused the DLS to jam; the DLS continued to indicate that the door was locked. While the state of the DLS remained unchanged, the EDCU continued to energise the electro-magnet.

7 After 3 seconds, the EDCU identified the conditions for an 'EM/DLS error'; it logged the fault and informed the TMS. The TMS logged a 'locking fault'; because of its classification, neither the train manager nor the driver was alerted. The door was not locked out of service.

8 On detecting the fault, the EDCU immediately cut the current to the motor and de-energised the electro-magnet; the falling latch was released and attempted to engage in the locking hook.

9 A recent EDCU software upgrade had resulted in a software error which limited the door motor current to 0.9A (rather than the intended 4.7A). This probably meant that the engagement slot on the falling latch was incorrectly aligned with the path of the returning falling latch. As the falling latch was not able to engage, the door remained unlocked.

10 The train was permitted to depart. At the loss of the low speed signal, the pneumatic door seal was inflated; the door motor was not commanded to hold the door closed.

Bedford (11:07 hrs), Wellingborough (11:18) and Kettering (11:27) stations

11 The events were similar at each of the stations. Passengers attempted to open the door, by pressing the door open pushbutton, but it was in a dormant state and failed to respond.

12 The deflation and re-inflation of the door seal at each station caused the door leaf to be pushed out of the portal progressively.

Train travelling north of Kettering

13 By this time the door leaf had moved far enough out of the portal to cause the DCS to change state and for the door seal to be unable to provide any significant restraint. A 'DCS failure' was logged on the EDCU.

14 The DCS state change cut the safety loop and automatically applied the enhanced service brake.

15 As the door was free to move and unrestrained, it didn't decelerate with the rest of the train. It was therefore able to slide open fully.

16 The indications given in the driving cab were confusing and difficult to interpret. No level 3 TMS anomaly report was given to the driver or the train manager. The 'pass comm/door activated' indicator light was on but no voice channel was open, and the extinguishing of the door inter-lock light was difficult to observe. This resulted in the driver initially reacting in a way which suggests he thought there was a fault with the PCA. He overrode the brake with the intent of stopping at the first suitable location. He was not aware that the door was open.

17 At least two passengers passed by the open door. Neither used a PCA emergency brake handle but, one went on to report it to the customer host.

18 The immediate response of the customer host was to call the train manager and not to use a PCA emergency brake handle. The train manager told the customer host to pull a handle. This was attempted but without success.

19 During this call the driver became aware of the passenger report, and working with the train manager, confirmed that there was an exterior door open. The train was not immediately stopped but allowed to continue to the next signal post telephone where it was brought to a stand.

20 The door was closed and locked out of service.

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